Federal Department of Environment, Transport
Energy and Communications No. u1793

Investigation Report of the Aircraft Accident Investigation Bureau

on the accident

to aircraft AVRO 146-RJ100, HB-IXM,

operated by Crossair under flight number CRX 3597,

on 24 November 2001

near Bassersdorf/ZH

This report has been prepared for the purpose of accident/incident prevention. The legal assessment of accident/incident causes and circumstances is no subject of the accident investigation (Art. 24 Air Navigation Law).

The language of the valid formulation of this report is German.

Within 30 days after receipt of the investigation report, any person giving proof of a well-founded interest in the investigation result may request the report to be examinated by the Review Board (*Eidg. Flugunfallkommission* – EFUK) for completeness and conclusiveness.

Bundeshaus Nord, CH-3003 Berne

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Appendix 1: Chronological sequence of key events

Appendix 2: Oil Indicator as Installed

Appendix 3: Warning Envelope of the Ground Proximity Warning System (GPWS)

Appendix 4: Approach Profile of Flight CRX 3597

Appendix 5: Simulator Comparison Flights to Runway 28

Appendix 6: Localizer DME Approach to Runway 03 in Lugano (today IGS Approach Rwy 01)

Appendix 7: Approach Chart AIP Switzerland LSZH AD 2.24.10.7-1

Appendix 8: Approach Chart 13-2 Zurich, Switzerland, Jeppesen Inc.

Appendix 9: Graphical compilation of the results of the commander’s line, route and simulator checks

Appendix 10: Detailed Approach Profile of Flight CRX 3597

Appendix 11: Standard VOR/DME Approach 28 - Illustration of the Final Segment

In accordance with the Agreement of the International Civil Aviation Organization (ICAO Annexe 13) the sole objective of the investigation of an aircraft accident is the prevention of future accidents. It is not the purpose of this investigation to determine blame or to clarify questions of liability.

Investigation report

Operator:	Crossair Limited Company for Regional European Air Transport, CH-4002 Basel	
Aircraft type and version:	AVRO 146-RJ100	
Nationality:	Swiss	
Registration:	HB-IXM	
Owner:	Crossair Limited Company for Regional European Air Transport, CH-4002 Basel	
Location of accident:	Geissbühl, municipality of Bassersdorf ZH	
	Coordinates of first contact with trees:	
	Swiss coordinates:	689 607/256 564
	Latitude:	N 47° 27’ 14’’
	Longitude:	E 008° 37’ 37’’
	Treetop height:	565 m AMSL 1854 ft AMSL
	Mean coordinates of final position of the wreckage:	
	Swiss coordinates:	689 350/256 600
	Latitude:	N 47° 27’ 15’’
	Longitude:	E 008° 37’ 24’’
	Elevation of location:	515 m AMSL 1690 ft AMSL
	4050 m short of runway 28 of Zurich airport, 150 m north of the runway centreline.	
Date and time:	24 November 2001 at 21:07 UTC	

Synopsis

Brief presentation

On 24 November 2001 at 20:01 UTC the aircraft AVRO 146 RJ 100, registered as HB-IXM of the Crossair airline company took off in darkness from runway 26L at Berlin-Tegel airport as scheduled flight CRX 3597 to Zurich.

At 20:58:50 UTC, after an uneventful flight, the aircraft received the clearance for a standard VOR/DME approach 28 at Zurich airport.

Ahead of the aircraft involved in the accident, an Embraer EMB 145, flight CRX 3891, landed on runway 28 at Zurich airport. The crew informed the control tower that the weather was close to the minimum for this runway.

At 21:05:21 UTC flight CRX 3597 reported on the aerodrome control frequency. When the aircraft reached the minimum descent altitude (MDA) of 2390 ft QNH at 21:06:10, the commander mentioned to the copilot that he had certain visual ground contact and continued the descent.

At 21:06:36 UTC the aircraft collided with treetops and subsequently crashed into the ground.

The aircraft caught fire on impact. Twenty-one passengers and three crew members died from their injuries at the site of the accident; seven passengers and two crew members survived the accident.

Investigation

The AAIB set up an investigation team designated to investigate an aircraft accident of a catastrophic nature to large aircraft.

According to Annex 13 of the International Civil Aviation Organization Agreement (ICAO Annex 13), the state which manufactures the aircraft and the home countries of the passengers have the option of assigning accredited representatives to the investigation. The United Kingdom of Great Britain and Northern Ireland (UK), as the state of manufacture, and Germany, as the home country of some passengers, assigned such representatives.

The accident is attributable to the fact that on the final approach, in own navigation, of the standard VOR/DME approach 28 the aircraft flew controlled into a wooded range of hills (controlled flight into terrain – CFIT), because the flight crew deliberately continued the descent under instrument flight conditions below the minimum altitude for the approach without having the necessary prerequisites. The flight crew initiated the go around too late.

The investigation has determined the following causal factors in relation to the accident:

- The commander deliberately descended below the minimum descent altitude (MDA) of the standard VOR/DME approach 28 without having the required visual contact to the approach lights or the runway
- The copilot made no attempt to prevent the continuation of the flight below the minimum descent altitude.

The following factors contributed to the accident:

- In the approach sector of runway 28 at Zurich airport there was no system available which triggers an alarm if a minimum safe altitude is violated (minimum safe altitude warning – MSAW).
- Over a long period of time, the responsible persons of the airline did not make correct assessments of the commander’s flying performance. Where weaknesses were perceptable, they did not take appropriate measures.
- The commander’s ability to concentrate and take appropriate decisions as well as his ability to analyse complex processes were adversely affected by fatigue.

- Task-sharing between the flight crew during the approach was not appropriate and did not correspond to the required procedures by the airline.
- The range of hills which the aircraft came into contact with was not marked on the approach chart used by the flight crew.
- The means of determining the meteorological visibility at the airport was not representative for the approach sector runway 28, because it did not correspond to the actual visibility.
- The valid visual minimums at the time of the accident were inappropriate for a decision to use the standard VOR/DME approach 28.

In the course of the investigation, 13 safety recommendations were drawn up by the AAIB for the attention of the Federal Office for Civil Aviation (FOCA):

- Altitude setting during a non-precision approach
- Terrain awareness and warning system
- Weather observation system
- Installation of a minimum safe altitude warning system (MSAW) for the approach sector of runway 28 in Zurich-Kloten
- Marking of flight obstacles in the Jeppesen Route Manual
- Publication of a visual descent point
- Minimum visibility for non-precision approaches
- Terrain profile on approach charts
- Crewpairing
- Monitoring of the pilots' performance
- Flight crew duty times
- Improving the quality system of airline operators
- Acceptance of skill tests and proficiency checks

1 Factual information

1.1 Prior history and history of the flight

1.1.1 Prior history

1.1.1.1 Aircraft

Aircraft HB-IXM made the following flights prior to the accident:

Date	Flight number	Flight from	Take-off time (UTC)	Flight to	Landing time (UTC)
23.11.01	LX 209	Thessalonica	03:00	Zurich	06:02
23.11.01	LX 3532	Zurich	06:57	Frankfurt	08:00
23.11.01	LX 3533	Frankfurt	09:12	Zurich	10:09
23.11.01	LX 3234	Zurich	11:17	Tunis	13:05
23.11.01	LX 3235	Tunis	14:00	Zurich	16:22
23.11.01	LX 3628	Zurich	17:37	Milan	18:35
23.11.01	LX 3629	Milan	19:10	Zurich	20:01
23.11.01	LX 208	Zurich	20:57	Thessalonica	23:17
24.11.01	LX 209	Thessalonica	03:10	Zurich	06:03
24.11.01	LX 3790	Zurich	07:00	Amsterdam	08:25
24.11.01	LX 3791	Amsterdam	08:55	Zurich	10:10
24.11.01	LX 3450	Zurich	11:15	Ljubliana	12:14
24.11.01	LX 3451	Ljubliana	13:03	Zurich	14:09
24.11.01	LX 3596	Zurich	17:54	Berlin-Tegel	19:30

The following items were entered in the deferred defect list (DDL):

- ATA 21 Flt. Deck temp. in auto mode difficult to control. In full cool duct temp. rises up to 70 – 80°.

  Please use man. temp. control, xfer to DD acc MEL 21-60-5.

- ATA 49 Crew reported APU needs always two attempts to start.

  Following parts are already replaced:

  - Igniter plugs
  - Fuel filter
  - Start fuel manifold
  - FCU
  - APU bleed valve
  - Start solenoid

  Further T/S needed.

- ATA 30 Please perform reinspection of aileron and elevator after use of de-icing fluid type IV acc. P/H 1.3 “WINTER OPS”

1.1.1.2 Flight crew

1.1.1.2.1 Commander

On 23 November 2001, at about 05:00 UTC, the commander met a student pilot at the general aviation centre (GAC) of Zurich airport. This corresponds to the beginning of his flying activity on that day. On behalf of the flying school Horizon Swiss Flight Academy, he made a training flight with the student pilot to Friedrichshafen (D) between 06:15 UTC and 07:20 UTC, under instrument flight rules (IFR). At 07:34 UTC they began the return flight to Zurich, where they arrived at 08:57 UTC.

Later, the commander flew four scheduled flights for Crossair. Between 11:02 UTC and 13:09 UTC he made a flight to Tirana (AL). The return flight to Zurich lasted from 13:53 UTC to 16:16 UTC. At 17:37 UTC the commander began another flight, to Milan-Malpensa (I), where landing took place at 18:35 UTC. At 19:10 UTC the commander flew back to Zurich. After the landing at 20:01 UTC he ended his duty at 20:31 UTC after a total flying duty time of 15 hours and 31 minutes. Under favourable conditions, a commuting time of approximately 30 minutes was needed to reach his place of residence.

On 24 November 2001, after a rest period of 10 hours and 59 minutes, the commander returned to the Zurich airport GAC at 07:30 UTC in order to make an IFR training flight with a student pilot on behalf of the flying school Horizon Swiss Flight Academy. Departure from Zurich was at 09:34 UTC and the landing in Donaueschingen-Villingen (D) was at 10:20 UTC. Half an hour later, at 10:50 UTC, they flew on to Friedrichshafen (D) where they landed at 11:36 UTC. The return flight from Friedrichshafen (D) to Zurich lasted from 11:53 UTC to 12:27 UTC. According to the student pilot's statement, the debriefing ended at 13:30 UTC.

The departure of Crossair flight number CRX 3596 to Berlin-Tegel was scheduled for 17:20 UTC and took place at 17:54 UTC.

1.1.1.2.2 Copilot

On 23 November 2001, the copilot made four scheduled flights for Crossair. He started his duty at 11:50 UTC and left Zurich at 13:23 UTC for Budapest (H), where the aircraft landed at 15:04 UTC. Between 16:07 UTC and 17:45 UTC the copilot flew back to Zurich and then, at 18:40 UTC, on to Dusseldorf (D). The landing in Dusseldorf took place at 20:05 UTC and the return flight to Zurich began at 20:30 UTC. At 21:35 UTC the copilot landed in Zurich and finished his duty, after a flight duty time of 10 hours and 15 minutes, at 22:05 UTC. The commuting time between his place of residence and Zurich airport was approximately 45 minutes.

The copilot's spouse stated that the copilot described this working day as very stressful and had felt very exhausted.

After a rest period of 18 hours and 15 minutes, the copilot started his duty at Zurich airport on 24 November 2001 at 16:20 UTC. The departure of Crossair flight number CRX 3596 to Berlin-Tegel was scheduled for 17:20 UTC and took place at 17:54 UTC.

1.1.2 History of the flight

1.1.2.1 Flight preparation

Prior to the fatal flight, aircraft HB-IXM was used on 24 November 2001 for the scheduled flight CRX 3596 from Zurich to Berlin-Tegel, where it landed at 19:25 UTC. The crew was the same as on the following sector with flight number CRX 3597. After the landing in Berlin, the aircraft reached passenger ramp 11 at 19:30 UTC, i.e. 40 minutes after the scheduled time of arrival, and the passengers left the aircraft. No refuelling took place, since the aircraft still had 5650 kg fuel on board (actual block fuel). For the return flight, according to the flight plan, a fuel amount of 4893 kg (minimum block fuel) was required. As usual, the return catering was carried on the outward flight.

During the ground time, the passenger cabin was cleaned. The ramp handling agent handed over the load sheet to the flight crew. According to this agent, the commander left the aircraft, presumably to carry out a routine external check. A brief conversation took place between the commander and the ramp handling agent. The latter described the behaviour of the commander as normal. In particular, he noticed no signs of stress or urgency. Whilst the aircraft was on the ground the copilot remained in the aircraft.

Twenty-eight passengers and 23 pieces of luggage were checked in for flight CRX 3597. On the basis of bookings, 49 passengers were expected. A group of 21 travellers did not show up. No freight was carried. The passengers boarded the aircraft between 19:40 UTC and 19:45 UTC.

1.1.2.2 The flight from Berlin-Tegel to Zurich

The commander was pilot flying (PF). The copilot was pilot not flying (PNF) and, among other things, was therefore responsible for radio communications with air traffic control throughout the flight.

All radio conversations between the various ATC units and the flight crew of CRX 3597 from Berlin-Tegel to Zurich were conducted in English. The conversations between the crew members in the cockpit took place predominantly in Swiss German. There are no indications of misunderstandings between the two pilots, nor of misunderstandings between the air traffic controllers and the flight crew.

At 19:48 UTC the flight crew requested start-up and push-back clearance. In the process they confirmed the reception of the ATIS message “GOLF”. ATC informed the pilots that ATIS information “INDIA” was valid and gave them clearance to start the engines. Transponder code 3105 was assigned together with the standard instrument departure (SID) clearance “Magdeburg 4L”.

At 19:50 UTC, i.e. 10 minutes after the scheduled time of departure, passenger ramp 11 was withdrawn and two minutes later CRX 3597 was pushed back, after another aircraft had docked at the adjacent ramp 10.

At 19:56 UTC the aircraft was instructed to taxi “via the bridge” to the holding position for runway 26L. After the aircraft had received clearance to line up onto runway 26L, the respective stop bars remained lit. The crew complained about this and taxied onto the runway only after the stop bars had been extinguished. At 20:01 UTC CRX 3597 lifted off from the take–off runway and was subsequently cleared to flight level (FL) 160 by air traffic control.

Neither the radio conversations nor the flight profile for this first phase of the flight indicated any peculiarities.

The recordings of the cockpit voice recorder (CVR) extend back to 20:36 UTC. At that time the aircraft was flying at FL 270 in the Rhein radar control area. Between 20:36:48 UTC and 20:37:23 UTC the copilot deciphered the Zurich airport runway report. In response to the comment that the braking action was not specified, the commander reacted with approximately two minutes of detailed explanations on the interpretation of a runway report.

At 20:40 UTC the aircraft was cleared for a descent to FL 240. At 20:42 UTC clearance for a further descent to FL 160 was given. In this phase, the commander as PF explained to the copilot how the approach has to be executed (approach briefing). The basis of his conversation was the expected instrument approach to runway 14 (ILS 14) in Zurich-Kloten according to standard procedure. At 20:43:44 UTC, during this approach briefing, the copilot draw the commander's attention to the fact of an increasing speed into a possible overspeed: "Mer chömed glaub mit de speed ächli in rote Bereich ine". – I believe that our speed is going somewhat into the red. The commander answered: "Ja, ja, ja, uuh, ja, isch mer devo gloffe, sorry. Mues en echli zrugg näh... so, das isch... zwenig zrugg gschruubet, hä". – Yes, yes, yes, it ran away, sorry. Have to bring it (airspeed) back a bit ... so... that's ... set back too little, hmm. The commander left the copilot to handle the navigation setup (NAV setting): "Denn, äh, s'NAV setting isch up to you. Final NAV setting wär zwei Mal d'ILS" – Then, er, the NAV setting is up to you. Final NAV setting would be twice the ILS.

Between 20:20 UTC and 20:36 UTC the crew had received the ATIS message "KILO", which envisaged an instrument landing system approach on runway 14. At 20:40:10 UTC the ATIS transmission changed to the code letter "LIMA", containing the change of landing runway with "Landing runway 28, VOR/DME standard approach". From 20:44:56 UTC the ATIS message "MIKE" was transmitted, including a chronological update of the runway report compared with "LIMA". This runway report, however, contained no substantive change compared with the previous one.

At 20:44:38 UTC CRX 3597 made contact with Zurich Radar ATC and continued its descent to FL 160. The flight crew was instructed to reduce speed to 240 KIAS and later on to descend to FL 130. Thereafter, at 20:47:56 UTC a transfer to Zurich Arrival East Sector took place. On initial contact, the copilot confirmed reception of the ATIS message "KILO". The air traffic controller did not inform the crew that in the meantime the ATIS message "MIKE" had become valid. He informed CRX 3597 concerning the change versus the ATIS message "KILO", that a standard VOR/DME approach 28 was foreseen. At 20:48:39 UTC the commander stated: "Ou Sch*****[1], das äno, guet, ok" – Oh, sh*****, that as well, fine, ok.

At 20:50:00 UTC the ATIS message "NOVEMBER" became active. Among other changes the visibility improved to 3500 m and the ceiling droped to 5-7/8 at 1500ft AAL. These changes were not communicated to the crew by the Zurich Arrival East Sector air traffic controller.

Shortly afterwards, CRX 3597 was instructed to fly on to waypoint RILAX for a holding. Flying in the holding pattern, between 20:51:56 UTC and 20:52:52 UTC the commander gave an approach briefing for the standard VOR/DME approach 28: "Guet, dän gäb's es re-briefing runway two eight... das wär d'Charte drizäh zwei. Kännsch guet de achtezwänzger Aaflug?" – Okay, then there'd be a re-briefing runway two eight... that would be chart 13-2. Are you familiar with the twenty-eight approach?" To which the copilot replied: "Ja, i has e paar mal scho gmacht, gell" – Yes, I've done it a couple of times. The commander then continued: "Es gaat via Trasadinge, Züri Oscht sächstuusig Fuess, dänn abe uf föiftuusig, dänn turn inbound to Chlote radial Zwei Föifesibzig." – It leads via Trasadingen, Zurich East 6000 feet, then down to 5000, then turn inbound to Kloten radial 275. The copilot confirmed: "Jawohl" – "Yes" and the commander further explained: "Wämer en self line-up würd mache, heted mer föiftuusig nach Züri Oscht, dänn viertuusig abe. Wämer de turn macht bi Ko... Komma Sächs Meile, Sächs Komma Föif Meile left turn and dänn dä Aafluug da gemäss Profiil: Vier-

[1] Expressions which constitute a spontaneous personal assessment of the current situation as well as personal utterances without any direct relation to the accident are identified by *****.

tuusig verlah bi acht Meile and bi sächs Meile Drüü Drüü Sächzig and s'neu Minimum isch Zwei Drüü Nünzig mit drüühundert am radio altimeter. Go around via Chlote radial Two Füfefüffzg intercept Zero One Two from Wilisau proceed to EKRIT climb to six thousand feet uf der APA." – If we had to do a self line-up, then we'd have 5000 after Zurich East, then descend down to 4000. If you make the turn at poi... point six miles, six point five miles, left turn and then the approach according to the profile: leave 4000 at 8 miles and at 6 miles 3360 and the new minimum is 2390 with 300 on the radio altimeter. (Crossair procedure: the radio altimeter is set to 300 ft RA for non-precision and visual approaches.) Go around via Kloten radial 255, intercept 012 from Wilisau proceed to EKRIT climb to 6000 on the APA. The copilot confirmed the procedure with: "Yes, checked yes".

The setting of the navigation instruments was discussed as follows: "S'NAV-setting bitte zweimal Chloote für de approach bis deet ane isch's up to you, hä" – The NAV setting: twice Kloten please for the approach. Till then it's up to you.

At 20:53:42 UTC CRX 3597 was instructed to turn right onto heading 180°. Two minutes later, the following instruction was given by air traffic control: "CRX 3597, on present heading intercept, follow ZUE VOR radial 125 inbound". The Copilot read back this instruction as follows: "Present heading, intercept inbound to ZUE, radial 152, CRX 3597". The air traffic controller answered: "No, radial 125". The copilot confirmed: "125, CRX 3597". This instruction gave rise to surprise in the crew. The commander finally interpreted the instruction "radial 125" as track 125. There was no query to the air traffic controller.

At 20:57:18 UTC clearance was given for a descent to 6000 ft QNH. The commander then said that he had set QNH to 1024 hPa on his primary altimeter. As part of the approach check the crew checked the altimeter reading by means of a cross-comparison. The copilot then added: "Fuel panel... set. Remaining, mer händ no Drüütuusig Zweihundert". – Fuel panel... set. Remaining, we still have three thousand two hundred (note: 3200 kg of fuel).

At 20:58:50 UTC the aircraft received clearance for a standard VOR/DME approach 28. After Zurich Arrival had instructed flight CRX 3597 to reduce the speed to 180 knots at 21:03:01 UTC, the handover to ADC 1 air traffic control took place (Zurich Aerodrome Control 1, Zurich Tower). In this phase HB-IXM was in a descent between 5000 and 4000 ft QNH and was turning right to fly onto the final approach track of 275° VOR/DME KLO and to follow it. The position of the aircraft at the time of handover to Zurich Tower was approximately 11 NM to the east of the airport. During the right turn the commander mentioned to the copilot that he had visual ground contact.

At 21:03:29 UTC an Embraer EMB 145, flight number CRX 3891, landed on runway 28 and transmitted the following information on the Zurich Tower frequency at 21:04:31 UTC: "Yes, just for information, erm..., the weather at... for runway 28 is er... pretty minimum; so we had runway in sight about 2.2 NM distance away". This aircraft was the first that evening to execute the standard VOR/DME approach 28. This weather information was not transmitted to the following aircraft by ATC. As the CVR recordings from 21:05:59 UTC and 21:06:25 UTC prove, the commander of the accident flight was aware of this report from CRX3891.

At 21:04:23 UTC the copilot stated: "Jetzt simmer acht Meile denn, chömmer vier tuusig verlaa." – We're now coming to eight miles, so we can leave four thousand.

The commander then replied at 21:04:27 UTC: "Jawohl, guet, established simmer... sächs tuusig ine bitte, go around altitude... vertical, sorry... vertical at tuusig". – Yes, fine, we're established ... set six thousand please, go around altitude... vertical, sorry...

vertical... thousand. The copilot confirmed the command to set a go around altitude of 6000 feet on the mode control panel with "Yes".

At 21:04:36 UTC the aircraft left the altitude of 4000 ft QNH. At this time its speed was 160 kt and it adopted initially a rate of descent of 1000 ft/min, which was later increased to 1200 ft/min. This rate of descent was not changed until just before the collision with the obstacles.

At 21:05:21 UTC the flight crew of CRX 3597 reported to ADC 1: "Tower, good evening, CRX 3597, established VOR/DME runway 28". At this time the aircraft was at an altitude of 3240 ft QNH and at a DME distance of 6 NM from VOR/DME KLO. Shortly thereafter, the crew completed the final check as preparation for the landing. The commander commented at 21:05:27 UTC: "Sächs Meile drüü drüü isch checked." – Six miles three three (3300)... is checked.

As the aircraft approached the minimum descent altitude (MDA) for the approach, the commander mentioned at 21:05:55 UTC that he had noted this and explained that he had certain visual ground contact: "Zwei vier, ground contact hämmer, hä" – Two four (2400), we have ground contact". The copilot answered: "Yes". At 21:05:59 UTC the commander stated: "Mä hät gseit, Pischte hät er spaht gseh da... approaching minimum descent altitude... da hämmer ächli ground contact..." – Someone said he saw the runway late here ... approaching minimum descent altitude... here we've got some ground contact. At 21:06:10 UTC the aircraft reached the MDA of 2390 ft QNH and the commander said: "...zwo vier, s'Minimum... ground contact han ich... mer gönd wiiter im Moment... es chunnt füre, ground contact hämer... mer gönd wiiter..." - ...two four (2400), the minimum ... I have ground contact ... we're continuing at the moment ... it appears, we have ground contact ... we're continuing on ... . At the same time, the copilot said quietly to himself: "Two four". The descent continued unchanged below the MDA. At 21:06:22 UTC the synthetic voice of the ground proximity warning system (GPWS) announced the radio altimeter reading 500 feet above ground. Immediately thereafter, the commander stated: "Sch*****, zwee Meile hät er gseit, gseht er d'Pischte" – Sh*****, two miles he said, he sees the runway. At 21:06:31 UTC the commander mentioned that 2000 feet had been reached: "Two thousand". In addition, one second later the synthetic voice gave the "minimums" GPWS message, which was triggered by the radio altimeter reading at 300 feet. At 21:06:32 UTC aerodrome control ADC 1 gave flight CRX 3597 the landing clearance. During this radio conversation, the commander said quietly: "...go around mache?" – ...make a go around? At 21:06:34 UTC the commander instructed a go around and an acoustic signal indicated that the autopilot had been switched off. A few fractions of a second later, the copilot likewise expressed the intention to go around. The recordings of the digital flight data recorder prove that the crew pushed the power levers towards the take-off thrust position and the engines' RPM increased. One second later, the CVR began to record the sounds of an impact. A short time later, the CVR recording broke off.

The first traces of the impact of aircraft HB-IXM were at an elevation of 1854 ft AMSL in the crown of a tree. HB-IXM then impacted approximately 200 m further downhill at an elevation of 1690 ft AMSL. The aircraft caught fire during this final flight phase.

When the aerodrome controller granted the landing clearance, he still could see the aircraft on the bright display (display of the radar image on a TV monitor). After he had given the landing clearance to CRX 3597 without having received confirmation, he assumed that the pilots were very busy in this phase of the flight and could therefore not answer immediately.

After this radio transmission, the ADC controller was busy with other tasks, before he was able to turn back to CRX 3597. He noted that the aircraft was no longer visible on the bright display and therefore began to search for the whereabouts of CRX 3597 together with the ground air traffic controller. At 21:10:32 UTC, 4 minutes after granting landing clearance, he triggered the highest alarm level.

The first vehicles from the Zurich airport fire brigade arrived at the accident site at 21:22 UTC together with the medical rescue services.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3	21	-
Serious	1	4	-
Minor/none	1	3	

1.3 Damage to the aircraft

The impact and the subsequent intense fire destroyed the cockpit, the front part of the fuselage, the central part of the fuselage and large sections of both wings. Only the aft section of the fuselage, which was torn off complete with the elevator unit and rudder unit, was not affected by the fire.

1.4 Other damage

There was significant damage to woods. Since the crash, vegetation at the point of impact has re-grown.

1.5 Personnel information

1.5.1 Commander

Person	+Swiss citizen, male, born 1944
Flight duty times	Start of duty at the flying school Horizon Swiss Flight Academy on 23.11.01: 05:00 UTC End of duty with the airline on 23.11.01: 20:31 UTC Flight duty time on 23.11.01: 15:31 h Rest time: 10:59 h Start of duty at the flying school Horizon Swiss Flight Academy on the day of the accident: 07:30 UTC Flight duty time at the time of the accident: 13:37 h
Licence	Air transport pilot licence ATPL (A) according to JAR, issued by the Federal Office for Civil Aviation, valid till 02.05.2006
Ratings	Radiotelephony International RTI (VFR/IFR) Night flying NIT (A) Instrument flight rules IFR (A)

Ratings to be extended	Single engine piston aircraft SE piston Motor glider TMG Multi-engine piston aircraft ME piston Type rating AVRO RJ/BAe 146 PIC Type rating Saab 340 PIC Flight instructor FI (A) Instrument flight instructor IRI (A)
Instrument ratings	SE piston, CAT I, valid till 11.02.2002 ME piston, CAT I, valid till 11.02.2002 AVRO RJ/BAe 146 PIC, CAT III, valid till 28.05.2002 Saab 340 PIC, CAT II, valid till 11.02.2002
National ratings	Aerobatics extension ACR (A)
Last proficiency check	Semi annual recurrent check at Crossair on 24.10.2001
Last line check	CDR type rating at Crossair on 22.06.2001
Medical certificate	Last periodic examination on 10.08.2001, commencement of validity 11.08.2001, Classes 1 and 2

Flight experience	19555:29	h total
on powered aircraft	19441:31	h
on gliders	113:58	h
as pilot in command	19341:08	h
on the type involved in the accident	287:13	h
during the last 90 days	193:14	h
on the type involved in the accident	163:06	h
on the day before the accident	8:47	h
on the type involved in the accident	6:19	h
on the day of the accident	4:57	h
on the type involved in the accident	2:51	h
Begin of pilot training	1961	

1.5.1.1 Professional training

After primary school, the commander attended the regional school, which he left after two years. He then took an apprenticeship as a mechanic, which he completed successfully in 1964.

1.5.1.2 Pilot training and activity

At age 17, the commander applied for preliminary pilot training (*Fliegerische Vorschulung* – FVS). He failed the first entry exam. An application for renewed permission to take the 1963 entry examinations and two applications in 1965 were rejected by the institute of aviation medicine of the Swiss Air Force with reference to a lack of educational qualifications.

During professional training, the commander began training on gliders and single-engine aircraft. The pilot's licence for gliders was issued by the Federal Aviation Office on 17 August 1963, and the licence for private pilots on 19 February 1964. The commander then participated in a theory course for instrument rating and the professional pilot's licence. After the corresponding training, on 12 April 1966 he obtained the extension for aerobatics and on 16 August 1966 the professional pilot's licence.

In spring 1966 the commander passed the aptitude test for piston engine flight instructor and after the corresponding course and practical experience of about six months duration, on 31 January 1967 he was promoted with the authorisation to train private pilots.

Between 1967 and 1970 the commander worked intensively as a VFR flight instructor for private pilots. During this time he increased his visual flight rules flying experience from about 200 to more than 2000 flight hours.

From 1965 to 1970 he converted successfully to six other aircraft types; five of these aircraft types were used predominantly for visual flying.

Instrument flight training commenced in 1966, but the special instrument rating was not granted until 10 July 1969, because the complementary theoretical examinations and the practical examination were failed several times between 1967 and 1969. The experts from the Federal Aviation Office complained in particular about inadequate comprehension and incorrect use of navigation systems. The examination to acquire the instrument rating was passed with the grading "average".

From then until 1979 the commander regularly flew charter flights on Cessna 337 and Cessna 414 aircraft types for various operators. In autumn 1972 the commander was allowed to participate in a Federal Aviation Office IFR flight instructor's course. Subsequently he regularly trained students outside of Crossair in instrument flying up to the time of the accident.

The periodic instrument flying checks between 1969 and 1979 were generally passed with the gradings "average". The respective experts occasionally criticised the fact that checklists were not used consequently, that procedures were not complied with and that navigation instruments were not used appropriately. These assessments also related to his work as a flight instructor.

On 28 January 1979 the commander applied for the position of pilot with Crossair. No documentation on checking of his aptitude is available. In spring 1979 the commander undertook a conversion course at Flight Safety International to the SA 226 TC Metroliner II used by Crossair at that time. On 5 April 1979, with a total flying experience of 4490 flying hours, he passed the type rating examination with the grading "below average – average".

From 15 June 1979 to 31 August 1979 the commander worked as a freelance pilot in addition to his regular duties, and between 1 September 1979 and 31 May 1982 he was employed full-time by Crossair. In spring 1981 the commander converted from aircraft type SA 226 TC Metroliner II to the SA 227 AC Metroliner III. He was employed as commander, flight instructor, route check pilot and expert. Furthermore he was deputy chief pilot for the company. During the same time he was still registered in the flight operations manual (FOM) of three airlines as a flight instructor and pilot. At his own request he left Crossair on 31 May 1982. The commander's flying performance was assessed by Crossair as above average.

From 1 June 1982 to 31 May 1991 the commander worked under seven freelance contracts for Crossair. On 12 August 1987 the commander obtained the type rating for the Saab 340. From 1 June 1991 to 31 December 1993 he was employed on an 83% part-time basis by the airline. From 1 January 1994 up to the time of the accident, the commander was working 100% for Crossair. Since 11 September 1981 he also had a part-time employment contract with the Horizon Swiss Flight Academy flying school as a flight instructor.

1.5.1.2.1 First conversion course to aircraft type MD 80

In 1993 and 1994 the commander was assessed three times for conversion to the aircraft British Aerospace 146 “Jumbolino”. For various reasons he was not referred for conversion and the commander continued to fly the Saab 340.

In the course of 1995 the commander was designated for conversion to the MD 80 aircraft type. No selection procedure or aptitude check took place. The conversion course began on 2 January 1996 and shortly after the beginning of simulator training the commander experienced problems reaching the required performance levels. Two additional simulator sessions were therefore offered to him. Even after these training sessions there remained gaps in comprehension and coordination. Since his learning progress was too slow, it was decided to abort the conversion course and to allow the commander to make another attempt to convert to the MD 80 aircraft type after a few months.

A deeper analysis of the reasons for failing the conversion course did not take place. The commander was subsequently requalified on the Saab 340 aircraft type and employed on scheduled traffic.

1.5.1.2.2 Second conversion course to aircraft type MD 80

On 24 June 1996 the commander was able to begin a second conversion course to the MD 80. Before this course, no aptitude check took place. In the second simulator session it became apparent that the commander was having major problems with the MD 80’s digital flight guidance system (DFGS) and this had a major impact on his overall performance. When the difficulties became even greater after the fourth simulator session, an additional simulator exercise was carried out. One additional exercise was planned after the following regular simulator session and after the eighth training respectively.

On 15 August 1996 the commander failed the type rating check at the end of the conversion course. The inadequacies concerned, among other things, the manual control of the aircraft and a deficient systematic approach to the use of the flight guidance system; a limited ability to analyse and to take decisions at the appropriate time was also noted.

Afterwards, the commander was once again requalified on the Saab 340 and from 1 September 1996 was again employed on scheduled services. No performance check and no more detailed examination of the reasons for the repeated failure of the conversion course took place.

1.5.1.2.3 Conversion course to aircraft type Avro RJ 85/100

As early as 1993 and 1994 the commander was discussed for conversion to the Avro RJ 85/100 aircraft type. This conversion did not take place, for various reasons. After the failed attempts to convert to the MD 80, the commander continued to be employed on the Saab 340. In the course of the year 2000, decommissioning of the Saab 340 was being envisaged and Crossair attempted to find another aircraft type which the commander could fly in the future. The commander, who wished to fly until aged 65, again applied for the MD 80. Since at that time there was no need of pilots for the MD 80 aircraft type, conversion to this type was out of the question. It was decided to convert the commander to the Avro RJ 85/100. The relative simplicity of this aircraft type was cited by the responsibles of the airline as a reason for this decision.

Prior to the conversion to the Avro RJ 85/100, the commander was not subject to any aptitude checks. The chief flight instructor of the Avro RJ 85/100 indicated that he was not aware that the commander had already had two unsuccessful attempts at conversion to another jet aircraft.

On 6 May 2001 the commander began conversion to the Avro RJ 85/100 aircraft type. On 28 May 2001 a first part of the proficiency check was carried out. Because of a simulator failure, the rest of the check had to be completed on 4 June 2001 on another simulator. Route introduction under supervision ended on 22 June 2001 with a line check after 20 sectors. On 24 October 2001 the commander passed the last semi annual recurrent check as a proficiency check. On the corresponding checkforms, only positive comments from the experts are to be found concerning the commander’s performance. During the proficiency and line check as well as during the line-introduction under supervision, no mistakes were pointed out and no items were mentioned that the commander could have improved.

During assignment to the Avro RJ 85/100 aircraft type, the following exercises in relation with non-precision approaches were carried out in the cockpit procedure mockup (CPM), in simulator training (SIM) and during the subsequent checks.

Date	Training	Number and type of approaches
26.04.2001	CPM lesson 5	2 non-precision approaches
04.05.2001	CPM lesson 8	1 non-precision approach
12.05.2001	SIM lesson 1	1 VOR approach Zurich
13.05.2001	SIM lesson 2	1 VOR approach Geneva
14.05.2001	SIM lesson 3	2 NDB approach Stuttgart
20.05.2001	SIM lesson 5	1 LOC/DME circling approach
		1 VOR approach Milan-Linate
25.05.2001	SIM lesson 9	2 NDB approaches Basel
28.05.2001	proficiency check	1 VOR approach Zurich
10.07.2001	CDR type rating line check	1 standard VOR/DME approach 28 Zurich
29.10.2001	Semi annual recurrent check	1 LOC/DME approach Zurich

During route training under supervision, no non-precision approaches were flown. During his training on the Avro RJ 85/100 aircraft type, therefore, the commander carried out 14 non-precision approaches as pilot flying. Among those was one standard VOR/DME approach 28 in Zurich in the simulator and one approach in the aircraft.

1.5.1.3 Activity as flight instructor

The commander was employed as flight instructor by the Horizon Swiss Flight Academy for over 20 years. He was mainly assigned as an instructor for future professional pilots seeking for instrument rating. At his request, he carried out the training almost exclusively on aircraft and hardly ever used the simulator.

On 22 September 1992 the commander was designated by the Federal Office for Civil Aviation as an expert for the acceptance of flying examinations for achieving instrument rating. Four years later, on 13 August 1996 the commander additionally received authorisation for flying examinations according to visual flight rules.

From 1990 to 1993 he was employed as an instructor on FOCA courses for the training of instrument flight instructors.

In autumn 1998 the commander took part in the FOCA's VFR piston engine flight instructor refresher course for two weeks in order to obtain his teaching authorisation for visual flight rules, which had expired on 15 December 1986.

Since the introduction of JAR-FCL 1 between 1999 and 2002, flight instructors have to pass periodically a proficiency check in order to get certain ratings renewed. Each flight instructor at the Horizon Swiss Flight Academy had to undergo a proficiency check for multi-engined aircraft with piston engines on the school's own simulator. As, according to several statements, the commander did not hold simulators in particularly high esteem, this proficiency check was carried out on the aircraft instead.

On 28 April 2000 the commander made two training flights as flight instructor with the copilot of the aircraft involved in the accident. At this time the copilot was in the process of acquiring his professional pilot's licence with instrument rating.

As shown on the flight activity records, the commander occasionally made training flights in the morning and then flew several sectors on the same day as an air transport pilot. On 13 November 2001, for example, between 06:00 UTC and 13:00 UTC the commander made four flights with two student pilots. He then flew two sectors with Crossair and went off duty after 13 hours and 34 minutes. Neither the Crossair airline nor the Horizon Swiss Flight Academy carried out any supervision of flying time and rest time across different companies.

1.5.1.4 Particular incidents during his professional career

1.5.1.4.1 General

As the investigation showed, various incidents occurred during the commander's professional career between 1967 and the time of the accident. Only the most important events are dealt with below; they occurred during his employment with the Crossair company and some of them became known only after the accident.

1.5.1.4.2 Unintentional retraction of the landing gear on the ground

On 21 February 1990 the commander, as instructor, carried out a system training on the Saab 340 aircraft type with a copilot onboard the aircraft HB-AHA. The discussion turned to the procedure for remedying a landing gear retraction fault. The commander was of the opinion that on the ground, with the landing gear under load, the function of the retraction mechanism was interrupted, as is the case, for example, with smaller aircraft. Actually, however, the corresponding safety device of the Saab 340 only prevented operation of the landing gear lever. The commander pressed the down lock release button, which overrode the safety device and the copilot brought the landing gear lever to the retract position. Contrary to the commander's assumption, the hydraulic pumps began to work and the retraction process could not be interrupted. The aircraft impacted on the ground and was a whole loss. The commander suffered a head injury whilst the other persons who were in and around the aircraft were uninjured.

The incident was investigated by the airline and the commander was subsequently no longer employed as an instructor. This event had no further effects on the commander's career.

1.5.1.4.3 Aborted route check

On 25 June 1991 the commander was taking a route check during which he did not comply with a speed instruction from air traffic control for several minutes. This led to a situation where the aircraft flew into the wake turbulence of a Boeing 747 during the final approach. The check for approach and the final check had been forgotten and on landing the cabin attendant was still standing in the passenger cabin corridor. The expert assessed the commander's comprehension as inadequate and aborted the route check, which had to be repeated subsequently.

1.5.1.4.4 Cessation of activity as training captain

At the end of 1991 the commander was relieved of activity as a line training captain, because his performance was inadequate.

1.5.1.4.5 Night-time instrument approach to Lugano

According to the statement of the copilot involved, in December 1995 the commander was carrying out an approach to Lugano airport as pilot flying, at night and under instrument flight conditions. Shortly before the Saab 340 reached the PINIK waypoint at an altitude of 7000 ft QNH, the aircraft was configured for the landing, i.e. the landing gear was lowered and a landing flap setting of 35° was selected. For the descent, the commander used the autopilot's vertical speed mode and selected a rate of descent of 4000 ft/min. Since rates of descent of less than 2000 ft/min are usually used for this approach, the copilot asked for the reason for the increased rate of descent. The commander explained that one could implement the procedure in this way. During the descent, which continued unchanged to a radar altitude of 300 ft RA above the lake, the speed of the aircraft increased from 135 to more than 200 KIAS. When the aircraft changed over to horizontal flight at 300 ft RA, part of the lake shore and the mountainside could be seen. The aircraft then flew at this altitude in the direction of Lugano aerodrome until the runway finally came into view and the aircraft was able to land.

The overspeed warning and the ground proximity warning system (GPWS) had been deactivated before the descent.

The incident became known only after the accident. Reconstruction flights in the Simulator showed that it is possible to fly the approach in the described way.

1.5.1.4.6 Navigation error during a private sight-seeing flight

The Crossair airline offered its employees the possibility to charter commercial aircraft for private flights. The way such sight-seeing flights were carried out, usually according to visual flight rules, was regulated in the operations manual. In principle, the same standards were applied as for scheduled flights. The commander made many Alpine sight-seeing flights in a chartered Saab 340; the passengers in each case were organized by the crew.

On 21 March 1999, together with a copilot and a cabin attendant, the commander made a private flight with 30 passengers onboard Saab 340 HB-AKI. The plan was to execute an alpine sight seeing flight from Zurich with an intermediate landing in Sion and then a return flight to Zurich.

In Zurich the sky was nearly overcast, whilst the weather conditions in the Alpine region were fine.

On the outward flight to Sion, Crossair flight number CRX 4718, the commander was pilot flying. The departure from Zurich took place under instrument flight rules. Above the clouds the flight continued towards the Bernese Alps under visual flight rules.

Witnesses' statements and a film document prove that the commander issued extended explanations of the flight path and that the passengers were allowed to visit the cockpit.

When the aircraft was at an altitude of about 12 000 ft QNH above the Savoy Alps, the copilot made radio contact with Sion aerodrome control. Shortly afterwards, the commander realised that the planned flight time to Sion had more or less expired. He immediately initiated a descent in the direction of an aerodrome which he had in sight. This was Aosta (I) aerodrome, which is located approximately 50 km to the south of Sion in a valley which runs along the other side of the main ridge of the Alps. No discussion on the approach took place and the most important checklist points were covered intuitively and in an undefined order. The copilot tried several times to make contact again with Sion aerodrome control, which he was unable to do because of the topographical conditions. The commander did not react to interventions from the copilot. Several descending turns were made above Aosta aerodrome and the approach was continued without radio contact. When the aircraft was making its final approach, the passengers could see from road signs that they were in Italy. The commander then initiated a go around and flew over the St. Bernhard pass into the Rhone valley, where the landing in Sion took place.

The navigation error was explained to the passengers. The airline was not informed of the incident and learned of it only after the accident. There is no indication that the health of the crew was adversely affected.

1.5.1.5 Working and management behaviour

According to several copilots' statements, the commander occasionally operated the aircraft alone as pilot flying (one-man operation) and did not always integrate copilots consequently in the operating procedures and decision-making process. It is also documented that he placed a value on being able to land punctually, especially on the final flight sector of a day's duty.

From the conversion course documentation and from witness statements, it is apparent that the commander had a distinctly defensive behaviour in relation to more complex technical systems and frequently exhibited difficulty with their operation.

The commander's behaviour was unanimously described as very quiet and tending toward the remote. Copilots occasionally felt a perceptible drop in their authority during cooperation, which they attributed predominantly to the commander's vastly higher experience.

1.5.2 Copilot

Person	+Swiss citizen, male, born 1976
Flight duty times	Start of duty on 23.11.01: 11:50 UTC End of duty on 23.11.01: 22:05 UTC Flight duty time on 23.11.01: 10:15 h Rest time: 18:49 h Start of duty on the day of the accident: 16:20 UTC Flight duty time at the time of the accident: 4:47 h
Licence	Commercial pilot's licence CPL (A) according to JAR, issued by the Federal Office for Civil Aviation, valid till 06.07.2005
Ratings	Radiotelephony International RTI (VFR/IFR) Night flying NIT (A) Instrument flight rules IFR (A)
Ratings to be extended	Single engine piston aircraft SE piston Multi-engine piston aircraft ME piston Type rating AVRO RJ/BAe 146 COPI
Instrument ratings	SE piston, CAT I, valid till 12.05.2002 ME piston, CAT I, valid till 12.05.2002 AVRO RJ/Bae 146 COPI, CAT III, valid till 31.03.2002
Last proficiency check	Semi annual recurrent check at Crossair on 02.07.2001
Last line check	F/O first line check at Crossair on 12.05.2001
Medical certificate	Last periodic examination on 18.12.2000 Commencement of validity 20.01.2001, Classes 1 and 2
Flight experience	490:06 h total
on powered aircraft	490:06 h
as pilot in command	81:55 h
on the type involved in the accident	348:20 h
during the last 90 days	120:22 h
on the day before the accident	5:49 h
on the day of the accident	2:51 h
Begin of pilot training	1999

1.5.2.1 Professional training

After primary and secondary school, the copilot attended cantonal school and completed the latter in 1997 with the school leaving examination (Matura) specialising in mathematics and natural sciences. In autumn 1998 he took up studies at a technical college, which he gave up after six months in favour of pilot training.

1.5.2.2 Pilot training

In January 1999 the copilot began training as an air transport pilot at the Horizon Swiss Flight Academy and on 27 August 1999 passed the flying examination for private pilots. As part of an integrated course according to the Federal Office for Civil Aviation regulations for licensing flying personnel [Reglement für die Ausweise von Flugpersonal – RFP], he took the theory examination for professional pilots and for instrument flight rating on 10 June 1999 and on 9 September 1999. The theory examination for air transport pilots followed on 2 May 2000. The pilot took the flying examination to obtain a commercial pilot's licence on 12 May 2000 together with the practical examination for instrument flight rating.

The training documentation and statements from fellow pupils prove that the copilot had been instructed in non-precision approaches in accordance with the provisions of JAR-OPS 1. In particular, it can be assumed that he knew the visual references which are necessary in order to be able to fly below the minimum descent altitude (MDA).

1.5.2.3 Selection of the copilot by the Crossair operator

On 9 July 2000 the copilot applied to Crossair for a pilot's position. The first checking, in the form of individual and group assessments, took place on 1 September 2000. The observations of the four recruitment officers responsible for these tests differ in some respects. However, all four assessors found that the copilot had a tendency to subordinate himself.

During the simulator check on 21 September 2000, which was carried out as part of the selection procedure, minor problems were found with the correct attitude flying; these were considered to be rectifiable. The recruitment officer who conducted both the simulator check and an initial interview described the copilot's personality as very positive. In particular, he attested to his high motivation and assessed him as suitable for the company.

The psychodiagnostic report of an external test and assessment centre describes the copilot as, among other things, lively but not aggressive, sensitive, benevolent and seeking harmony. There was found to be a need for development in terms of self-confidence and personal maturity.

The results of all the checks were subsequently forwarded to the selection board. The selection board meeting took place on 26 November 2000 and consisted of a member of the management and an expert from the pilot recruitment division. The copilot was assessed positively and recruited with the exception that he was assigned for five additional training units on the simulator in order to practise attitude flying. After the accident, the selection board members indicated that the copilot was considered to be well qualified according to the selection profile applied to new pilots by Crossair.

1.5.2.4 Conversion course to aircraft type Avro RJ 85/100

On 8 January 2001 the copilot began a course for future copilots which among other things included a two weeks' introduction to the operator. As part of this company introduction, a theoretical introduction was also provided to the effective use of crew co-operation (crew resource management – CRM).

On 31 March 2001 the copilot passed the skill test in the simulator and was cleared after flight training on 7 April 2001 for the route introduction under supervision. After completing 40 sectors he passed the line check on 12 May 2001. On 2 July 2001 he passed the last semi annual recurrent check. The corresponding checkforms indicated almost exclusively positive comments by the experts in relation to the copilot's performance.

During assignment to the Avro RJ 85/100 aircraft type, the following exercises in connection with non-precision approaches were carried out in the cockpit procedure mockup (CPM), in simulator training (SIM) and during the subsequent checks.

Date	Training	Number and type of approaches
02.03.2001	CPM lesson 5	2 non-precision approaches
10.03.2001	CPM lesson 8	1 LOC approach 16 Zurich
19.03.2001	SIM lesson 2	1 VOR approach Geneva
22.03.2001	SIM lesson 3	1 LOC approach Stuttgart
29.03.2001	SIM lesson 8	1 VOR approach Basel
30.03.2001	SIM lesson 8a	1 VOR approach 23 Geneva
31.03.2001	proficiency check	1 VOR approach 16 Zurich
02.07.2001	semi annual check	1 NDB approach 25 Stuttgart

Since there were no further non-precision approaches during route training under supervision, the copilot therefore carried out 9 non-precision approaches during conversion to aircraft type Avro RJ 85/100. There is evidence that he was pilot not flying during an approach to runway 28 at Zurich airport.

1.5.2.5 Particular incidents during his professional career

No particular incidents during his professional career are known.

1.5.3 Cabin attendant A

Function	Senior cabin attendant SCA-CA 1
Person	+Swiss citizen, female, born 1974
Qualifications	Emergency procedure refresher course, issued by Crossair, valid till 30 April 2002.

1.5.4 Cabin attendant B

Function	Cabin attendant CA 2
Person	Swiss citizen, female, born 1976
Qualifications	Emergency procedure refresher course, issued by Crossair, valid till 31 August 2002.

1.5.5 Cabin attendant C

Function	Cabin attendant CA 3
Person	Swiss citizen, female, born 1973
Qualifications	Emergency procedure refresher course, issued by Crossair, valid till 31 December 2001.

1.5.6 Air traffic control officer A

Function	Approach control (APE) until 21:04 UTC
	Aerodrome control (ADC 1) from 21:06 UTC
Person	Danish citizen, male, born 1961
Training	The air traffic control officer (ATCO) began working for swisscontrol on 13 March 2000. At the time he possessed an air traffic controller's licence, which he had acquired in Denmark. The air traffic control officer underwent conversion tailored to local requirements and then completed the necessary on the job training (OJT). On concluding this conversion course, the Federal Office for Civil Aviation granted him, upon request of skyguide, the Swiss Confederation's air traffic controller licence.
Licence	For air traffic control officers, issued by the Federal Office for Civil Aviation on 3 October 2000, last renewed on 22 August 2001, valid till 7 August 2002.

1.5.7 Air traffic control officer B

Function	Approach control (APW) until 21:04 UTC
	Approach control (APW+APE) from 21:04 UTC
Person	Swiss citizen, male, born 1974
Licence	For air traffic control officers, issued by the Federal Office for Civil Aviation on 15 November 1996, last renewed on 5 March 2001, valid till 13 February 2002.

1.5.8 Air traffic control officer C

Function	Aerodrome control (ADC 1) until 21:06 UTC
Person	Swiss citizen, male, born 1949
Licence	For air traffic control officers, issued by the Federal Office for Civil Aviation on 29 June 1972, last renewed on 29 June 2001, valid till 29 June 2002.

1.5.9 Air traffic control officer D

Functions	Ground control (GRO) until 21:03 UTC
	Ground control (GRO) and supervisor aerodrome control tower (SUPER-TWR) from 21:03 UTC
Person	Swiss citizen, female, born 1972
Licence	For air traffic control officers, issued by the Federal Office for Civil Aviation on 17 November 1998, last renewed on 29 June 2001, valid till 20 June 2002.

1.5.10 Air traffic control officer E

Function	Aerodrome control tower supervisor until 21:03 UTC
Person	Swiss citizen, male, born 1947
Licence	For air traffic control officers, issued by the Federal Office for Civil Aviation on 29 August 1973, last renewed on 21 September 2001, valid till 29 August 2002.

1.6 Aircraft information

1.6.1 Aircraft HB-IXM

1.6.1.1 General

Type	AVRO 146-RJ100
Manufacturer	British Aerospace Ltd., Woodford, Cheshire England
Registration	HB-IXM
Serial number	E3291
Year of construction	1996
Owner	Crossair Limited Company for Regional European Air Transport, CH-4002 Basel
Operator	Crossair Limited Company for Regional European Air Transport, CH-4002 Basel

Airworthiness certificate	23 August 1996, issued by the Federal Office for Civil Aviation, valid until revoked
Registration certificate	23 August 1996, issued by the Federal Office for Civil Aviation
Airframe flying hours	13194:30
Number of cycles (landings) of the airframe	11518
Engines	4 Allied Signal LF507-1F
Auxiliary power unit (APU)	Sundstrand 4501690A
Wingspan	26.34 m
Length	31.0 m
Height	8.59 m
Wing area	77 m^2
Thrust per engine	3175 kN
Fuel consumption in flight	1800 kg/h
Range at maximum permitted load	3000 km
Maximum flying altitude	9400 m AMSL

1.6.1.2 Engine number 1

Serial number	LF07623
Operating time since manufacture	10474 h
Flying cycles since manufacture	9153
Operating time since installation in HB-IXM	10421 h
Flying cycles since installation in HB-IXM	9108

1.6.1.3 Engine number 2

Serial number	LF07572
Operating time since manufacture	11218 h
Flying cycles since manufacture	9363
Operating time since installation in HB-IXM	3405 h
Flying cycles since installation in HB-IXM	2972

1.6.1.4 Engine number 3

Serial number	LF07434
Operating time since manufacture	13336 h
Flying cycles since manufacture	11508
Operating time since installation in HB-IXM	501 h
Flying cycles since installation in HB-IXM	407

1.6.1.5 Engine number 4

Serial number	LF07391
Operating time since manufacture	13778 h
Flying cycles since manufacture	11828
Operating time since installation in HB-IXM	2898 h
Flying cycles since installation in HB-IXM	2529

1.6.1.6 Auxiliary power unit

Serial number	SPE967480
Operating time since manufacture	10239 h
Flying cycles since manufacture	12214
Operating time since installation in HB-IXM	4242 h
Flying cycles since installation in HB-IXM	3739

1.6.1.7 Navigation equipment

The following systems were available to the pilots for navigation:

- Dual Navigation Management System (NMS) by Global Wulfsberg
- Dual Inertial Reference System (IRS) by Honeywell
- Dual VHF-Navigation System by Collins
- Dual DME system by Collins
- Dual ADF system by Collins
- Dual Air Data System (ADS) by Honeywell
- Dual Radio Altimeter System by Collins
- Standby Attitude Indicator by Smith Industries
- Standby Altitude/Airspeed Indicator by Smith Industries

Those navigation systems which might have influenced the accident during the approach phase of CRX 3597 were investigated.

The navigation management system (NMS) was considered as part of the flight guidance system.

1.6.1.8 Communications equipment

The communications equipment consisted of the following systems:

- Audio integrating system
- Passenger address system
- Cabin interphone system
- Dual VHF communication system
- Mobile telephone

1.6.2 Mass and centre of gravity

The entries in the aircraft load sheet which were made for flight CRX 3597 in Berlin-Tegel were used as a basis for determining the mass and centre of gravity at the time of the accident. These data were confirmed by the findings at the site of the accident and by statements on the CVR.

Total traffic load	2477 kg	
Dry operating mass	26731 kg	
Zero fuel mass actual	29208 kg	Max 37421 kg
Actual block fuel	5650 kg	
Take-off fuel	5400 kg	
Take-off mass actual	34608 kg	Max 46039 kg
Trip fuel	2500 kg	
Landing mass actual	32108 kg	Max 40142 kg
Dry operating index	7	
Deadload index	14	
Loaded index at zero fuel mass	-7	
Loaded index at take off mass	18	
Stabilizer setting for take off	3.6	

Mass and centre of gravity were within permissible limits. At the time of the accident, according to crew statements at the time of the check for approach, a total of 3200 kg of fuel was onboard.

1.6.3 Aircraft control

1.6.3.1 Primary aircraft control

The DFDR recordings of the ailerons, elevator and rudder could not be analysed. The recorded values for control surface deflections in the final approach up to the first contact with the trees differed from the target values which correspond to this flight phase.

The serviceability of the primary aircraft control therefore had to be verified on the basis of an analysis of proved flight parameters (cf. section 2.1.2).

1.6.3.2 Secondary aircraft control

The DFDR secondary aircraft control data could be analysed satisfactorily and indicated no defective behaviour. The recorded positions corresponded to the configuration specified for the landing approach.

1.6.4 Engines

1.6.4.1 Visual inspection

The mechanical damage to the fan blades was minimal on all engines. Pine brushwood was found in all engines, sometimes combined with thicker branches.

Engines 1 and 2 exhibited major damage on the underside and major traces of fire. Both engines were still connected to the left wing structure.

Engines 3 and 4 were separated from the right wing on initial contact with the ground. The engine inlet cowlings were badly deformed and parts of the inlet area were filled with soil.

On the basis of the deformation of the rotating parts it can be assumed that all engines were running at medium power on impact.

1.6.4.2 Analysis of the digital flight data recorder and engine life computer data

From the DFDR recordings, the power lever angle (PLA) data for engines 1 to 4 were compared with the corresponding speeds of low-pressure compressor N1 during the last 15 minutes of the flight.

Regulation of the engines in the last 15 minute phase was unobtrusive, from an operational viewpoint it varied within the normal limits and corresponded to the power requirements of this flight phase. Two seconds before the last recording, the power levers were set to the take-off thrust direction. The RPM of all engines followed the power lever position with the customary delay. From the wreckage it was established that all power levers were approximately in the forwardmost position.

The data read out from the engine life computer (ELC) on 23 November 2001 were evaluated and the last 1000 flights were compared. None of the parameters present indicated an engine problem.

1.6.4.3 Oil indicator installation

From the wreck it was established that the oil indicator for engine 1 had been installed upside down (cf. Appendix 2). The investigation showed that the last documented work performed on this indicator was on 6 October 2001. During the period up to the accident, there is no evidence that anyone complained about the incorrect installation of the instrument.

1.6.5 Auxiliary power unit

1.6.5.1 Visual inspection

The auxiliary power unit (APU) was removed from the tail of the aircraft. The unit was externally undamaged. Foliage which had been sucked in was found on the air inlet mesh, indicating that the APU was in operation at the time of the accident.

1.6.5.2 Maintenance documentation

On examination of the technical documentation it was established that the APU had had a high number of faults since the aircraft was put in service. In all, more than a hundred complaints were made about the APU during the lifetime of the aircraft involved in the accident.

According to statements of Crossair employees, these problems occurred on all aircraft of the AVRO 146-RJ85/100 type which were equipped with this APU.

In the DDL it was noted that the APU would only start at the second attempt. On the flight involved in the accident, the APU only started on the second attempt as well.

1.6.6 Ice detection system

There are no indications of malfunctions in the ice detection system.

1.6.7 Flight guidance system

1.6.7.1 Electronic flight instrument system

1.6.7.1.1 Description of the system

The electronic flight instrument system (EFIS) contains four identical display units (DU), two symbol generators (SG), two EFIS control panels (ECP) and two display dimming panels (DP).

The display units (DU) are arranged in pairs, one on top of the other on the left and right instrument panel. The upper DU performs the function of a primary flight display (PFD) and the lower one that of a navigation display (ND).

The PFD shows the following flight parameters: aircraft attitude, airspeed, speed trend, mach number, vertical speed, radar altitude, decision height, flight director, vertical deviation, lateral deviation and marker beacon. In addition, the PFD displays the selected or preselected mode (roll, pitch, thrust) of the auto flight systems.

The ND displays the navigation data heading, selected heading, course, bearing, deviation and distance. It can be operated in the various ROSE, ARC, MAP and PLAN formats which are selectable on the ECP.

By means of the EFIS control panel (ECP), the display format (ROSE, MAP, etc.), the parameters to be displayed and their source, plus the range to be covered (RANGE) are determined for the ND. The 2nd CRS pushbutton additionally allows selection of a second course in addition to the selected course. Example: selected course LNAV 1, second course VOR 2. The NAV data pushbuttons allow nav aids, airports or other information to be masked in or out.

The EFIS symbol generator (SG) acquires data from IRS, ADC, RA, VOR, ILS, NMS, WXR and DFGS. It generates the symbols which are represented on the PFD and ND, and monitors or compares incoming signals. In the two SG the attitude, glide slope, localizer, radar altitude and airspeed parameters are compared. Invalid parameters are flagged accordingly. Example: if differences occur in the pitch and roll parameters, ATT is displayed in yellow on both primary flight displays. If an inertial reference unit supplies an incorrect input signal, ATT is displayed in red on the corresponding side. Data is displayed in both analogue and digital formats.

On the commander's instrument panel there is a selector switch which makes it possible to switch to the intact SG if one EFIS symbol generator (SG) fails (BOTH1-NORM-BOTH2).

The functions of the EFIS are continuously monitored by a comprehensive self-monitoring system. Malfunctions can be detected on the PFD and ND as fault codes. The symbol generator is able to store up to 20 fault messages per flight for 10 flights. A return-to-service test can also be carried out.

Power for EFIS number 1 is supplied by essential bus ESS 115 VAC; EFIS number 2 is supplied by the 115 VAC2 bus.

1.6.7.1.2 Non-volatile memories

Non-volatile memories are incorporated in the EFIS symbol generators. These can provide information on the operating condition of this equipment. These memories were analysed and it was shown that no malfunctions occurred during the fatal flight (cf. section 1.19).

1.6.7.2 Automatic flight system

1.6.7.2.1 Description of the system

The automatic flight system (AFS), in the AVRO 146-RJ100 also called the digital flight guidance system (DFGS), essentially contains two digital flight guidance computers (DFGC), one mode control panel (MCP), one thrust rating panel (TRP), plus a number of servos/actuators and position sensors, to implement the DFGC commands.

The digital flight guidance computer performs the following main functions:

- presentation of flight director commands
- three-axis autopilot control including automatic landing
- autothrottle speed and thrust control including thrust rating limits calculation
- windshear detection and recovery guidance
- pitch trim, flap trim compensation
- yaw damper and turn-coordination
- aural and visual altitude alerting
- built-in fault monitoring and maintenance test system

The DFGC generates a flight director command for the following functions:

- acquisition and holding of airspeed, mach, vertical speed and altitude
- acquisition and holding of a selected heading
- capture and holding of a selected VOR radial or ILS localizer beam
- capture and holding of an ILS glide slope beam
- capture and tracking of a flight plan provided by the navigation management system
- commands for take-off and go around
- windshear recovery guidance

Flight director commands are displayed on the EFIS primary flight display (PFD) and followed by the pilot. When the autopilot is switched on, the commands calculated by the DFGC are executed directly via servos.

Airspeed, mach, heading, clearance altitude and vertical speed are selected on the mode control panel (MCP). Flight director/autopilot modes are also selected or pre-selected on the MCP. These are displayed on the primary flight display (PFD) for confirmation. Flight director, autopilot and autothrottle are activated on the MCP.

The autopilot controls movements in flight via the ailerons, elevators and rudder. Prolonged control deflections on the elevator control tab are reduced by the elevator trim tab (pitch trim).

The rudder is operated in two different ways: in series mode, as yaw damper, rudder movements are very limited. In parallel mode, during autoland, take-off and go around, this restriction on rudder deflections is not effective. During these phases, full deflections may be necessary for controlling the aircraft on the ground (ground rollout) or for reacting to any engine failure (engine out compensation). The autoland, take-off and go around functions are calculated with redundancy in two channels and compared (fail passive operation).

The DFGC receives signals from the IRS (attitude, attitude rate, heading, ground speed, acceleration), from the ADC (altitude, vertical speed, speed, mach), from the VOR, ILS (course, deviation) and from the NMS (steering command). When the autopilot is switched on, the corresponding sensors can be selected by means of the pushbuttons NAV1 or NAV2.

In autothrottle speed/mach control mode or thrust control mode, the digital flight guidance computer (DFGC) cooperates with the full authority digital engine control (FADEC). In an initial control loop, the four power levers are brought to the position corresponding to the thrust target by the DFGC via a common servomotor. The thrust target is calculated in the DFGC. In a second control loop the FADEC regulates the fuel flow to each individual engine according to the thrust target. Minor differences are automatically compensated for by the FADEC. For monitoring purposes the thrust target is displayed on the primary engine display (PED). The engines themselves are always under FADEC control. In this way the thrust limit (TOGA MAX, TOGA REDU, MCT, CLB MAX, CLB NORM) indicated on the thrust rating panel (TRP) is complied with.

For the different aircraft configurations, the DFGC calculates a maximum and minimum permissible speed. Limits are also set with regard to aircraft attitude. One of the tasks of the autopilot is to keep the aircraft within the specified speed/attitude envelope.

Depressing a pushbutton on power lever 2 or 3 initiates an auto go around, if the autopilot is switched on. In this mode engine power is automatically increased to go around thrust, the current ground track is maintained and a vertical profile with the maximum climb gradient is flown.

The autopilot can be switched off by means of a pushbutton on the left and right control wheel respectively. When it is switched off, whether intentionally or unintentionally, a warning horn sounds which can be silenced by momentarely pressing the same pushbutton.

The FGC SELECT change-over switch in the overhead panel determines which of the two DFGCs is active. The remaining DFGC is available as a hot spare.

The DFGC includes an integrity monitoring system. Malfunctions are indicated on the flight guidance system (FGS) advisory annunciator, or on the central status panel. On start-up, an automatic power-up test is carried out. The result, PASS FGC 1 or 2 or FAIL FGC 1 or 2, is displayed on the PFD. Furthermore, a return to service test can be carried out. During an autoland approach, an autoland test is run. The crew are continuously informed of the readiness/status of the autoland system.

Power for the digital flight guidance system DFGS number 1 is supplied by the ESS 115 VAC, 28 VDC1, ESS 28 VDC, EMERG 28 VDC, ESS/BATT bus, whilst DFGS number 2 gets its power from the 115 VAC2, 28 VDC2, EMERG 28 VDC, and ESS/BATT bus.

1.6.7.2.2 Non-volatile memories

Non-volatile memories are incorporated in the digital flight guidance computer. These are able to provide information on the operational condition of these devices. These memories were analysed and it was revealed that no malfunctions were recorded during the flight in which the accident occurred (cf. section 1.19).

1.6.7.2.3 Use of the automatic flight system

The automatic flight system was switched on continuously for the last 30 minutes of the flight during which the accident occurred.

The autothrottle system was in mach mode to FL 235 and below that in IAS mode. The selected airspeed was being reduced continuously, according to the DFDR recordings. The last selected speed was 116 KIAS.

The lateral mode of the autopilot changes in the following sequence: LNAV 1, HDG-SEL, VORNAV 1, LNAV 1, VORNAV 1. In the last phase of the flight during which the accident occurred, VORNAV 1 mode was active. The last selected VOR course was 275°.

The vertical mode of the autopilot changed several times between ALT HOLD and VERT SPD. In the last phase of the flight the VERT SPD mode was active. The selected rate of descent at this time was 1200 ft/min.

The autopilot was switched off at 21:06:34 UTC. The corresponding warning horn was recorded on the CVR.

1.6.7.3 Navigation management system

1.6.7.3.1 Description of the system

The GNS-X by Global Wulfsberg is an integrated navigation management system (NMS) which supports the following functions:

- determination of position by means of various sensors (GPS, IRS, DME/DME, VOR/DME)
- calculation of flight parameters (ground speed, track angle, drift angle, desired track, crosstrack distance, distance to waypoint, bearing to waypoint, estimated time of arrival, wind speed and direction)
- generation of a route on the basis of manually entered waypoints and with the aid of the navigation data base (NDB)
- retrieving a pre-programmed company route, a standard instrument departure route (SID) or a standard arrival route (STAR)
- support for fuel planning
- outputting navigation data to the electronic flight instrument system (EFIS)
- outputting control signals to the automatic flight system (AFS)

Manual insertion of waypoints along a route, retrieving a company route or changing a route is all effected via the control display unit (CDU). The resulting flightplan and the relevant navigation parameters are then displayed on this instrument.

Compiling a company route, essentially involves sequencing waypoints relating to a route regularly flown by an operator. Such routes are given a designation, such as for example: ZRH-GVA1. As a rule, this work is performed by the operator at a PC and includes inputting navigation fix designators such as LSZH, FRI, EKRIT, etc. The completed company routes are then uploaded using a data loader into a dedicated database in the NMS. The navigation management unit finds the data assigned to the navigation fix designators (lat/long, variation, etc.) in the navigation database, which is updated every twenty-eight days. The purpose of company routes is to simplify the programming work in the cockpit.

When a company route is retrieved during flight preparation, the navigation management unit generates a flightplan. Once ATC clearance has been obtained, this can be linked to a standard instrument departure route (SID). The SIDs are stored in the navigation data base and cannot be modified by the pilot. In the navigation management unit SIDs are constructed by means of a set of so-called procedural legs. Since the system does not distinguish between fly-by and fly-over waypoints, the GNS-X may be used only as a secondary navigation aid when approaching a fly-over waypoint. This fact limits the application of the LNAV function in the terminal area of an aerodrome.

In flight, the navigation management system navigates along a defined flightplan, i.e. from waypoint to waypoint. By means of the direct to (DTO) function it is possible to head towards any waypoint along the flightplan directly from the current position.

Control signals generated by the navigation management unit are sent to the digital flight guidance system (DFGS). LNAV mode must be selected on the mode control panel (MCP) in order to process these signals. It is possible to pre-select (arm) LNAV mode and then intercept the flightplan in heading select mode.

The GNS-X navigation management system (NMS) consists of the following components:

- two navigation management units (NMU) each with a configuration module
- two control display units (CDU)
- a common global position unit (GPU)

The NMU contains the navigation computer and the navigation data base. The navigation computer receives signals from the IRS (position, velocity, heading), VOR (bearing), DME (distance), air data computer (ADC - true airspeed, altitude), GPU (position) and the fuel flow system.

The vortac position unit (VPU) is a subsystem of the NMU. The VPU performs frequency selection for the VOR/DME and calculates the geographical position from the incoming data (bearing/distance or distance/distance).

With data from the inertial reference system (IRS), the VPU, and the GPU the navigation management unit (NMU) calculates the so-called composite aircraft position, which is continuously updated.

The CDU is used both to enter and display navigation data.

By means of the LNAV change-over switch on the forward centre pedestal it is possible to determine which of the two navigation management units (NMU) provides data to the commander's or copilot's EFIS navigation display (ND) and to the EFIS primary flight display (PFD).

With the change-over switch in the LNAV 1 position, NMU 1 supplies data to the commander's and copilot's EFIS. With the switch in LNAV 2 position, NMU 2 supplies data to the commander's and copilot's EFIS. In the SPLIT position, NMU 1 supplies data to the commander's EFIS and NMU 2 supplies data to the copilot's EFIS.

The two navigation management units supply navigation data to the EFIS and steering commands to the DFGS.

Frequency selection for the VOR/DME system can be carried out manually by the crew or by the navigation management system (NMS). The data of the manually selected VOR/DME stations are displayed on the electronic flight instrument system (EFIS) and on the distance bearing indicator (DBI).

A DME interrogator unit can address up to five ground stations in quick succession. Four of these channels are selected exclusively by the navigation management system (NMS) and the distances obtained are transferred to the NMS.

The navigation management system is constantly monitored by a monitoring system in the NMU and system faults are indicated to the crew.

Power for NMU 1 is supplied from the DC 1 bus, CDU 1 from the DC 1 bus, NMU 2 from the DC 2 bus, CDU 2 from the DC 2 bus and the GPU from the DC 1 bus.

1.6.8 Navigation equipment

1.6.8.1 Inertial reference system

1.6.8.1.1 Description of the system

The inertial reference system (IRS) is used to calculate aircraft position, speed (along track velocity), compass heading (true/magnetic heading), attitude and aircraft accelerations. Three laser gyros and three accelerometers are used as sensors. Two IRS systems are installed for reasons of redundancy.

The aircraft position is forwarded to the navigation management system (NMS). Compass heading and attitude reference are represented on the EFIS display and used for aircraft control by the digital flight guidance system (DFGS). Other user systems are weather radar, the ground proximity warning system (GWPS) and the traffic alert and collision avoidance system (TCAS). The essential parameters are recorded continuously by the digital flight data recorder (DFDR).

Each IRS includes an inertial reference unit (IRU) and a mode select unit (MSU). The MSUs of the two IRS systems are accommodated in a common housing.

The IRU consists of three laser gyros and three accelerometers, which act as sensors for determining aircraft position (inertial position), speed (along track velocity), distance (along track distance), compass heading (true/magnetic heading), attitude and aircraft accelerations. The accelerometers measure acceleration along the X, Y and Z axes. The laser gyros are arranged so that they measure a rotation around these axes. Both the laser gyros and the accelerometers are installed in a fixed manner with respect to the IRU housing or the fuselage respectively (strap down configuration). This means that a virtual platform has to be formed in the IRU computer. This platform is constantly updated during flight by means of the data supplied by the laser gyros.

During alignment of the platform on the ground (align mode), the accelerometers are additionally used to determine local vertical. This requires that the aircraft does not move during the procedure. The earth's rotation, which is detected by the laser gyros, is used to determine the true north heading. In central Europe, aligning the platform (align mode) takes about ten minutes. The present position must be entered beforehand via the navigation management system (NMS).

The MSU includes a rotary switch and a status annunciator. The following basic modes can be selected via the rotary switch:

OFF – IRS is switched off.

ALN – During the first twenty seconds, the inertial section of the IRU performs a power up self test. If this is successful, aligning of the virtual platform begins (align mode). The NAV OFF lamp on the MSU is illuminated for the duration of this procedure and ALN is displayed on the control display unit (CDU) of the navigation management system. If a fault occurs during alignment, the NAV OFF lamp begins to flash and navigation mode cannot be accessed. The present position must be entered via the NMS for successful alignment. Towards the end of the alignment procedure the entered geographical latitude is compared with the latitude calculated by the IRU. Also, the entered position is compared with the last stored position of the previous flight and must coincide with this, subject to a pre-specified tolerance.

NAV – The rotary switch on the MSU can be set to the NAV position once alignment has been concluded successfully. The NAV OFF lamp on the MSU is then extinguished. The longer the IRU remains in align mode, the more accurate the calculated data. Normally the rotary switch is set directly to the NAV position and the IRU changes automatically from align mode to navigation mode as soon as alignment is completed.

In navigation mode the IRU supplies the calculated inertial position to the navigation management system. The inertial position is calculated using a dual integration on the basis of the along track acceleration via along track velocity and finally the along track distance. The starting point for calculating the inertial position is the manually entered present position.

ATT – In attitude mode the IRS can only provide the EFIS in flight with the standby attitude and standby heading data, but subject to operational restrictions. This mode is envisaged only for the case in which the IRS has previously lost certain reference data.

A switch on the commander’s instrument panel allows switching between true heading and magnetic heading. The switch is normally set in the ‘MAG’ position and is secured by a protective cap.

In the event of an IRU fault, the corresponding ATT and/or HDG warnings are displayed on the corresponding EFIS displays. It is possible to switch over to the intact IRU using the ATT/HDG switch.

Each IRU has a primary and a secondary power source. The primary IRU 1 supply is via the ESS 115 VAC bus and the secondary supply is via the BAT 28 VDC bus, whilst the primary IRU 2 supply is via the 115 VAC2 bus and the secondary supply is via the ESS 28 VDC bus.

1.6.8.2 VHF navigation system

1.6.8.2.1 Description of the system

The VHF navigation system receives signals from VHF omnidirectional radio-range (VOR) beacons, the localiser and glide slope transmitters of instrument landing systems (ILS) and marker transmitters. The bearing and deviation signals generated in the corresponding receivers are then displayed on the EFIS primary flight display (PFD), the EFIS navigation display (ND) and the distance bearing indicator (DBI). Separate receivers are provided for reception of VOR and ILS signals. The ILS receivers must comply with the strict internal monitoring requirements for Category III ILS approaches. The description below is limited to the VOR function.

The type AVRO 146-RJ100 is equipped with a dual VOR system. Each of the two systems consists of a VOR receiver, a VOR/ILS/DME control unit and a VOR/LOC antenna.

The purpose of a VOR system is to establish the aircraft's bearing with relation to a ground station with known geographical coordinates. If a VOR course is set on the mode control panel (MCP), the EFIS symbol generator is able to calculate the course deviation. The EFIS symbol generator also provides the TO/FROM information.

The VOR bearing is represented primarily on the DBI, if the latter's VOR/ADF switch is set to VOR. If no ground station is being received or if a fault is found in the VOR receiver, a warning flag appears on the DBI and the bearing pointer goes to the "three o'clock" (park) position. The VOR bearing can also be merged on the EFIS navigation display (ND), if the BRG change-over switch on the EFIS control panel is set to the VOR position.

The VOR course set on the mode control panel is displayed on the EFIS navigation display (ND), if the CRS change-over switch on the EFIS control panel is set to the V/L position. The VOR deviation is also shown in this switch position.

The VOR frequency is selected on the VOR/ILS/DME control unit. A second VOR frequency can be preselected and called up by pressing a button. The VOR system works in the 108.00 – 117.95 MHz frequency range, with 50 kHz channel spacing. In the 108 – 111 MHz frequency range, only the even tenths of a megahertz are specified as VOR frequencies.

A specific Morse code is modulated onto the VOR transmitter to identify the VOR ground stations. This Morse code can be monitored via the audio system.

The VOR course and VOR deviation signals are also available to the digital flight guidance computer (DFGC). In VOR mode the digital flight guidance system (DFGS) guides the aircraft along a selected VOR course. The VOR mode can be armed, e.g. in heading mode or in LNAV mode. Then, on approximation to the VOR course, the autopilot automatically activates VOR mode.

The VOR system is continuously monitored by a monitoring system in the VOR receiver and in the EFIS symbol generator. Any system fault is indicated to the crew.

VOR receiver 1 is supplied via the emergency AC bus, and VOR receiver 2 is supplied by the AC 2 bus. VOR/ILS/DME control unit 1 gets its power via the emergency DC bus and VOR/ILS/DME control unit 2 is supplied from the DC 2 bus.

1.6.8.3 Distance measuring equipment

1.6.8.3.1 Description of the system

The AVRO 146-RJ100 is equipped with dual distance measuring equipment (DME). Each of the two DME systems consists of a DME interrogator unit, a VOR/ILS/DME control unit and an antenna in the L band (962 - 1213 MHz).

The purpose of a DME system is to establish the distance from the aircraft to a ground station with known geographical coordinates. DME ground stations are generally co-located with VOR ground stations. Therefore the frequency is also selected via a common VOR/ILS/DME control unit.

A DME interrogator unit can address up to five ground stations in rapid succession. The distance to the ground station selected by means of a VOR/ILS/DME control unit is displayed on the electronic flight instrument system (EFIS) and on the distance bearing indicator (DBI). The channels of the other four ground stations are selected automatically by the navigation management system (NMS) and the established distances are transferred to the NMS.

The DME interrogator unit sends pairs of pulses to the ground station, which responds with identical pairs of pulses after a defined delay. In the aircraft, the time difference between transmission and reception of these pairs of pulses is then calculated, taking the above-mentioned delay into account, in order to calculate the distance. Several aircraft can work with the same ground station.

The DME system works in the L band frequency range (962 - 1213 MHz) where 252 channels are available. Some of these channels are paired with one of the VOR frequencies. If a VOR frequency is set on the VOR/ILS/DME control unit, the corresponding DME channel is selected simultaneously.

In order to identify the DME ground stations, a specific Morse code is modulated by the DME transmitter. This Morse code can be monitored via the audio system.

The DME system is continuously monitored by a monitoring system in the DME interrogator unit. Any system fault is indicated to the crew. In addition, a self-test can be initiated from the VOR/ILS/DME control unit.

The operating mode of the DME system is selected on the VOR/ILS/DME control unit.

DME system 1 receives power from the essential AC bus and from the essential DC bus. DME system 2 receives power from AC bus 2 and from DC bus 2.

1.6.8.4 Air data system

1.6.8.4.1 Description of the system

The heart of the air data system is the digital air data computer (DADC). This is connected to the static pressure system, the pitot pressure system, a temperature probe for external temperature and two sensors for the angle of attack (angle of attack vanes). In the DADC, pressure changes in the pitot/static system are converted into electrical signals. The signals at the input to the DADC are processed digitally and the calculated parameters (altitude, airspeed, mach number, vertical speed, total air temperature, angle of attack) are finally transmitted via the databus to the user systems (inertial reference units, digital flight guidance computers, navigation management units, mode S transponders, air data accessory unit, flight data recorder, EFIS symbol generators, servo altimeters, ground proximity warning computer).

The internal data processing of the digital air data computer is continuously monitored. If any malfunctions occur, the erroneous output data are labelled accordingly. This label is detected as a faulty signal by the internal monitoring of the user systems, e.g. the EFIS symbol generator, servo altimeter, etc.

Internal data processing is also monitored in the EFIS symbol generator and in the servo altimeter, in addition to the incoming data. Malfunctions are indicated to the crew.

In the digital air data computer (DADC), the angle of attack is used for correcting the measurement in the static pressure system (static source error correction). Other correction factors are taken from the tables stored in the DADC. The barometric altitude is indicated in the servo altimeter. The altitude, based on standard pressure is used in the mode S transponder for (mode C) altitude reporting.

Airspeed (computed airspeed, mach number) and vertical speed are displayed on the EFIS primary flight display (PFD). If the maximum permissible operating speed V_{mo} or the highest permissible operating mach number M_{mo} are exceeded, an acoustic warning is triggered. The vertical speed calculated in the DADC is merged with that from the inertial reference system (IRS).

The AVRO 146-RJ100 is equipped with a dual air data system. Both digital air data computers (DADC) work independently of each other. Normally data from DADC 1 are displayed on the left PFD and on the left servo altimeter. Data from DADC 2 are shown on the right-hand side. If one DADC fails, the intact DADC can be selected via a change-over switch on the commander's instrument panel. 'ADC1' or 'ADC2' then appears in yellow on both PFDs.

The airspeed values are compared in both EFIS symbol generators. A deviation outside the specified tolerance is indicated as 'SPD' in yellow on both PFDs.

In addition to the two air data systems, the AVRO 146-RJ100 is equipped with a standby altitude/airspeed indicator. This must be used by the pilots if the primary displays indicate different values. The standby altitude/airspeed indicator is equipped with an independent pitot/static system.

The two DADC systems can be checked by a self test on the ground.

Power for the air data system is supplied as follows.

DADC 1	ESS 115 VAC bus
DADC 2	AC 2 115 VAC bus
AOA vane 1	ESS 26 VAC bus
AOA vane 2	AC 2 115 VAC bus
Left servo altimeter	ESS 115 VAC bus, ESS 26 VAC bus
Right servo altimeter	AC 2 115 VAC bus, AC 2 26 VAC bus
Standby altitude/airspeed indicator	EMERG/BATT 28 VDC, EMERG 28 VDC

1.6.8.4.2 Non-volatile memories

Non-volatile memories are incorporated in the air data computer. These are able to provide information on the operational condition of this device. These memories were analysed and it was revealed that no faults were recorded during the flight on which the accident occurred or during the previous nine flights (cf. section 1.19).

1.6.8.5 Radio altimeter

1.6.8.5.1 Description of the system

The radio altimeter system is used to display the precise altitude above ground during approach and on landing, in so far as this altitude is less than 2500 ft.

Two identical radio altimeter systems are installed in the aircraft. Each consists of one transmitter/receiver suitable for Category III instrument approaches and two antennas.

The radar altitude is displayed on the EFIS primary flight display (PFD). The measured altitude of radio altimeter transceiver 1 is displayed on the commander's PFD, and that of radio altimeter transceiver 2 is displayed on the copilot's PFD. The digital display is green; it changes to yellow below the decision height (DH). If one radio altimeter fails, the altitude from the remaining radio altimeter transceiver is displayed and 'RA' appears in white next to the altitude indication. If both radio altimeter transceivers fail, both altitude indications disappear and 'RA' is displayed in red. If the left and right altitude information does not correspond, 'RA' appears in yellow next to both altitude indications.

The button for setting the decision height (DH) is located on the EFIS dimming panel. The DH can be set between 0 and 500 ft and is then displayed on the respective PFD in cyan (e.g. DH/100).

When the aircraft descends below an altitude which is 50 ft above DH, the DH display begins to flash in order to warn the crew. When the decision height is reached, the flashing DH display changes to a constantly illuminated ‘DH’ in yellow and at the same time the “minimums” acoustic warning sounds. The ‘minimums’ warning is affected only by the DH setting on the commander’s side.

The ‘minimums’ acoustic warning is generated by the ground proximity warning computer (GPWC). In addition to this warning, a synthetic voice calls out radar altitudes of 500, 100, 50, 40, 30, 20 and 10 ft.

In addition to the EFIS, the radar altitude is also supplied to the following systems:

- DFGC (both radio altimeter transceivers)
- GPWS (only radio altimeter transceiver 1)
- FDR (both radio altimeter transceivers)
- TCAS (both radio altimeter transceivers)

When the test button on one of the EFIS dimming panels is pressed, the corresponding radio altimeter transceiver carries out a self test, during which an altitude of 40 ft is displayed.

Radio altimeter transceiver 1 receives power from the AC essential bus via avionics master switch 1 and radio altimeter transceiver 2 receives power from the AC bus 2 via avionics master switch 2.

1.6.9 Findings after the accident

1.6.9.1 Electronic flight instrument system

Location	**Control unit / display**	**Position**
instrument panel left	EFIS switch	NORM protective cap intact
	EFIS 1 MSTR (lever lock switch)	ON
display dimming panel	knob for weather radar	at the stop, counter-clockwise
instrument panel right	EFIS 2 MSTR (lever lock switch)	ON
EFIS control panel left	bearing selector (BRG)	VOR
	range selector (RNG)	10
	course selector (CRS)	OFF
	format	MAP
EFIS control panel right	bearing selector (BRG)	OFF
	range selector (RNG)	10
	course selector (CRS)	LNAV
	format	MAP

1.6.9.2 Inertial reference system

Location	Control unit / display	Position
instrument panel left	MAG/TRU switch	MAG protective cap intact
	ATT/HDG	BOTH 2 switch bent, protective cap broken off

1.6.9.3 VHF navigation system

Location	Control unit / display	Position
VOR/ILS/DME control unit 1	DME selector	HOLD
VOR/ILS/DME control unit 2	DME selector	HOLD
distance bearing indicator (DBI) 1	heading	302°
	single pointer	3 o'clock
	double pointer	3 o'clock
	VOR/ADF switch left	ADF
	VOR/ADF switch right	ADF
distance bearing indicator (DBI) 2	heading	could not be determined, scale turning freely
	single pointer	torn off
	double pointer	turning freely, mechanically damaged
	VOR/ADF switch left	ADF
	VOR/ADF switch right	slightly below the position ADF, mechanically dam-aged

1.6.9.4 Air data system

Location / instrument	Control unit / display	Position
servo altimeter left	flag	visible
	baro setting	1024 hPa
	altimeter bug	0
	altitude drum	~ 1920 ft
	pointer	~ 900 ft
servo altimeter right	flag	visible
	baro setting	1024 hPa
	altimeter bug	~ 390 ft (MDA 2390 ft)
	altitude drum	~ 1890 ft
	pointer	~ 890 ft

standby altitude/airspeed indicator	baro setting	1024 hPa
	altitude drum	~ 3000 ft
	pointer, altimeter	~ 450 ft
	pointer, speed	0
instrument panel left	air data switch	NORM protective cap intact

1.6.10 Ground proximity warning system

The ground proximity warning system (GPWS) generates visual and acoustic warnings when the aircraft approaches the ground in a dangerous manner. The GPWS also generates acoustic altitude information in order to inform pilots that they are approaching the ground.

The ground proximity warning computer (GPWC) monitors and processes specific signals from the aircraft and triggers a warning if one of the following warning envelopes is violated:

- mode 1 excessive descent rate
- mode 2 excessive terrain closure rate
- mode 3 altitude loss after take off
- mode 4 unsafe terrain clearance
- mode 5 inadvertent descent below glide slope
- mode 6 altitude awareness call outs (radar altitude)

For each mode, acoustic warnings (synthetic voice) are defined. In the event that multiple acoustic warnings trigger at the same time, they have different degrees of urgency. For example, a stall warning or a wind shear warning take precedence over the GPWS warnings. The acoustic warnings for mode 1 to 4 additionally trigger a visual warning, GPWS 'PULL UP'. In order to take into consideration the different aircraft configurations (flaps, gear), the warnings for mode 2 and mode 4 are subdivided into submodes. The warning envelopes are described in detail in the aircraft maintenance manual ATA 34-46-00, in the Crosscat maintenance training manual, and in the manufacturer's operations manual VOL 1, book 1. For mode 1 – excessive descent rate – and mode 2B – excessive terrain closure rate – which are relevant to the flight involved in the accident, the envelopes are shown in appendix 3.

The GPWC requires the following signals for triggering the warnings: radar altitude (RA), vertical speed, altitude (ADC), inertial vertical speed (IRU), glide slope deviation (ILS Rx), flaps position and landing gear position.

In order to avoid an incorrect warning in the case of a deliberate landing with flaps not in the landing position, the current flap position can be overridden with the 'FLAP WARN OVRD' switch (mode 4B).

The GPWC is supplied by the essential bus ESS 115 VAC. On power up, an automatic test is carried out in the GPWC. A self test (short test or long test) can be carried out on the ground by pressing one of the GPWS/ PULL UP/GP INHIBIT buttons in the glare shield panel. A short test is also possible in flight at a radar altitude of over 1000 ft. Certain functions of the GPWC are monitored continuously in flight. A fault in the GPWS triggers the GPWS INOP warning in the central status panel.

1.6.11 ATC transponder system

The air traffic control (ATC) transponder system is the onboard element of an airspace surveillance system which is known as the secondary surveillance radar system (SSR). The SSR allows the air traffic control officer to identify aircraft and determine their altitude. The SSR complements the primary radar system.

The aircraft was equipped with a mode S transponder. Beside the functions mentioned before, the mode S transponder is capable of transferring additional data. This capability is used for instance for TCAS data transmission.

In order to guarantee the desired availability, the AVRO 146-RJ100 is equipped with a dual ATC transponder system. Operation is from a common control unit which is incorporated in the centre pedestal.

In order to be able to identify different aircraft, a characteristic identifier (a squawk) is assigned to each flight. This (four-digit, octal) number is entered at the control unit on instruction from the air traffic control officer and transmitted in binary form. A control knob on the control unit is used to switch the ATC transponder on and off. A second knob is used to determine which air data computer (ADC) is used for altitude information or whether this function should be totally suppressed. In addition it is possible to switch between transponder 1 and transponder 2. The XPDR FAIL lamp indicates when the selected transponder is defective (continuous built-in test). The correct operation of the selected transponder can be checked after maintenance work or prior to the flight by means of the test button.

For each ATC transponder, one L band antenna is located above and below the fuselage respectively. Depending on the attitude, the upper or lower antenna is used. Change-over is automatic.

ATC transponder 1 receives power from the ESS 115VAC bus. ATC transponder 2 receives power from the AC 2 115VAC bus.

1.6.12 Maintenance of the aircraft

From the documentation on maintenance of the aircraft it was apparent that the work specified by the maintenance programme had been scheduled and carried out technically correctly and completely. All checks were performed within the intervals specified by the FOCA, including tolerances.

The lifetime documentation for the periodic checks and complaints as well as the list of parts replaced since the last C2 check in May 2000 were examined in detail and deemed to be correct and complete, with the exception of the APU and calibration of the altimeter and DFDR sensors (cf. section 1.17.1.11).

1.6.13 Test on the fuel used

No analysable amount of fuel could be recovered. The majority of the fuel combusted whilst the remainder seeped into the ground.

1.7 Meteorological information

1.7.1 Summary

The course of scheduled flight CRX 3597 (Berlin-Zurich) ran approximately parallel to a warm front lying over western Europe. In the southerly part of the route, the aircraft was expected to fly part of the time at FL 270 in the high clouds of the warm front.

On descending, between FL 160 and FL 130 the aircraft penetrated the cloud layer situated over the northern side of the Alps. This was compact, but between FL 110 and FL 80 there were thin, cloud-free layers.

Moderate icing occurred in this cloud mass and between FL 120 and FL 80 even severe icing was possible. Below FL 60 the risk of icing decreased appreciably.

Between 2700 ft AMSL and 2400 ft AMSL the descending aircraft emerged out of the cloud mass. In the last phase of the flight, forward visibility from the cockpit was adversely affected by deep patches of stratus, the base of which was between 2000 ft AMSL and 1800 ft AMSL.

1.7.2 General weather situation

On 23 November 2001 a high pressure area extended from the Azores to France. In Switzerland a so called ‘Nordstau’ weather situation reigned, with strong winds at high altitudes.

In the night before 24 November 2001 the axis of the jet stream slowly moved eastward and on 24 November was just east of Switzerland. With this eastward shift of the jet stream, somewhat milder air flowed towards Switzerland, resulting in warming to about 4 °C. In association with this, the effect of the ‘Nordstau’ gradually abated.

On 23 November, the warm front associated with the above-mentioned jet stream lay over the British Isles. It slowly moved eastwards and reached the continent on 24 November. At the time of the accident, the warm front lay along the line: Stavanger-Lüttich-Orléans-La Rochelle.

Images from the high-resolution American NOAA satellites in the visual and infra-red range at 12:52 UTC on 24 November show the ‘Nordstau’ cloud cover in the central and eastern parts of Switzerland and the clouds of the warm front approaching from France as a coherent cloud mass. However, the weather radar image at 21:10 UTC shows the precipitation zone in the ‘Nordstau’ region (the central and eastern Alpine foothills) as still being distinctly separate from the warm front precipitation over the Vosges. The light precipitation in the Zurich area was therefore still attributable to the abating ‘Nordstau’ weather situation.

1.7.3 Weather on the Berlin – Zurich route

The surface weather chart show that on the Berlin-Zurich route the aircraft was flying more or less parallel to the warm front lying above western Europe. The cloud of this warm front extended as far as eastern Germany. According to the Meteosat infrared satellite image at 21:00 UTC the cloud in the northern part of the route did not extend as high as it did above southern Germany. At the cruising altitude of FL 270, therefore, the aircraft should have initially been above the clouds. The outside air temperature at FL 270 in the northern part of the route was -41 °C. The wind at this altitude was from 020 degrees at a speed of 80 knots. In the southern sector of the route, the aircraft would have flown for part of the time in the high clouds of the warm front.

In the southern sector of the route the outside air temperature at FL 270 was -42 °C. The wind at FL 270 was from 020 degrees at a speed of 70 knots. On descending, between FL 160 and FL 130 the aircraft entered the cloud layers of the 'Nordstau'. At FL 160 the outside air temperature was -17 °C, and the wind was from 010 degrees at a speed of 40 knots.

No warnings were active in German airspace for flying at FL 270. Berlin and Frankfurt had issued AIRMET reports, but these related only to airspace near the ground.

According to the London WAFC significant weather chart (SWC) valid for 18:00 UTC no weather phenomena hazardous to flight were expected on the Berlin-Zurich route at FL 270; however, according to the SWC valid 00:00 UTC moderate clear air turbulence was to be expected in the northern part of the route between FL 220 and FL 370.

1.7.4 Weather in the approach sector

1.7.4.1 Cloud

1.7.4.1.1 Statements from flight crews

On descending, the aircraft entered the cloud layers of the 'Nordstau'. The top of this cloud layer was not uniform and fluctuated between FL 130 and FL 160. Below this the cloud was compact down to an altitude of FL 110. Between FL 110 and FL 80 there were thin, cloud-free layers. Below FL 80 the cloud was again compact down to the cloud base.

The cloud base in an extended circle around Zurich airport was not uniform. An analysis of pilots' statements provides the following overview (mean values, altitude information with reference to the elevation of the airport):

Airport zone	Runway	Cloud
North	Take-off runway 34	SCT 500 ft AAL
		BKN 1000 ft AAL
		OVC 1500 ft AAL
	Approach runway 14	FEW 1000 ft AAL
		BKN 1600 ft AAL
		OVC 2000 ft AAL
West	Take-off runway 28	FEW 600 ft AAL
		SCT 1100 ft AAL
		OVC 2600 ft AAL
East	Approach runway 28	FEW 500 ft AAL
		BKN 1000 ft AAL

1.7.4.1.2 Ceilometer measurement

A ceilometer is an instrument which measures the delay of a reflected pulse of a vertical laser beam (point measurement). This allows the determination of the height of the cloud base of cloud lying vertically above the instrument. Ceilometer data is able to provide only limited information on the quantity of cloud.

An analysis of the ceilometer measurements for the 7 minutes prior to the accident between 21:00 UTC and 21:07 UTC provided the following overview (height related to airport elevation).

Airport zone	**Ceilometer**	**Cloud layers**
North	Runways 14/16	500 - 1050 ft AAL
		1150 - 1350 ft AAL
	Middle marker	450 - 1350 ft AAL
		900 - 1150 ft AAL
	Outer marker	1400 - 1750 ft AAL
East	Bassersdorf	1300 – 3100 ft AAL
		2100 – 2750 ft AAL

The Bassersdorf ceilometer is installed on the roof of a building in Bassersdorf, approximately 1 km to the south of the axis of runway 28.

1.7.4.1.3 Synthesis of flight crew statements and ceilometer measurements

The actual main cloud base (BKN) in the approach area for runway 28 was between 2400 ft AMSL and 2700 ft AMSL. This layer was not dense; flight crews stated that they had partial visual ground contact. Below this cloud mass were patches of stratus (FEW), whose base was between 1800 ft AMSL and 2000 ft AMSL. According to crew reports, such patches of stratus restricted forward cockpit visibility down to approximately 2 km from the start of runway 28.

1.7.4.2 Visibility from the cockpit and meteorological visibility

When flying just below the main cloud base, forward visibility from the cockpit was greatly restricted because of the patches of stratus. Approaching aircraft had sight of runway 28 only about 2 km before the beginning of runway 28.

Below the cloud layers, meteorological visibility was approximately 4 km; in light precipitation and near the cloud base it was reduced to about 2 km in some places.

1.7.4.3 Wind profile

The measured values from the inversion measurement chain AMETIS1 and the radio sondes of Payerne, Stuttgart and Munich were spatially and temporally interpolated to produce the following overview for wind conditions in the approach sector:

Altitude	**Direction in degrees**	**Speed in kt**
FL 160	010	40
FL 140	360	35
FL 120	360	30
FL 100	350	25
FL 080	340	15
6000 ft AMSL	300	15
5000 ft AMSL	270	12
4000 ft AMSL	250	12
3000 ft AMSL	220	10
2000 ft AMSL	210	06

In the vertical wind profile, as altitude increases there is pronounced veering of the wind direction; this corresponds to a warm air advection (approach of the warm front). There was no significant turbulence.

1.7.4.4 Temperature profile

The measured values from the inversion measurement chain AMETIS1 and the radio sondes of Payerne, Stuttgart and Munich were spatially and temporally interpolated to produce the following overview for temperature and humidity conditions in the approach sector:

Altitude	**Temperature in °C**	**Dewpoint in °C**
FL 160	-17	-22
FL 140	-14	-16
FL 120	-11	-12
FL 100	-07	-08
FL 080	-05	-05
6000 ft AMSL	-04	-04
5000 ft AMSL	-03	-03
4000 ft AMSL	-02	-02
3000 ft AMSL	-01	-01
2000 ft AMSL	0	0

The altitude of the freezing level was 2200 ft AMSL, as ground witnesses at an elevation of approx. 1700 ft AMSL observed precipitation in the form of snowfall mixed with rain, indicating that the freezing level was about 500 ft higher.

1.7.4.5 Icing

Moderate icing occurred below FL 140 in the approach sector. Several crews experienced severe icing between FL 120 and FL 80. Below FL 60 the degree of icing was less.

Experience indicates that the most severe icing occurs in stratus cloud in the temperature range from -4 °C to -8 °C. In the present case this corresponded to an altitude range of 6000 ft AMSL to 10 500 ft AMSL.

1.7.4.6 Warnings

At the time of the accident the following AIRMET report, issued by MeteoSwiss, was active:

LSAS SWITZERLAND AIRMET 241930/242400 LSZH- SWITZERLAND FIR MOD ICE OBS ALPS AND N OF ALPS BTN FL060 AND FL130 STNR NC =

In clear text this means: above the Alps and to the north of the Alps moderate icing was observed between FL 60 and FL 130; stationary; no change.

1.7.5 Weather in the area of the accident

1.7.5.1 Cloud

The plain near Bassersdorf is at an elevation of about 1500 ft AMSL; to the north and north-east of this plain, the hilly terrain rises to the plateau in the Oberwil/Brütten region, which is at an elevation of 1900 to 2000 ft AMSL. The site of the accident is situated in this area. In a south-westerly wind, the inflowing air is lifted slightly on this incline. If atmospheric humidity is sufficiently high, low-level orographic cloud can form as a result.

The main cloud base in the area of the accident (BKN) was between 2400 ft AMSL and 2700 ft AMSL. On the hilly slope towards Oberwil low banks of stratus were formed by moist air flowing in from the south-west and rising. The base of this cloud was between 1800 ft AMSL and 2000 ft AMSL, i.e. in places some of these banks of stratus covered the hills or slopes.

This conclusion can also be drawn from statements of eye witnesses in the area of the accident (the plain near Chrüzstrass crossroads): “aircraft suddenly emerged from clouds” and “aircraft flew through low-level wall of cloud”.

1.7.5.2 Precipitation

In the area of the accident light precipitation was observed, in the form of snow mixed with rain. The air temperature in the area of the accident was approximately +0.5 °C.

1.7.5.3 Visibility

Visibility in the small plain near the Chrüzstrass crossroads was about 2-3 km. Somewhat higher up the slopes and therefore nearer to the cloud base, visibility was affected even more by the low-level patches of stratus.

1.7.5.4 Wind

In the area of the accident the wind was from the south at a speed of 3-5 knots.

1.7.6 Weather conditions at Zurich airport

1.7.6.1 Development over the day

At Zurich airport the cloud cover was broken or overcast throughout the day, under the influence of the ‘Nordstau’. Light snowfall was recorded in the early morning and occasionally again in the afternoon. From 14:50 UTC up to the time of the accident it was snowing uninterruptedly, though very lightly. Only at 18:20 UTC moderate snowfall was observed.

The main cloud base gradually descended over the course of the evening, as did visibility, which was approximately 20 km at midday though which fell to values around 4 km. Throughout the day the wind was light and the wind direction varied between south-westerly and south-easterly.

1.7.6.2 Weather at the time of the accident

Wind measurement point runway 14/16	from 130° at 2 kt
Wind measurement point runway 34	from 180° at 3 kt
Meteorological visibility	3500 m
Runway visual range runway 14A	more than 1500 m
Runway visual range runway 16A	more than 1500 m
Runway visual range runway 28A	more than 1500 m
Precipitation	light snowfall

Cloud base	section 1.7.4.1.1 and 1.7.4.1.2
Air temperature	+0.6 °C (2 m above ground)
Measurement point runway 14/16	+0.3 °C (5 cm above ground)
	+0.5 °C (5 cm above concrete)
Atmospheric humidity	98 %
Atmospheric pressure	QNH 1023.9 hPa
	QFE runway 14: 973 hPa
	QFE runway 16: 973 hPa
	QFE runway 28: 972 hPa
Ground conditions	Melting snow, fully covering the ground

1.7.6.3 METAR routine airport weather reports

At the time of the accident the following METAR was valid:

METAR 242050Z 16002KT 3500 –SN FEW006 BKN015 OVC022 00/M00 Q1024 8829//99 TEMPO 5000=

In plain language this means that on 24 November 2001 at 20:50 UTC at Zurich airport the following weather conditions were observed:

Wind	from 160° at 2 kt
Meteorological visibility	3500 m
Precipitation	light snowfall
Cloud	1-2/8 at 600 ft AAL
	5-7/8 at 1500 ft AAL
	8/8 with cloud base at 2200 ft AAL
Temperature	0 °C
Dew point	between -0.5 °C and -0.1 °C
Atmospheric pressure	1024 hPa, pressure reduced to mean sea level, calculated using ICAO standard atmosphere values
Runway report	More than 50% of the runway surfaces are wet or covered with puddles of water. The depth of these water deposits is not significant operationally or not measurable and no reliable information on the braking effect can be provided.
Landing forecast	In the two hours following the weather observation, it is to be expected that meteorological visibility will change temporarily to 5000 m. The total duration of this change is expected to be less than one hour.

At 21:20 UTC the following METAR came into effect:

METAR 242120Z 13002KT 4000 –SN FEW006 BKN015 01/M00 Q1023 8820//99 NOSIG=

1.7.6.4 TAF aerodrome forecast

LSZH 241800Z 241904 24005KT 6000 SN FEW015 BKN025 BECMG 2224 3000 SNRA SCT008 BKN015=

1.7.7 Broadcast weather information

1.7.7.1 VOLMET

On 24 November 2001 at 20:20:21 UTC broadcasting of the following VOLMET report began:

THIS IS ZÜRICH MET BROADCAST MET REPORTS.

ZÜRICH 2020.

170 DEGREES 3 KNOTS.
VISIBILITY 3 THOUSAND METRES.
LIGHT SNOW.
FEW 5 HUNDRED FEET.
SCATTERED 1 THOUSAND 5 HUNDRED FEET.
BROKEN 2 THOUSAND 2 HUNDRED FEET.
TEMPERATURE 0. DEWPOINT MINUS 0.
Q.N.H 1024.
NOSIG.

GENEVA 2020.

.....

BALE 2000.

.....

At 20:46:51 UTC broadcasting of the next VOLMET report began:

THIS IS ZÜRICH MET BROADCAST MET REPORTS..

ZÜRICH 2050.

160 DEGREES 2 KNOTS.
VISIBILITY 3 THOUSAND 5 HUNDRED METRES.
LIGHT SNOW.
FEW 6 HUNDRED FEET.
BROKEN 1 THOUSAND 5 HUNDRED FEET.
OVERCAST 2 THOUSAND 2 HUNDRED FEET.
TEMPERATURE 0. DEWPOINT MINUS 0.
Q.N.H 1024.
TEMPO
VISIBILITY 5 THOUSAND METRES.

GENEVA 2020.

.....

BALE 2030.

.....

At 20:50:19 UTC broadcasting of the next VOLMET report began:

THIS IS ZÜRICH MET BROADCAST MET REPORTS.

ZÜRICH 2050.

160 DEGREES 2 KNOTS.
VISIBILITY 3 THOUSAND 5 HUNDRED METRES.
LIGHT SNOW.
FEW 6 HUNDRED FEET.
BROKEN 1 THOUSAND 5 HUNDRED FEET.
OVERCAST 2 THOUSAND 2 HUNDRED FEET.
TEMPERATURE 0. DEWPOINT MINUS 0.
Q.N.H 1024.
TEMPO
VISIBILITY 5 THOUSAND METERS.

GENEVA 2050.

.....

BALE 2030.

.....

1.7.7.2 ATIS

The flight crew of CRX 3597 were in receipt of ATIS information KILO:

INFO KILO
LANDING RUNWAY 14 ILS APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2020 UTC 24.11.2001
190 DEG 4 KT
VIS 3000 M
LIGHT SNOW
FEW 500 FT, SCT 1500 FT, BKN 2200 FT
000/-00
QNH 1024 TWO FOUR
NOSIG

TRANSITION LEVEL 50

TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT

RUNWAY REPORT 1800

ALL RUNWAYS,
FULL LENGTH 60 M WET
APRON AND TAXIWAYS WET

AIRMET 1 VALID BETWEEN 1930 AND 2400

SWITZERLAND FIR MODERATE ICING OBSERVED ALPS AND NORTH OF ALPS BETWEEN FLIGHT LEVEL 60 AND FLIGHT LEVEL 130. STATIONARY NO CHANGE

Therafter the following ATIS reports were broadcasted:

INFO LIMA

LANDING RUNWAY 28 VOR DME STANDARD APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2020 UTC 24.11.2001
190 DEG 4 KT
VIS 3000 M
LIGHT SNOW
FEW 500 FT, SCT 1500 FT, BKN 2200 FT
000/-00
QNH 1024 TWO FOUR
NOSIG

TRANSITION LEVEL 50

TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT

RUNWAY REPORT 1800

ALL RUNWAYS,
FULL LENGTH 60 M WET
APRON AND TAXIWAYS WET

AIRMET 1 VALID BETWEEN 1930 AND 2400

SWITZERLAND FIR MODERATE ICING OBSERVED ALPS AND NORTH OF ALPS BETWEEN FLIGHT LEVEL 60 AND FLIGHT LEVEL 130. STATIONARY NO CHANGE

INFO MIKE

LANDING RUNWAY 28 VOR DME STANDARD APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2020 UTC 24.11.2001
190 DEG 4 KT
VIS 3000 M
LIGHT SNOW
FEW 500 FT, SCT 1500 FT, BKN 2200 FT
000/-00
QNH 1024 TWO FOUR
NOSIG

TRANSITION LEVEL 50

TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT

RUNWAY REPORT 2040

ALL RUNWAYS,
FULL LENGTH 60 M WET
APRON AND TAXIWAYS WET

AIRMET 1 VALID BETWEEN 1930 AND 2400

SWITZERLAND FIR MODERATE ICING OBSERVED ALPS AND NORTH OF ALPS BETWEEN FLIGHT LEVEL 60 AND FLIGHT LEVEL 130. STATIONARY NO CHANGE

INFO NOVEMBER

LANDING RUNWAY 28 VOR DME STANDARD APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2050 UTC 24.11.2001
200 DEG 4 KT
VIS 3500 M
LIGHT SNOW
FEW 600 FT, BKN 1500 FT, OVC 2200 FT
000/-00
QNH 1024 TWO FOUR
TEMPO VIS 5000 M

TRANSITION LEVEL 50

TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT

RUNWAY REPORT 2040

ALL RUNWAYS,
FULL LENGTH 60 M WET
APRON AND TAXIWAYS WET

AIRMET 1 VALID BETWEEN 1930 AND 2400

SWITZERLAND FIR MODERATE ICING OBSERVED ALPS AND NORTH OF ALPS BETWEEN FLIGHT LEVEL 60 AND FLIGHT LEVEL 130. STATIONARY NO CHANGE

At the time of the accident the following ATIS information was broadcasted:

INFO OSCAR

LANDING RUNWAY 28 VOR DME STANDARD APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2050 UTC 24.11.2001
200 DEG 4 KT
VIS 3500 M
LIGHT SNOW
FEW 600 FT, BKN 1500 FT, OVC 2200 FT
000/-00
QNH 1024 TWO FOUR
TEMPO VIS 5000 M

TRANSITION LEVEL 50

TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT

RUNWAY REPORT 2040

ALL RUNWAYS,
FULL LENGTH 60 M WET
APRON AND TAXIWAYS WET

AIRMET 1 VALID BETWEEN 1930 AND 2400

SWITZERLAND FIR MODERATE ICING OBSERVED ALPS AND NORTH OF ALPS BETWEEN FLIGHT LEVEL 60 AND FLIGHT LEVEL 130. STATIONARY NO CHANGE

1.7.8 Weather broadcasts between 20:00 and 21:00 UTC

During the first call from CRX 3597 to APE at 20:48:22 UTC the pilot reported that he was aware of ATIS information "KILO".

Subsequently, the ATIS broadcasts changed several times up to the time of the crash at 21:07 UTC, without the pilots being informed about the changes regarding visibility and ceiling.

Start of broadcast	Automatic Terminal Information Service
20:40:10 UTC	LIMA: Met Report Zurich 20:20 UTC, change from landing runway 14 ILS approach to landing runway 28 VOR DME standard approach.
20:44:56 UTC	MIKE: Met Report Zurich 20:20 UTC, new runway report No. 32 at 20:40 UTC.
20:50:00 UTC	NOVEMBER: Met Report Zurich 20:50 UTC, new observation time and improved meteorological visibility of 3500 m. Lowering of the ceiling to 5-7/8 at 1500 ft AAL.
20:50:16 UTC	OSKAR: Met Report Zurich 20:50 UTC, new code letter due to switch-over between two computer servers.

1.7.9 Astronomical information

1.7.9.1 Position of the sun

Azimuth	305° 42' 43"
Elevation	-53° 12' 08"

1.7.9.2 Position of the moon

Azimuth	217° 54' 11"
Elevation	+26° 58' 57"
Phase	Waxing
Age	0.68 (0 = new moon, 1 = full moon)

1.7.10 Runway visual range and meteorological visibility

1.7.10.1 Runway visual range

According to ICAO document 4444 the runway visual range (RVR) is defined as follows: "The range over which the pilot of an aircraft on the centreline of a runway can see the runway surface markings or the lights delineating the runway or indentifying its centre line." This means the RVR is essentially the maximum distance in the direction of the runway at which the runway lights can still be detected. It is measured using a transmissometer (TMM). With a short-base TMM (15 m measurement distance) values in the range from 50 m to approx. 800 m can be measured, and with the long-base TMM (50 m measurement distance) RVR values between approximately 100 m and 2000 m can be determined; in the lower measurement range the measurement is somewhat less accurate. For runways with ILS approaches, short- and long-base TMMs are essential. Both types are therefore installed on runways 14 and 16 at Zurich airport. At the time of the accident, only long-base TMMs were installed on runway 28.

In the weather reports RVR values from 50 m to 1500 m are indicated. If the runway visual range is below 50 m, M0050 is reported. If it is above 1500 m, this is designated as P1500. Thus in VOLMET (METAR) and ATIS (QAM) no RVR values above 1500 m were reported.

1.7.10.2 Meteorological visibility

The meteorological visibility is defined as the maximum distance at which an object of appropriate size can still be detected. Meteorological visibility is determined only in the horizontal plain. If visibility is not the same in all directions, the lowest visibility is reported. Switzerland and other countries are subject to the following exception in this respect: If visibility is not the same in all directions, the prevaling visibility is reported. Prevaling visibility is understood as the value which is reached or exceeded in half the circumference around the observation site; the half-circumference may comprise different separate sectors.

1.7.10.3 Relationship between meteorological visibility and runway visual range

A light source can be detected at a greater distance than an unilluminated object. The RVR value at night is therefore 3 to 4 times higher than the meteorological visibility. In daylight, the sun causes a glare effect in fog, i.e. the RVR value is only approximately twice the meteorological visibility.

1.7.10.4 Cloud observation

At airports with precision approach runways, according to the standards of the International Civil Aviation Authority (ICAO), cloud observations in QAM reports (ATIS) must be representative of the middle marker position of the instrument landing system. Cloud observations in METAR reports (VOLMET) must be representative of the entire airport area and the immediate environment.

According to these stipulations, in QAM reports (ATIS) for Zurich airport the cloud conditions should be indicated in the former middle marker position of runway 16. In the METAR reports the cloud conditions are to be summarised for the entire airport area and the immediate environment.

1.8 Aids to navigation

1.8.1 General limitations

On the approach charts for Zurich airport, the following comment is made concerning the VHF omnidirectional radio range (VOR):

“KLO VOR partially unreliable below 12 000 ft”.

As part of the relocation of VOR/DME KLO due to construction of the Midfield Terminal, two coverage diagrams were prepared for the new location of the VOR. Analysis of these two diagrams showed that the signal suffers from partial interference below 12 000 ft.

The approach and take-off corridors are not affected by these topography-related coverage defects, as has been established by test flights. Nor are any incidents or reports related to irregularities of VOR KLO known to air traffic control units.

On the basis of this fact, on the occasion of a meeting with the IFR procedure group (IPG) Zurich in 1999, it was decided to publish the above-mentioned limitation, which was also accepted by the FOCA. A detailed report was also produced by skyguide.

1.8.2 Navigation aids for standard VOR/DME approach 28

Standard VOR/DME approach 28 is a non-precision approach. The navigation aids used are DVOR/DME Kloten (KLO) and DVOR/DME Zurich East (ZUE). These navigation equipment items are omnidirectional radio beacons which operate on the Doppler principle. Both are equipped with distance measuring equipment (DME).

Navigation aid	DVOR/DME KLO
Geographical position	47° 27’ 25.73” N, 008° 32’ 44.14” E
Elevation	1414 ft AMSL
Coverage (DOC)	50 NM/25000 ft
Frequencies	DVOR 114.85 MHz, DME channel 95 Y
Operating time	24 hours

Navigation aid	DVOR/DME ZUE
Geographical position	47° 35’ 31.82” N, 008° 49’ 03.55” E
Elevation	1730 ft AMSL
Coverage (DOC)	80 NM/50000 ft
Frequencies	DVOR 110.05 MHz, DME Channel 37 Y
Operating time	24 hours

The transmission equipment of the DVOR/DME KLO and DVOR/DME ZUE stations were in normal operation on 24 November 2001 from 20:45 to 21:15 UTC and were available to operating services without any restrictions.

On 26 November, on behalf of the AAIB, a state aircraft from France’s Direction générale de l’aviation civile (DGAC) made several control flights. The signal quality of the approach aids for standard VOR/DME approach 28 was checked. The recorded values were within the operational tolerances and the DGAC therefore came to the following conclusion:

"Aux vues des enregistrements effectués par l'avion du contrôle en vol de la DGAC (ATR 42 F-GFJH), l'approche VOR/DME enregistrée depuis ZUE jusqu'au seuil est dans les tolérances opérationnelles".

1.8.3 Other navigation aids

Equipment	Type and manufacturer	Commissioned
LOC ILS 14 ZRH	LOC 411 by Thales ATM	1999
GP ILS 14 ZRH	GS 412 by Thales ATM	1999
DME ILS 14 ZRH	FSD 40 by Thales ATM	1999
LOC ILS 16 ZRH	S 4000 by Thales ATM	1990
GP ILS 16 ZRH	S 4000 by Thales ATM	1990
DME ILS 16 ZRH	FSD 10 by Thales ATM	1990

1.8.4 Radar monitoring of instrument approaches

Standard VOR/DME approach 28 is not flown with radar guidance but using the aircraft's own navigation.

According to workstation documentation it is the task of the FINAL ATCO to monitor the flight path flown by the crew and if necessary to arrange course corrections (vectoring).

It was established that the APW ATCO who was responsible at the time of the accident was handling CRX 3597 from a distance of 9 NM from the threshold of runway 28 within the defined guidelines of radar monitoring. In the process the APW ATCO stated that he saw the aircraft on his radar screen when it was at a distance of 9 NM, 6 NM and approximately 4 NM from the runway threshold. He consciously perceived the altitude of the aircraft only at approximately 6 NM, when he noted an altitude of approximately 3600 ft.

The ATCO stated: "I did not carry out any more altitude checks later. I merely monitored the continuing flight path. The reason I did not carry out any deliberate altitude checks was that the aircraft was using its own navigation and in my opinion in this status there was no need for me to carry out such altitude checks as part of radar monitoring".

The understanding of the interrogated ATCOs concerning the content and practical execution of radar monitoring of standard VOR/DME approach 28 differed:

- One ATCO stated, that during radar monitoring, he usually monitors the lateral track but would not monitor the altitude continuously. He monitors the altitude only for staggering with another aircraft.
- Another ATCO stated that during radar monitoring, the execution of given instructions have to be monitored. According to his understanding this monitoring ends approximately at the minimum of the standard VOR/DME approach 28 (approx. 3 NM DME).

After an Alitalia aircraft collided with Stadlerberg mountain on 14 November 1990, the AAIB issued a safety recommendation (cf. 1.18.3.2), which among other things recommended the introduction of a minimum safe altitude warning system (MSAW). The MSAW is a safety system which triggers a visual and acoustic warning in the ATC centre if predefined minimum altitudes are infringed.

Runways 14 and 16 were subsequently equipped with an MSAW, but the approach sector of runway 28 was not.

1.9 Communications

1.9.1 Air traffic control units involved

1.9.1.1 General

ATC unit	Abbreviation	Frequency
Approach control east	APE	120.750 MHz
Approach control west	APW	118.000 MHz
Aerodrome control (tower)	ADC	118.100 MHz
Ground control	GRO	121.900 MHz

In TWR/APP Zurich no systematic workstation records were kept. This means that workstation hand-overs were not documented. Personnel changes at workstations were therefore documented as part of the investigation on the basis of the voice transcript and statements.

1.9.1.2 Assignment of personnel in the approach control office

When CRX 3597 made contact with Zurich approach control at 20:48:22 UTC, two ATCOs were in the approach control office. They covered the approach west (APW) and approach east (APE) positions.

A total of 3 aircraft were on the frequencies of the two ATCOs. The ATCO at the position APW was vectoring two aircraft and flight CRX 3597 was being handled by the ATCO at the position APE.

By mutual agreement, these two ATCOs allowed first the two aircraft to approach from the west in order subsequently to sequence CRX 3597 as the third aircraft for the approach.

CRX 3597 was the last aircraft which the APE ATCO had to control. By agreement with his colleague on APW he closed his workstation at 21:04 UTC and went to the control tower with the intention of relieving a colleague there.

According to the skyguide sector occupancy plan, at the time of the accident (21:07 UTC) 4 working positions should still have been occupied in the APP unit. Actually, one working position was occupied.

1.9.1.3 Assignment of personnel in aerodrome control

The ATCO who gave CRX 3597 the landing clearance had taken over the ADC 1 workstation at 21:06 UTC, after he had been working till 21:04 UTC in sector APE and had guided CRX 3597 to the approach to runway 28.

The supervisor, after the landing of the first (of three) aircraft on standard VOR/DME approach 28, had decided to reduce the crew in the control tower to two ATCOs. At 21:03 UTC he handed over the daily OPS management to the ATCO at workstation GRO and then left the control tower to make his way home after briefly staying in the office.

The ATCO at the position GRO who from 21:03 UTC also fulfilled the functions of the supervisor had not received any supervising training. According to his statement he was aware of the rights and obligations of the supervisor function when he took over the position. He had already taken over the supervisor function fairly often, even during the day, with corresponding traffic levels.

According to the skyguide sector occupancy plan, at the time of the accident 4 working positions at the aerodrome control tower should still have been occupied. Actually, 2 working positions were occupied. According to the sector occupancy plan the supervisor position was indicated until 22:00 UTC.

1.9.2 Recordings of conversations

The following data in TWR and APP were recorded continuously by a digital storage system and stored on digital data storage (DDS):

- all VHF radio channels used; in APE, APW and ADC one recorder respectively is installed for short-term recording
- all wired connections between workstations
- all telephone conversations at the workstations
- radiotelephony connections for communication with the police and rescue services

Comprehensibility was good and the recording was complete.

The conversations in the radar room and at the control tower are not recorded by a room microphone.

1.9.3 Communications equipment

At the time of the accident the TWR and APP operations records and the system management (SYMA) log book showed no failures or faults in the air traffic control communications equipment. The same applied to all ATC internal links (intercom, telephone).

1.10 Aerodrome information

1.10.1 General

Zurich airport is located in north-east Switzerland. In 2001 the skyguide air traffic control organisation handled a traffic volume of approximately 297 000 approaches and departures according to instrument flight rules (IFR).

At the time of the accident an extensive construction programme was in progress, the focal point of which was the dock midfield inside the triangle of runways.

The runways at Zurich airport have the following dimensions:

Runway	Dimensions	Elevation of the runway thresholds
16/34	3700 x 60 m	1390/1386 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

The airport’s reference altitude is 1416 ft AMSL and its reference temperature is 24.0 °C.

1.10.2 Runway equipment

The airport is characterised by a system of three runways; two of these runways (16 and 28) intersect at the airport reference point. The approach corridors of two other runways (16 and 14) intersect approximately 850 metres to the north-west of the threshold of runway 14. Runways 16 and 14 are equipped with a Category CAT III instrument landing system (ILS) and are therefore suitable for precision approaches.

Runway 28 allows non-precision approaches on the basis of the VOR/DME KLO. The approach sectors of runways 14 and 16 are equipped with a minimum safe altitude warning system (MSAW). This system triggers a visual and acoustic alarm in air traffic control if aircraft infringe defined minimum altitudes. No MSAW is installed in the runway 28 approach sector.

1.10.3 Operating concept

At the time of the accident the noise abatement procedures in force for Zurich airport played a decisive role in determining take-off and landing runways, above all for take-offs before 07:00 and after 21:00 local time (LT). The relation between Swiss local winter time and UTC equals: LT = UTC + 1 h. In addition, on 19 October 2001 the operating concept was changed with regard to landings before 06:00 and after 22:00 LT. The basis for this was the forward drawn measures of a state agreement between Switzerland and Germany which was in the ratification stage in the autumn of 2001.

The following operating concept therefore applied to Zurich airport with regard to the use of runways:

Time (LT) / wind conditions	Runway directions specified for use	Restrictions / comments
05:30 – 06:00 h	Landing: standard VOR/DME approach on runway 28 Take-off: none	Minimums acc. to AIP. If minimums not achieved, runway 16 or 14 could be used for landing.
06:00 – 07:00 h	Landing: runway 16 for all aircraft Take-off: runway 34 for jet aircraft runway 28 for propeller aircraft	Between 06:30 and 07:00 four jet aircraft take-offs were permitted on runway 28.
07:00 – 22:00 h	Landing: runway 14 for all aircraft	
07:00 – 21:00 h	Take-off: runway 28 for all aircraft	Take-off on runway 16 possible, if take-off on runway 28 is impossible because of performance limitations
07:00 – 08:30 h 09:45 – 13:00 h 18:30 – 21:00 h	Take-off: runway 16 allowed for all aircraft	Possibility for increasing capacity
After 21:00 h	Take-off: runway 34 for jet aircraft Take-off: runway 28 for propeller aircraft only	
After 22:00 h	Landing: standard VOR/DME approach on runway 28 For aircraft of the category heavy including B757, runway 16 could be used	Minimums acc. to AIP. If minimums not achieved, runway 16 or 14 could be used for landing.

West wind condition	Take-off: runway 32 Landing: runway 28	
'Bisenlage' – north/north-east wind condition	Take-off: runway 10 Landing: runway 14	Take-off on runway 16 possible, if take-off on runway 10 is impossible because of performance limitations

1.10.4 Rescue and fire-fighting services

Zurich airport was equipped with Category 9 fire-fighting equipment. The airport's professional fire-fighting service was on permanent readiness during flight operations. In the event of an incident, the forces deployed are in constant contact with the control tower and the police via appropriate communications equipment.

ICAO conditions stipulate that compulsory emergency exercises have to be carried out at Zurich airport every two years. The last exercise took place on 27 October 2000 and was named EVAC 2000. Representatives of the Federal Office for Civil Aviation (FOCA) were present and made no complaints.

In the environs, the surrounding municipalities have communal fire brigades organised in the militia system.

An airport medical service with emergency vehicles and appropriate specialist personnel are available around the clock at Zurich airport.

At the time of the accident, the nearest centre of the Swiss Air Rescue Service, REGA, was located at the Zurich children's hospital.

1.11 Flight recorders

1.11.1 Digital flight data recorder

1.11.1.1 Technical description

The Allied Signal flight recorder system consisted of a flight data acquisition unit (FDAU), a digital flight data recorder (DFDR), a flight data entry panel (FDEP) and a triaxial accelerometer.

In the FDAU, data from various aircraft systems and sensors are polled according to a predetermined programme and then forwarded sequentially to the digital flight data recorder. The scanning rate was defined on the basis of the rate of change of the individual parameters. For example, normal acceleration is sampled eight times per second. All data, analogue or digital, are converted to a uniform format in the FDAU and stored digitally in the DFDR in a specified sequence. For subsequent analysis, the data must be reconverted by an external computer into so-called engineering units (heading in degrees, altitude in feet, etc.). The FDAU, as a data concentrator, was housed in the avionics rack.

The DFDR is installed in the tail of the aircraft. It stores the data prepared by the FDAU in a memory unit, which is housed in an impact-resistant and fire-proof capsule in order to be able to withstand the effects of an aircraft crash. In order to be able to locate the DFDR under water, it is equipped with an underwater locator beacon (ULB). The memory unit can record 64 data units, termed words, for about 50 hours. When the memory is full, the oldest data are automatically overwritten.

The flight data entry panel (FDEP) is installed on the centre pedestal. It contains warning lamps which provide warnings about certain malfunctions in the DFDR or FDAU. A switch allows the DFDR to be switched on for test purposes on the ground and another pushbutton allows a specific event to be marked (the event button).

The triaxial accelerometer is located in the centre of the aircraft fuselage. It records accelerations along the three aircraft axes.

Several potentiometers are used as sensors for control movements. In addition, position switches are present for recording “discrete states” (e.g. gear down).

The digital flight data recorder begins to work when one of the engines is running and the parking brake is released.

The DFDR is supplied from the essential bus ESS 115 VAC and the FDAU plus the accelerometers receive their power from the essential bus ESS 28 VDC.

1.11.1.2 Maintenance and monitoring

The flight recorder system had an integrated monitoring system which monitored the DFDR functions both on start-up and during operation.

The DFDR was last calibrated during the C2 check on 3 June 2000. The details relating to this sequence of processes are described in section 1.17.1.11.

1.11.2 Cockpit voice recorder

1.11.2.1 Technical description

The audio signals which are sent and received via the VHF radio equipment, as well as the conversations conducted in the cockpit over the intercom, are automatically recorded by the cockpit voice recorder (CVR). Additionally, voices and noises in the cockpit are recorded by a cockpit area microphone (CAM).

Aircraft HB-IXM was equipped with a solid state cockpit voice recorder (SSCVR) manufactured by Allied Signal. Unlike conventional cockpit voice recorders, the SSCVR does not record onto a magnetic tape but digitally in an electronic memory. The maximum recording time of this equipment is 30 minutes.

The memory unit is located in the SSCVR in a shock- and fire-proof capsule in order to be able to withstand the effects of an aircraft crash. In order to locate the SSCVR under water if necessary, it is equipped with an underwater locator beacon (ULB).

The recordings can be erased by the crew after landing, as soon as at least one aircraft door is opened.

Correct operation of the SSCVR can be checked before the flight by means of an integrated test function. The test is initiated by means of a pushbutton on the CVR control unit.

The SSCVR is supplied with power from the essential bus ESS 115 VAC.

The SSCVR records four audio channels:

- channel 1 observer audio
- channel 2 first officer audio
- channel 3 captain audio
- channel 4 cockpit area microphone (CAM)

For synchronisation purposes, a pulse signal is recorded on channel 1 every four seconds.

The recording system as a whole consists of three components. The solid state cockpit voice recorder is installed in the tail of the aircraft. The control unit is installed in the cockpit on the left side panel and the cockpit area microphone is fitted under the glareshield.

1.11.2.2 Maintenance

Since an SSCVR has no moving parts, it requires no periodic checks in the workshop. Only the logic functions (on/off, erase memory) and the quality of recording are checked periodically on the aircraft.

1.11.3 Reading the flight data recorders

The DFDR and der SSCVR were recovered from the wreck of the aircraft on the night of the accident. The flight data recorders were in good condition.

1.11.3.1 Quality of the CVR recording

Comprehensibility was good and the recording was complete

1.11.3.2 Quality of the FDR recording

The DFDR recordings of the aileron, elevator and rudder could not be analysed.

Part of the recordings of the power lever angle (PLA) was erratic.

The other parameters were of good quality and the recording had no gaps.

1.12 Wreckage and impact nformation

1.12.1 Impact

Immediately prior to the first contact with the trees, the aircraft was flying on a heading of 274° and its ground speed was approximately 118 kt, corresponding to approximately 60 m/s. In this phase the aircraft's bank angle was close to zero. In the course of the attempted go around and during the initial contact with the trees, engine power increased and pitch changed from 2° attitude nose down (AND) to 5° attitude nose up (ANU). The rate of descent reduced from an original 1200 ft/min to approximately 0 ft/min. HB-IXM was in landing configuration, i.e. the gear was down and the flaps were extended. At the time of the accident, there were 3150 kg of fuel on board and the actual mass was approximately 32 400 kg.

The impact zone was in a wooded area, approximately one kilometre north of Bassersdorf, below a rounded summit. The final position of the wreck was about 250 m to the west of the point at which the aircraft had first come into contact with trees, at the foot of the hill.

The collision with the first trees caused the aircraft to decelerate rapidly, although at this time a slight increase in engine power occurred. In this phase parts of the fuel tank were damaged to such an extent that kerosene was released into the air.

About 200 m further along the flight path, the two engines on the right and the right hand wing hit the ground. As a result of this first contact with the ground, the airframe kicked up and rolled. In the process the aircraft broke into several parts.

1.12.2 Debris field

The level debris field was in a wooded area with massive spruce and beech trees directly at the foot of the slope where the first contacts with the trees had occurred. Within it were the engines, the wings and four sections of the fuselage. The extent of the destruction as well as the spatial position of the debris were not in contradiction to the last recorded DFDR data and the preceding destruction caused by the contact with the trees.

The debris field extended from the initial impact point over an area of approximately 1000 m^2.

The impact zone and the central debris field were divided into sectors. In order to draw up a situation plan, the accident site was recorded by means of stereophotogrammetry. The positions of the larger parts of the wreckage were logged and the parts of the wreckage were photographed. When this work was complete, the wreck was recovered and stored.

A brook flowed to the north of the debris field. At the time of the accident and during salvage operations this watercourse carried approximately 10 l of water per second. The fire brigade took appropriate measures to protect the watercourse.

The soil which had been contaminated with fuel and oil was removed over a large area and disposed of appropriately.

1.13 Medical and pathological information

1.13.1 Commander

1.13.1.1 Previous history and medical findings

According to the documents available, the commander had never been seriously ill, apart from occasional colds. Nor had he suffered any serious injuries. The available documents from pilots' medical fitness examinations contain no findings related to illnesses. The commander was 180 cm tall and weighed 82.5 kg.

Because of incipient presbyopia (age-related-long sightedness) the commander had reading spectacles, but there were no medical restrictions or conditions regarding the wearing of spectacles during his activities as a pilot.

1.13.1.2 Medical forensic findings

The expert report of the Institut für Rechtsmedizin of Zurich University comes to the following conclusions:

"Summary: The pilot in command, reliably identified by DNA analysis as (commander's forename, surname and date of birth), died on the occasion of the crash of aircraft HB-IXM, (...) from multiple injuries. (...) Pre-existing changes in organs had no effect on flying fitness. At the time of the accident, (forename, surname) was not under the influence of either alcohol or active ingredients of other drugs or medications listed and tested for in the chemical-toxological report".

1.13.2 Copilot

1.13.2.1 Previous history and medical findings

From the previous medical history, an operation in 1998 on the cruciate ligament in the left knee joint is mentioned, and from the family's previous medical history the diabetes of a direct relative of the copilot is mentioned.

The medical fitness test by the FOCA's medical examiner was carried out three times; one of them is not fully documented. The copilot was 179 cm tall and weighed 86.6 kg. No findings or diagnoses restricting fitness to fly were documented.

1.13.2.2 Medical forensic findings

The expert report of the Institut für Rechtsmedizin of Zurich University comes to the following conclusion:

"(Copilot's surname, forename) was reliably identified by DNA analysis. The evidence of a slight pulmonary embolism shows that (surname, forename) was alive at the time of the above-mentioned aircraft crash. (...), it can be postulated that the death of (surname, forename) was caused by a reflex cardiac failure as a result of trauma to the thorax. Pre-existing changes in organs had no effect on flying fitness. At the time of the accident, (forename, surname) was not under the influence of either alcohol or active ingredients of other drugs or medications listed and tested for in the chemical-toxological report".

1.14 Fire

1.14.1 Examination of traces of fire on aircraft debris

There are no technical or forensic indications that fire had already broken out in the aircraft before the initial contact with the trees.

However, there are traces which indicate that on initial contact with the trees the right wing was torn open. Parts of the tank structure were found in the direction of flight on the right of the slope. In addition, a strong smell of kerosene was perceptible in this area on the day after the accident.

From this it was possible to conclude that fuel was spilled before impact with the ground.

The first part of the wreckage with traces of fire was found approximately 50 m before the impact zone, in an area with no other traces of fire. This was part of the right wing with part of the landing flap.

It may therefore be assumed that fire broke out in the final phase of the flight, after contact with the first trees and before impact with the ground.

Ignition of the fuel may have occurred as a result of the hot engine exhaust gases or short-circuits in the electrical system.

1.14.2 Results of interrogation of eye witnesses

Interrogation of eye witnesses also did not provide any indication that there was a fire onboard the aircraft before the initial contact with the trees.

Quote from passenger in seat 16A: "The aircraft flew into trees, a wing broke off and the aircraft caught fire. But then it gently hit the ground, shook, made a 'bang' and came down at an angle".

Quote from passenger in seat 16F: “Suddenly there was a thud..... On the right side I noticed a fireball outside the aircraft. Up to that moment I thought everything was going normally. Then it rumbled and jolted like a roller coaster. Suddenly, it went quiet”.

Quote from passenger in seat 10A: “Then there was a sudden crash and a fireball came at us at great speed from the nose”.

Quote from passenger in seat 14B: “.....suddenly a loud crashing noise could be heard and the aircraft shook violently. I immediately looked forward and saw through the open cockpit door and the cockpit windscreens that outside the aircraft a real shower of sparks was rising. Next moment there was a massive impact...”.

1.15 Survival aspects

1.15.1 General

The chances of surviving an aircraft accident are generally influenced by various factors. On the one hand, physical conditions such as speed, mass, attitude, configuration, topography and location, the fire energy released and the type of disintegration of the aircraft play a role in a crash. On the other hand, chances of survival are critically influenced by any preparation of the occupants of the aircraft for an imminent emergency landing and by the rescue operation.

1.15.2 Crash sequence

Immediately before the initial contact with the trees, the aircraft was flying on a heading of 274° and its ground speed was approximately 118 kt, corresponding to approximately 60 m/s. In this phase the bank angle was virtually zero. In the course of the go around attempt and during the initial contact with the trees, engine power increased and the pitch changed from 2° attitude nose down (AND) to 5° attitude nose up (ANU). The rate of descent reduced from the original 1200 ft/min to approximately 0 ft/min. HB-IXM was in landing configuration, i.e. the gear was down and the flaps were extended. At the time of the accident, there were 3150 kg of fuel on board and the current mass was approximately 32 400 kg.

There is no indication that the occupants of the aircraft, expecting an imminent landing, did not have their seatbelts on. They were prepared for a normal landing and were surprised by the emergency situation.

Because the angle between the flight path and the ground was small, after entering the trees the aircraft was decelerated over a distance of approximately 200 m before it impacted the ground and broke up.

1.15.3 Alarms and rescue operation

At 21:06:36 UTC radar contact with the aircraft involved in the accident was lost. The ATCO at aerodrome control (ADC) raised the alarm at 21:10:32 UTC.

The first police officer arrived at the Kreuzstrasse restaurant at about 21:16 UTC, where he was directed to the site of the accident by a witness. About two minutes later a police patrol arrived at the Kreuzstrasse restaurant. The patrol vehicle arrived at the location of the accident with its blue lights flashing. A few survivors ran towards the blue lights and were cared for by the police.

The approaching rescue personnel were directed by the police and the first seven vehicles with 14 men from the professional fire-fighting force at Zurich airport arrived at the site of the accident at 21:22 UTC. The medical rescue services arrived almost at the same time and looked after the survivors.

The fire brigade laid four water lines, each pumping 485 l/min. Approximately 30 000 litres of water and sufficient foam extract were available.

The fire, fed by the fuel which was still present, had spread unhindered until the fire brigade arrived. At the start of the extinguishing operation, white-yellow flames and almost smokeless combustion were observed, indicating a high temperature. Several small explosions occurred. At 21:39 UTC, i.e. 17 minutes after the arrival of the fire brigade, the fire was under control and largely extinguished.

Subsequently, more fire-fighting units from the surrounding municipalities of Nürensdorf, Bassersdorf and Kloten arrived at the accident site with a total of 180 men. The professional fire brigade from Zurich airport additionally increased its unit to 40 men.

Under the direction of the cantonal police, a major search operation was then undertaken for other survivors; this lasted until the early hours of the following morning. The search did not benefit from air support due to the bad weather.

No further survivors were found.

1.15.4 Emergency locator transmitter

The emergency locator transmitter (ELT) was a Litton ELT-952 which transmits on frequencies 121.5 MHz and 243 MHz. It was installed in the upper aft fuselage. The device was destroyed in the accident. The antenna plug connector with part of the housing and part of the printed circuit was found.

No emergency signal was received within a radius of 100 NM of Zurich on 24 November 2001 between 20:00 UTC and 23:00 UTC, either by the SARSAT/COSPAS system of the search and rescue service or by other aircraft or ground stations.

1.16 Tests and research

1.16.1 Terms and definitions

The following terms and definitions are taken from the ICAO manual of all-weather operations.

1.16.1.1 Visual descent point

The visual descent point (VDP) is a defined point on the final approach course of a non-precision straight-in approach procedure from which normal descent from the MDA to the runway touchdown point may be commenced, provided visual reference is established.

1.16.1.2 Missed approach point

The missed approach point (MAP) is the point in an instrument approach procedure at or before which the prescribed missed approach procedure must be initiated in order to ensure that the minimum obstacle clearance is not infringed.

1.16.1.3 Minimum descent altitude/height

The minimum descent altitude/height (MDA/H) is a specified altitude/height above sea level respectively above the ground in a non-precision approach or circling approach below which descent may not be made without visual reference.

1.16.2 Examination of standard VOR/DME approach 28

1.16.2.1 Introduction

The conformity of the standard VOR/DME approach 28 with the ICAO procedure for air navigation services-operations (PANS-OPS) was examined in cooperation with the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) from France.

1.16.2.2 Initial approach segment

The initial approach segment is constituted by the radial 178° of VOR/DME ZUE. The minimum altitude of 5000 ft AMSL for this segment guarantees, within the segment's protected corridor, clearance in excess of 500 m from the highest obstacle (Langfuri, 963 m AMSL).

The minimum obstacle clearance (MOC) required by PANS-OPS for the initial approach segment is 300 m.

1.16.2.3 Intermediate approach segment

The intermediate approach segment is constituted by the radial 095° of VOR/DME KLO and lies in the extension of the final approach segment. For this segment, PANS-OPS require a minimum length of 7 NM. In the case of the standard VOR/DME approach 28 the intermediate approach segment has a length of 3.5 NM. This deviation was noticed during the periodic check of this procedure by Swisscontrol on 23 November 2000 and thereafter, according to skyguide, forwarded to FOCA.

The intermediate approach segment is used to adapt the speed and configuration of an aircraft for the final approach. This is why PANS-OPS specify that the profile in this segment should not have any slope. If one is unavoidable, the standard lays down a maximum slope of 5%. In addition, a horizontal flight path of at least 1.5 NM is to be provided before the final approach segment.

Standard VOR/DME approach 28 specifies a loss of altitude of 1000 ft for the intermediate approach segment. The shortness of this segment allows aircraft which are following a flight path with a 5% slope a horizontal segment approximately 0.2 NM in length before commencing the final approach segment.

1.16.2.4 Final approach segment

The final approach segment is also defined by the radial 095° (radial inbound 275°) of VOR/DME KLO. It starts at the final approach fix (FAF), which is 8 NM from DME KLO, and ends at the missed approach point (MAP) at 2 NM DME KLO.

In order to guarantee the obstacle clearance altitude and obstacle clearance height respectively, a reference point with an altitude limit of 3360 ft QNH is defined at a distance of 6 NM from VOR/DME KLO.

PANS-OPS specify that the "final approach to a runway may be executed if the landing is in a straight line (a straight in approach), or towards an aerodrome if a circling approach must be done ".

Since VOR KLO is to the south of runway 28, the final approach segment has a direction which deviates from the runway axis by 1°. The final approach segment progresses in such a way that at a distance of 1400 m from the threshold of 28, it is less than 150 m from the axis of the runway. The alignment of the final approach therefore meets the PAN-OPS criteria for a straight in approach.

PANS-OPS specify that for a straight in approach the descent slope must be calculated as follows:

The distance between the FAF and the threshold of the runway and the difference between the height above sea level or ground of the FAF and the height of 15 m (50 ft) above the threshold of the runway are placed in relation to each other. Applying this method to the standard VOR/DME approach 28 procedure a slope of 6.0% or 3.4° is the result.

If a further height limitation is necessary in the final approach segment, as represented by the point at 6 NM in standard VOR/DME approach 28, in this case PANS-OPS specify that the above method must be applied with regard to this height limitation. A slope of von 6.3% or 3.6° is the result.

The published slope for the standard VOR/DME approach 28 of 5.3% or 3.03° does correspond to the slope between the FAF and the height limitation at 6 NM but is not in compliance with PANS-OPS.

In addition it must be stated that the glide path published for standard VOR/DME approach 28 with a slope of 5.3% or 3.03° intersects the glide path of the precision approach path indicator (PAPI) of 3.7° at a height of 1500 ft AAL and 3.5 NM before the threshold of the runway (cf. Appendix 11, Point P-1). These values lie far above the published OCH (MDA) and at a distance from the threshold of the runway which is distinctly higher than the corresponding visual minimums for a straight in approach. The approach chart for standard VOR/DME approach 28 specifies that the PAPI glide path should be followed as soon as visual reference points are achieved. In the case that the nominal glide path of 5.3% is followed and that the visual reference points become visible only at the OCH (MDA), one will be approximately 100 ft above the PAPI glide path (cf. Appendix 11, Point P-2). In order to reach the PAPI glide path, it is now necessary to initiate a descent which is steeper than the glide path of the PAPI (6.5% or 3.7°). Joining the PAPI glide path from above in this way conceals the danger of a non stabilised final approach at low altitude. This danger is even greater if an aircraft chooses a glide path with a lower pitch than nominal or if it flies horizontally at the OCH (MDA) until reaching the vicinity of the MAP in order to achieve visual reference points.

Moreover, the side view on the approach chart for the standard VOR/DME approach 28 makes it possible to draw the conclusion that the section which is flown according to instruments intersects the PAPI glide path at the OCH, although in reality this is not the case.

In this context, we refer to the radar recordings of flights CRX 3891 and 3797 of 24 November 2001 in appendix 4.

1.16.2.5 Missed approach segment

The missed approach segment of the standard VOR/DME approach 28 is formed first by following VOR/DME KLO radial 255° and then by radial 012° of VOR/DME WIL in the direction of the EKRIT point. It has no peculiar features. However, with regard to the angle of 117° between the above-mentioned flight paths a turning point should be defined for commencing the change of course.

1.16.2.6 Approach chart according to AIP Switzerland

The approach chart published in the Swiss AIP and numbered LSZH AD 2.24.10.7-1 for the standard VOR/DME approach 28 deviated in several points from the ICAO standards and recommendations.

1.16.2.7 Summary

The above facts allow the conclusion that the published procedure for the standard VOR/DME approach 28 exhibits deviations from PANS-OPS which are not provided for in the relevant national regulations (Swiss procedures design manual).

Switzerland had not informed the ICAO that the national rules and regulations deviate from the procedures of ICAO-Annex 4, the content of which is the production of charts.

1.16.3 Comparison flights in the simulator

1.16.3.1 General

In order to be able to assess the working procedures of the crew of an Avro 146 RJ 85/100 during a standard VOR/DME approach 28, the corresponding instrument setting and the resulting displays on the EFIS, several comparison flights and test flights were made on different simulators. These flights were carried out on the following basis:

- CVR recording and transcript
- DFDR recordings
- Radar recordings of the flight path
- Radio conversation recordings and transcripts
- Photographs of the cockpit panel with the post-accident switch positions
- Documentation of the approach procedures in force at the time of the accident
- The Crossair operating procedures in force at the time of the accident

On the one hand, approaches were made according to the Crossair operating procedures in force at the time of the accident. On the other hand, various comparison and test flights were made in which the parameters of the flight involved in the accident were used. Within this framework, the following tests were carried out in particular:

- Approach using the ALT HLD push button on reaching the MDA
- Approach during which a go around was initiated at 500 ft radar altitude
- Approach during which a go around was initiated at 300 ft radar altitude
- Approach to clarify the operation of the ground proximity warning system (GPWS)
- Clarification of the instrument setting and the corresponding displays on the primary flight displays (PFD) and navigation displays (ND) of the EFIS

The visual relationships as a function of the weather conditions and the lighting conditions, as well as the practical applicability of the published weather minimums for the standard VOR/DME approach 28 were tested in a simulator with the corresponding visualisation facilities. Clarification of the visual conditions was carried out in the flight complying with the MDA along the radial 095° of VOR/DME KLO.

For the approach, a visual descent point (VDP) based on a glide path of 3.7° (PAPI) and a minimum descent altitude (MDA) of 2390 ft QNH was calculated, resulting in a VDP located at 2.4 NM (4.4 km) from the threshold of runway 28. With reference to VOR/DME KLO, the VDP is located at a distance of 3.3 NM (6.1 km). A selection of corresponding images is provided in appendix 5.

1.16.3.2 Results

The tests in the simulators produced the following results:

- The workload during a standard VOR/DME approach 28 corresponds to the usual requirements of a non-precision approach. Compared with a precision approach the crew must additionally determine vertical navigation.
- The operating procedures implemented by Crossair at the time of the accident for precision approaches corresponded to the specifications of the Federal Office for Civil Aviation and the Joint Aviation Requirements JAR-OPS 1.
- If the ALT HLD pushbutton is pressed 100 ft above the MDA, i.e. at 2490 ft QNH, the aircraft initially descends to 2360 ft QNH, then climbs gently again and finally stabilises at an altitude of 2410 ft QNH.
- If the ALT HLD pushbutton is pressed at the MDA, i.e. at 2390 ft QNH, the aircraft initially descends to 2260 ft QNH, then climbs gently and finally stabilises at an altitude of 2310 ft QNH.
- During the go around attempt which was initiated at a radar altitude of 500 ft RA, it was found that the synthetic voice called out the information “five hundred” at actual 490 ft RA. At a radar altitude of 420 ft RA, the aircraft began to climb again. Full engine power was available 5.5 seconds after pressing the TOGA button. The entire procedure was flown with the autopilot and auto throttle switched on.
- During the go around attempt which was initiated at a radar altitude of 300 ft RA, it was found that the synthetic voice called out the information “minimums” at actual 290 ft RA. At 280 ft RA the autopilot was switched off and the go around was flown manually. At a radar altitude of 270 ft RA, the aircraft began to climb again.
- HB-IXM was equipped with a GPWS (cf. section 1.6.10). In landing configuration, if the ground is approached at an excessively high rate of descent, the mode 1 warning responds – excessive descent rate. During an approach at a rate of descent of 1200 ft/min, the acoustic warning “sink rate” sounded together with the visual “pull up” warning at a radar altitude of 125 ft RA. The go around initiated immediately afterwards, switching off the autopilot, was successful and led to a minimum altitude of 65 ft RA. The acoustic and visual warnings corresponded to the manufacturer’s specifications (cf. appendix 3). During the flight involved in the accident, the warnings did not sound, because the aircraft was always just outside the mode 1 resp. the mode 2B envelopes.
- At a meteorological visibility of 5000 m the approach lights were visible at a distance of 3.3 NM (6.1 km) from VOR/DME KLO. The runway lights were detectable at 2.8 NM (5.2 km).
- At a meteorological visibility of 3500 m the approach lights were detectable at a distance of 3.0 NM (5.6 km) from VOR/DME KLO. The runway lights were visible at 2.5 NM (4.6 km).
- At a meteorological visibility of 2000 m the approach lights were visible at a distance of 2.1 NM (3.9 km) from VOR/DME KLO. The runway lights were detectable at 1.8 NM (3.3 km).
- At a meteorological visibility of less than 3500 m neither the approach lights nor the runway lights could be detected from the VDP.

1.17 Organizational and management information

1.17.1 The Crossair operator

1.17.1.1 General

The Crossair operator was founded in 1975 and in its first few years handled mainly charter traffic using twin-engined aircraft for business flights. In 1979 the company purchased aircraft type SA 227 TC Metroliner II and started regular scheduled flights. In the following two decades the company grew into a large regional airline, which at the time of the accident was operating more than 80 aircraft of the Saab 2000, Embraer 145, Avro 146 RJ 85/100 and Boeing MD 83 types with about 3500 employees.

1.17.1.2 Structure of the flight operations division

With the introduction of the British Aerospace BAe 146-200 "Jumbolino" type in 1990, individual fleets were established in the flight operations division for the first time. The fleet managers were responsible for the procedures and the technical equipment of their fleet and among other things had their own chief flying instructor and their own technical pilot.

A chief pilot was designated at the same level as the fleet managers; he was mainly responsible for personnel matters and in particular for pilot selection.

Monitoring of flight crew performance and their qualifications was a matter for the fleet manager. In the case of conversions, the chief pilot coordinated personnel requirements and selected the appropriate pilots in agreement with the fleet managers. Seniority lists for the flight crews existed but were not always used in the case of conversions.

Since 1998, Crossair has been operated in accordance with Joint Aviation Requirements JAR-OPS 1 and therefore possessed, in addition to an accountable manager, other managers – so-called postholders – responsible for the areas of flight operations, maintenance, crew training and ground operations. In addition, a quality management system existed.

The vice president flight operations, as manager of flight operations, reported directly to the president and chief executive officer (CEO), who was at the same time the accountable manager. Until the year 2000, among other things, the latter also had at his disposal the staff offices of the flight safety and security officer and the selection board for flight crews.

The vice president flight operations managed the following divisions: fleet and cockpit personnel, flight operations support, resource planning, pilots' administration and flight operations engineering.

With the transition to the JAR-OPS 1 structure, the function of vice president fleet and cockpit personnel was created from the chief pilot function. The previous chief pilot was named as the Avro RJ 85/100 fleet manager. In contrast to the pre-1998 organisation, the fleet managers were now assigned all personnel aspects relating to their crews – with the exception of pilot selection. As far as conversions were concerned, the vice president fleet and cockpit personnel now coordinated personnel requirements; the selection process was now handled primarily at the fleet manager level. Prior to the accident, the company regulations (fleet manual), which dealt with acquiring a type rating, contained no information on how candidates for conversion were to be selected. Nor were there any regulations regarding the measures to be taken if performance problems occurred during a conversion or if a pilot did not pass the conversion course.

The fleet and cockpit personnel department consisted of the following four aircraft fleets: Saab 2000, Embraer 135/145, Avro RJ 85/100 and MD 80 and was managed by a vice president. Each of these fleets was managed by a fleet manager and in addition to the usual administrative apparatus also had a chief flying instructor and a technical pilot. In addition, this department also included the pilots' recruitment office, which dealt with pilot selection.

The flight operations support department, in addition to the performance and flight planning sections, also included safety, security and emergency training, base operations, policy and standards and an aircraft and accident response organisation. In autumn 2000 the flight safety and security officer was also assigned to the flight operations support division.

The resource planning division was subdivided into the long-term and strategic planning, training planning and rostering departments.

The pilots' administration division consisted of the licences, permits, documentation and IT coordination departments.

1.17.1.3 Flight safety department

The flight safety department initially reported to the vice president flight operations. In autumn 2000 it was assigned to the flight operations support division. It consisted essentially of a flight safety officer, who performed this function on a 50% part-time basis and who acted as a flight crew member for the remainder of the time. The flight safety officer had an assistant on a 30% part-time basis. Thus at the time of the accident the flight safety department amounted to 80% of a full-time equivalent post. The flight safety officer had no financial competencies.

Before the flight safety officer assumed his office in September 2000, this task was performed by the manager of the flight operations support division, who was also simultaneously the deputy for the vice president flight operations and was, furthermore, a commander on scheduled flights.

Under the leadership of the flight safety officer, meetings of the flight safety board took place four times a year. This committee, founded in 1999, discussed the questions and problems arising in the area of flight safety.

The tasks of the flight safety officer were defined in the operations manual part A (OM A). Essentially, he was responsible for monitoring flight safety and flight operations. The flight safety officer was associated with flight operations and the individual fleets via his direct superior, the vice president flight operations support.

In addition to personnel resources, the instruments available to the flight safety department since early 2001 also included an IT system for recording occurrences. Until summer 2001, Crossair had an occurrence report system, but no confidential reporting system. In June 2001 the flight safety officer established the possibility for crews to submit a flight safety confidential report. Until the time of the accident, an average of two confidential reports on flight safety problems was submitted to the flight safety department per month. In 1997 two internal publications – flight safety news and flight safety flash – were set up to inform crews of flight safety aspects.

The flight safety officer could conduct internal investigations of occurrences, bringing in other specialists, and make proposals to his superiors on improving flight safety. Between the time he took up the position in autumn 2000 and the time of the accident, he carried out no internal investigations. Within the same period, he recommended four measures to the vice president flight operations support, none of which had any relation to the accident which occurred.

When new aircraft types were introduced, the flight safety department was not involved. No exchange of experience took place between those responsible for conversion training and the flight safety officer.

The flight safety department had no knowledge of flight crews with indications of performance problems or gaps in performance, nor was it brought in in the case of flight safety problems which were attributable to infringements of regulations. The pilots involved were dealt with in this area by the fleet manager.

In summary, the flight safety officer described the activity of the flight safety department as reactive. According to his own statements, he was attempting to become proactive in this area, with new methods.

1.17.1.4 Flying culture

Several witnesses who had flown as flight crew on Saab 340, Saab 2000, MD 80, Embraer 145 and Avro 146 RJ 85/100 aircraft were questioned. An evaluation of these statements yields the following points:

- The individual fleets differed greatly in terms of their operation and operating culture. For example, the MD 80 fleet based itself on the processes and procedures of the Balair and Swissair airlines. The Saab 340 on the other hand, which was the basic aircraft for many Crossair pilots, was in some cases operated with less regard to conformity with the regulations, according to several people who provided information.
- Within the framework of the investigation, more than 40 incidents from 1996 to 2001 were raised in which crews had developed their own procedures or had not complied with specified procedures. These incidents were mostly concealed from the airline, even though in some cases safety had been a factor.
- The hierarchical gap between commander and copilot was described several times as great. Copilots felt it was not very effective to make certain commanders aware of errors or defects. The explanation cited for this state of affairs, among others, was the great difference in experience between older commanders and young copilots.

1.17.1.5 Selection procedure for copilots

1.17.1.5.1 Provisions of the Joint Aviation Requirements

According to the guidelines of the Joint Aviation Requirements (JAR) the airline must ensure that suitable crews are employed. In order to judge the Crossair selection procedure the following guidelines from the Joint Aviation Requirements flight crew licensing 3 (JAR-FCL 3), subpart A, B and C, section 2 are used. These guidelines regulate the makeout of certificates by the authorities and are in a way minimum requirement for flight crew members. For this accident the following parts from JAR-FCL 3 are applicable:

„The performance of aviators requires certain cognitive, psychomotor and interpersonal capabilities in order to perform operational tasks in a reliable way especially during high workload and stress. (…) A reduction in pilot capability is never easily detected or demonstrated. The majority of accidents in aviation is caused by human error not by physical incapacitation or technical failures. People may become unsafe for various

reasons: low mental or psychomotor problems or accelerated ageing, to name a few. Such personal conditions are not usually classified by psychiatric and neurological standards as disqualifying criteria. They have to be assessed by a psychological evaluation. (...) Only psychologists acceptable to the AMS or organisations which employ psychologists acceptable to the AMS are allowed to perform the psychological evaluation.“

According to the specifications of JAR-FCL 3, a selection procedure should raise and evaluate the biography and certain personality factors, in addition to capabilities directly related to flying (operational aptitudes):

- *“Operational aptitudes: logical reasoning, mental arithmetic, memory function, attention, perception, spatial comprehension, psychomotor function, multiple task abilities*
- *Biography: general life history, family, education, socio-economic status, training progress and occupational situation, critical behavioural incidents, diseases and accidents, delinquency*
- *Personality factors: motivation and work orientation, decision making, social capability, stress coping”*

With reference to the methodology of a selection procedure for flight crew members, the JAR-FCL 3 regulations read as follows:

“Because of the diversity of psychological methods (...) available for the assessment of the different criteria mentioned on the criteria list above, no tests, questionnaires or other methods have been recommended for the assessment of these criteria. However, general guidelines are described below for guidance and finding adequate assessment methods.

1. Whenever possible standardised psychological tests and questionnaires which fulfill at least the following general requirements should be used for criteria assessment.

Reliability: *The stability (test-retest-reliability) or at least the internal consistency of tests/questionnaires has been proved (whenever possible with regard to an application in personnel selection).*

Construct validity: *The extent to which a test/questionnaire measures the construct (aptitude, personality trait) it is intended to measure has been proved (whenever possible with regard to an application in personnel selection).*

The test or questionnaire should clearly differentiate between the applications (ideally normal distribution of test scores) even in a highly pre-selected group like, e.g. holders of pilot licence.

Norms: *In order to evaluate the test/questionnaire results of individual subjects, standard norms have to be available for the test/questionnaire. These norms should be derived from the distribution of test results in samples which are more similar in important characteristics (e.g. age, education, level etc.) to the group of applicants under discussion. For reasons of standardisation it is recommended to use STANINE scores as norms for all tests or questionnaire.*

2. In case that observer ratings are used for criteria assessment, it should be ensured that the observers are very well trained and that the inter-rater-reliability is high, i.e. that different observers agree about their evaluation of a certain behaviour shown by an applicant. As a rule a high inter-rater-reliability can be achieved by using clearly defined rating scales and/or classification systems.

3. The whole test system used for the criteria assessment should be characterised by redundancy with regard to the sources of information used to assess the apti-

tudes/personality traits mentioned in the criteria list above. Whenever possible each of these aptitudes/personality traits should be assessed/tested on the basis of at least two independent sources of information (tests, questionnaires, observer ratings, interview-data, biographical data). This kind of cross validation is recommended in order to improve the overall reliability of the whole test system.

4. Decision rules: The decision about the classification of an applicant or holder of a Class 1 or Class 2 medical certificates should be based on the following general rules. However, in the case of clear deficiencies in operational aptitudes of already experienced pilots, it has to be considered whether or not personality characteristics can compensate for the resulting risks.

***Operational aptitudes:** In order to assess as non-critical an examenee should not have a clear deficiency in any operational aptitude as compared with the norm group.*

***Personality factors:** An examinee must be evaluated (by a psychologist) as non-critical with regard to the main personality factors: motivation and work orientation, social capabilities and stress coping.*

This usually implies that the examinee is not assessed as an extreme case with regard to the normal range of variation in the contributing factors."

1.17.1.5.2 Implementation of the procedure by Crossair

The selection procedure for copilots consisted of a data acquisition process and a decision-making process. The first process – the actual examination of candidates – was the responsibility of the pilots' recruitment department, which was part of the fleet and cockpit personnel division. This department consisted of a psychologist, an aviation expert and about a dozen pilots with many years experience, without psychological training, who were employed part-time as recruitment officers.

In an initial step, a recruitment officer would conduct an interview with candidates of about one and a half hours' duration. Pairs of candidates were then tested together in a flight simulator. Using the results of these two tests, the aviation experts and the psychologist took the decision on further checks or rejection of candidates. Furthermore a test on aviation knowledge had to be passed.

In the case of the candidates who had been assessed positively, in a second stage the recruitment officers carried out individual and group assessments. In addition, an external psychologist was brought in to carry out a personality assessment using psychodiagnostic tests. In the process the aspects of "social skills" and "entrepreneurial competence" were raised; the external psychologist described the candidates in this respect in prose form. On the basis of their observations in the same areas, the recruitment officers completed the following tabular summary. The characteristics were evaluated digitally (Yes/No), i.e. as to whether they were or were not present.

Social skills		
Active go-getter	Acquires information, material, etc. independently; asks if something is unclear to him, meets his environment	Yes/No
Emotional compatibility	Feels comfortable in his environment, is his own person, does not hide his feelings, is relaxed, etc.	Yes/No

Individualist	Can delimit himself, does not simply follow suit, remains himself, creates a profile through his own opinions, etc.	Yes/No
Humour	Is able to laugh at himself and situations, is relaxed, etc.	Yes/No
Entrepreneurial skills		
Handling of general conditions	Can deal well with fast, unexpected changes in situations, can accommodate himself and adapt quickly (mentally and physically), etc.	Yes/No
Salesman	Sticks to his opinion, idea, etc. and can communicate it and convince others	Yes/No
Broadmindedness	Can cope with other people having their own opinions, takes in other people's thoughts even if they don't suit him, etc.	Yes/No
Decides in favour of the company	Can temporarily put aside his own needs and wishes in favour of the company or of something which is more important	Yes/No
Problem-solving	Can analyse problems, weigh up alternative solutions and work out the basis of decisions, can proceed in a structured manner, etc.	Yes/No

All the results were finally collated and forwarded to the selection board, which decides on the appointment of the candidates examined. No formal decision criteria could be presented to the investigators. The selection board generally consisted of several members of the company management. The specialists from the pilots' recruitment department also took part in selection board meetings in an advisory capacity.

On conclusion of the selection procedure, the dossier was passed on to the pilots' administration department. Except in a few individual cases, no cooperation took place with the fleets or with those responsible for training in crew resource management (CRM), which could have allowed feedback or quality control.

1.17.1.6 Training in crew resource management

Training and further training in crew resource management (CRM) is regulated in the JAR-OPS specifications.

Since the introduction of JAR-FCL on 1 July 1999, new air transport pilots are introduced to the following areas as part of their basic training and in the sphere of "human performance and limitations":

- "How do people function and why?"
- "How do people function in a team and why?"

To deal with these topics, aviation medicine and aviation psychology are taught as part of 70 to 100 hours of instruction in the context of the entire training as an air transport pilot. The copilot underwent this basic training. At the time of the commander's basic education no CRM training according todays standards was known. For this reason the commander did not undergo an equivalent basic training. According to the airline he was made familiar with CRM topics during annual training modules.

The CRM training was integrated into the following modules:

Initial operator CRM: first-time testing of the learned theoretical concepts with regard to their practical applicability according to the experience acquired during the first year of duty as an independent copilot, in a two-day course at the end of the first year of duty.

Conversion CRM: introduction to the specific features of a new aircraft or a different employer with regard to different technology, ergonomics, areas of application and procedures.

Command CRM: introduction to the specific requirements of a future commander in terms of human factors (leadership, motivation of colleagues, etc.).

Recurrent CRM: regular treatment of different topics in the areas of human factors, depth of methodology and periodicities. These regular human factors were incorporated in the following courses for cockpit personnel:

- Recurrent simulator training
- Emergency and survival equipment training (ESET)
- Modular CRM (human aspects development)

At Crossair, the initial operator CRM was provided during the company introduction as a 2- to 3-day course. The topics corresponded to the JAR-FCL specifications and were covered in face-to-face teaching. No syllabus is available.

Recurrent crew resource management from 1999 to 2001 was integrated in an annual one-day emergency procedure refresher course. In each case, three to four hours were dedicated to CRM. The topics covered corresponded to the JAR-FCL requirements.

1.17.1.7 Conversion course to aircraft type MD 80

In 1995 Crossair introduced twelve type McDonnell Douglas MD 82 and MD 83 aircraft, which had previously been operated by Balair/CTA, Swissair and Aero Lloyd. Together with the aircraft, a number of instructors and flight crews were also transferred from these Swiss airlines. The fleet manager of the new MD 80 fleet came from Crossair, whilst an experienced instructor, previously the chief flight instructor for Swissair and Balair/CTA was taken on as the chief flight instructor. The flight instructor team for converting the Crossair flight crews consisted of Crossair employees and former Balair/CTA or Swissair employees.

For the conversion courses, Crossair chose the same structure as for the previous operators of the aircraft and used the same operating procedures for the MD 80 as Swissair had. Likewise the same aids were used and the same number of simulator lessons was provided.

During 1996, 64 Crossair pilots took part in an MD 80 conversion course. Eight participants – including the commander of the aircraft involved in the accident – were unable to provide the required performance and did not pass the conversion course.

1.17.1.8 Regulations regarding flight duty times and incidental occupation

At the time of the accident freelance activities of flight crew members were regulated in the collective work agreement (*Gesamtarbeitsvertrag* – GAV) which the airline had signed with the pilots' union, Crossair Cockpit Personal (CCP).

The following provisions of the CCP GAV 2000 are of significance for the accident flight:

Quote:

- Art. 21.5: *„Die Annahme öffentlicher Ämter ist der Crossair zu melden. Nebenbeschäftigungen mit Erwerbszweck dürfen die Interessen der Crossair nicht beeinträchtigen und unterstehen der Meldepflicht.“* (The acceptance of public offices must be notified to Crossair. Freelance activities for gain shall not adversely affect the interests of Crossair and are subject to the obligation to notify.)
- Art. 21.6: *„ Die nachstehend genannten ausserdienstlichen Tätigkeiten bedürfen der schriftlichen Einwilligung von Crossair:* (The extra-official activities cited below require Crossair's written consent)
  - *Linienflüge, Rundflüge, Charter- und Taxiflüge bei einem anderen Flugbetriebsunternehmen.* (Scheduled flights, sight-seeing flights, charter and taxi flights with another airline)
  - *Fluglehrerdienst im Rahmen einer Flugschule oder einer Flugzeug-Verkaufsorganisation.* (Flying instruction within the framework of a flying school or an aircraft sales organisation)
  - *Einsätze für die Rettungsflugwacht.“* (Operations fort the air rescue service)

End quote

In addition the flight duty regulations of the operations manual part A (OM A) stipulated in chapter 7 article 7.1.1 that all flying activities are subject to these regulations.

There are no indications that the commander applied for a corresponding written authorisation or that he had received such an authorisation from the airline. Members of the airline's management stated that the commander's flight instructor activity was known. A coordination of planning and controlling the duty and rest times on his activities inside and outside of the airline did not take place.

1.17.1.9 Regulations on visibility references in the case of non-precision approaches

The relevant foundations for flight operations are laid down in the operation manual part A (OM A). At the time of the accident, the following regulations, among others, were in force:

Quote:

„Chapter 8A, Operating Procedures

8.1.3.2.2 Landing at Aerodromes with published Non-Precision Approach Procedures

No Pilot may continue an approach below MDA (MDH) unless one of the following visual references for the intended runway is distinctly visible to and identifiable by the pilot:

- *Elements of the Approach Lights System*
- *Threshold*
- *Threshold marking*
- *Threshold lights*
- *Threshold identification lights*
- *Visual glide slope indicator*
- *Touchdown zone or touchdown zone markings*
- *Touchdown zone lights*

- *Runway edge lights*
- *Other visual reference as published in the OM C* (Route Manual).

8.4.7.4.10 Pilot not flying

The pilot not flying (PNF) shall continuously monitor the approach, give every possible help and keep the basic and other flight/navigation instruments under careful check, including also momentary crosschecks of most important indications on both pilots instrument panel. He shall operate and set the aeroplane equipment in accordance with CROSSAIR procedures and must call the PF attention to:

- *Significant deviations from prescribed regulations and procedures*
- *Abnormal deviations from the approach flight path, prescribed aeroplane configurations, speeds, altitude and rate of descent*
- *Obvious deviations on the instruments*
- *DH, DA or MDA etc. by calling out "minimum"*
- *Approach lights, runway in sight*
- *If G/A is based on timing, when the stipulated time has elapsed*

8.4.7.4.15.2 Co-operation on Changeover to Visual Flying

When ground contact is expected to be obtained, the PNF shall divide his attention between the flight instruments and look-out. When the approach lights (or runway or runway-lights) are clearly in sight and the attitude of the aeroplane can safely be determined with reference to the ground, he shall tell the PF, e.g. "runway in sight". From this point, the PF will fly mainly by visual reference and make only quick cross-checks of his instruments. During that phase the PNF will monitor his instruments closely and call deviation to the attention of the PF until flare-out.

8.4.7.5.2 Visual Part of Final Approach and Landing

8.4.7.5.2.1 Definition

During this phase of flight all directional and bank information is entirely obtained from visual ground clues such as the lighting system or the runway texture and where instruments are used only for quick-glance reference to check speed and attitude/glide path.

8.4.7.5.2.4 Glide Path

If terrain clearance permits, the visual final must be arranged so as to follow the normal glide path of 2.5 deg to 3 deg in order to provide a safe descent and a good starting point for landing. Descending rapidly to the normal glide path or even diving below the normal glide path for obtaining a closer visual guidance of the ground or the approach lights is considered unsafe and must be avoided.

In some weather conditions visual illusions can lead to dangerous deviations from the nominal glide path. Therefore it is essential for the PNF to monitor his instruments and call out any deviation. (...)

8.4.7.5.2.6 Use of VASI/PAPI

The glide path defined by a standard VASI/PAPI shall be closely followed as a visual reference down to the height defined in OM C (Route Manual).

8.4.7.4.19.4 Go Around

A G/A shall immediately be executed by the commander at anytime:

- *If APPR WARN is displayed on the HGS combiner unless sufficent visual reference is available for performing an unguided landing. A G/A shall immediately be executed by the commander at DH/DA*
- *If no or not enough visual guidance to continue is available*
- *If visual guidance is obtained but the aeroplane is in a position not permitting a safe landing (not stabilised, etc.)"*

End quote.

1.17.1.10 Localizer DME Approach to Runway 03 in Lugano (today IGS Approach Rwy 01)

Authorisation to fly into Lugano airport was acquired as part of additional special training, a so-called airport qualification. According to the AIP Switzerland qualification is valid for the respective ICAO aircraft category. Within Crossair this airport qualification was aircraft type specific. During his many years flying the Saab 340 the commander of the aircraft involved in the accident possessed the airport qualification for Lugano on this aircraft type.

The AIP Switzerland the Crossair route manual (OM C) from Jeppesen respectively state the following regarding the approach procedure among other:

- The published altitudes (ALT) at DME ILU 4.5 NM and 3.0 NM are strictly to be observed.
- After missed approach point (MAP) proceed to runway (RWY) maintaining visual ground contact.
- At MAP the RWY is still 1.5 NM ahead and may not yet be in sight.
- Localizer track is aligned with RWY axis 01. Follow the precision approach path indicator (PAPI) for final descent segment.
- The approach shall not be flown in the approach mode but in the localizer mode together with a vertical mode.

The Crossair Saab 340 pilot information handbook (PIH) requires the localizer DME approach 03 Lugano to be flown with the autopilot in "NAV and vertical speed (V/S) mode only" and to follow the glide slope of 6.65°. At 3 NM DME ILU and an altitude of 3050 ft QNH it is recommended to fly below the glide path in order to intercept the PAPI. If, upon reaching the MDA the PAPI is not visible, the aircraft must continue to fly horizontally at the MDA. Latest at the MAP, 1.5 NM DME ILU, the pilot needs to obtain visual references in order to leave the MDA for final approach: "Looks out for visual references, ground contact". If no such visual references are present, a go around must be initiated. (cf. appendix 6).

According to statements from crews, it was also common practice to leave MDA before the MAP with merely "ground contact", i.e. without sight of the PAPI and to descend to a radar altitude of at least 300 ft RA above the lake. Then in each case the aircraft was flown horizontally until the PAPI finally came into view. This procedure is not mentioned anywhere in the Crossair flight operations regulations.

1.17.1.11 Aircraft maintenance procedures

1.17.1.11.1 Altimeter maintenance

It was shown that the periodical checks on the altimeter system (two air data computers and one standby altimeter) were not carried out in accordance with the regulations and were not documented.

The mechanic carrying out these checks did not possess a FOCA licence and did not have the appropriate authorisation from the airline to carry out this work.

1.17.1.11.2 DFDR calibration

The corresponding data were read out periodically from the flight data recorder in accordance with the regulations. These recordings showed complaints for the following parameters:

- elevator left hand and right hand
- aileron left hand and right hand
- rudder
- spoiler left hand

No work order to rectify these was found. The recordings from the flight involved in the accident showed the same complaints, apart from the spoiler left hand.

The log sheets for calibration work on the aircraft were missing. It was therefore not possible to trace whether adjustments were made or not.

1.17.1.11.3 APU trouble shooting

On examining the technical documents it was established that the APU was subject to an above-average incidence of faults. In the case of the flight involved in the accident, this complaint was recorded in the DDL with the statement that the APU starts only on the second attempt. Most faults related to “auto shut down” during operation and starting problems. Swapping out components was successful only in the short term. In the meantime, the entire APU was also replaced three times without success. In total, more than 100 complaints were made about the APU in the lifetime of the aircraft.

A reliability list for individual components did indeed exist, but reliability information for the entire unit was not present.

The airline’s maintenance documentation showed that the problem existed on all AVRO RJ 85/100 aircraft equipped with this APU.

On the flight involved in the accident, during the descent, a second attempt to start the APU was also necessary.

1.17.2 The supervisory authority

1.17.2.1 General

As in most states, the laws and regulations governing aviation in Switzerland are also based on the recommendations of the International Civil Aviation Organisation (ICAO). The requirements and rules of the Joint Aviation Authorities (JAA) additionally apply to commercial airlines and are anchored in the Swiss legislation.

According to the Aviation Law (Luftfahrtgesetz), the Federal Council exercises supervision over aviation throughout the territory of the Swiss Confederation. Direct supervision of civil aviation is exercised by the Federal Office for Civil Aviation (FOCA), which is an agency of the Federal Department of Environment, Transport, Energy and Communications (DETEC).

1.17.2.2 Structure

At the time of the accident, the Federal Office for Civil Aviation (FOCA) had a staff of approximately 150. At the beginning of 2001 a reorganisation project was put into effect which resulted in a process-based structure for the agency. Thus the units of the FOCA were subdivided into three divisions: the first division consisted of operational activities and was manned by seven process teams. The second division consisted of the centres of competency, which were to a certain extent determined by the processes. This unit's employees were basically involved in those processes where they brought to bear the specialist knowledge of their centre of competency to produce the respective product. The third division consisted of the management of the agency which performed cross-sectional functions and ensured the operation of the organisation.

In connection with the accident, the following processes are significant:

- Infrastructure Planning (IP) Process – By means of the aviation infrastructure plan (Sachplan Infrastruktur der Luftfahrt – (SIL) the IP Process handled the central planning framework for developing civil aviation in Switzerland. Concepts and foundations for planning also included the radio navigation plan and the radio frequency plans, as well as the commercialisation of the airspace structure. IP was also responsible for flight safety regulations and hence also for supervision of the Swiss air traffic control company skyguide, for fixing aviation charges and for safety-related aviation information.
- Flight Training and Licences Process (Flugausbildung und Lizenzen - FA) – the FA Process defined the standards for the license relevant area of pilots' training and further training and handled selection, training and designation of experts. It also handled certification of training equipment and systems (simulators).
- Air Transport Operations Process (Luftverkehrsbetriebe – LV) – The LV Process was responsible for licensing and professional supervision of aviation companies. This also included operational monitoring of flight material and the "SAFA ramp checks", involving random sampling on Swiss airports of foreign aircraft and crews. A corresponding organisation for Swiss aircraft was planned at the time of the accident but had not yet been introduced.

As the supervisory authority, the FOCA is responsible, among other things, for formal approval of all approach and departure procedures. The Federal Office was represented in the committees evaluating alternative approach and departure procedures, in order to meet Germany's demands for a reduction in the use of airspace over southern Germany.

1.17.2.3 Safety audit by the ICAO

From 1 to 8 November 2000 the International Civil Aviation Organisation (ICAO), as part of its Universal Safety Oversight Audit Programme, carried out a safety audit of the FOCA. The corresponding final report which was published by the ICAO in October 2001, states the following, among other things, with reference to operational supervision:

"With the crucial shortage of technical expertise necessary to conduct the core functions of certification of operators, surveillance activities are very limited. FOCA relies mainly on operators and other entities to ensure oversight of aviation activities. However, no system for the control and supervision of these tasks and functions pertaining to the State's safety oversight responsibilities has been established. The Flight Operations Section has established a programme for supervisory and technical control of persons within an operator's organization performing oversight/check airmen duties, but this oversight is not yet conducted due to the lack of operations inspectors capable of undertaking the task."

"FOCA has not established an audit schedule of Swiss air operators. Subsequent to the issue of an AOC, only a few operations inspections on some commercial air transport operators are conducted. The frequency of these inspections is low due to the limited human resources available to the Flight Operations Section and does not allow for the completion of a surveillance programme of Swiss air operators. Flight operations is an area where FOCA relies mainly on tasks performed by operators and on operators' check airmen, and no system for the control of these tasks and functions pertaining to the State's safety responsibility is established. Without a substantial increase in the number of adequately trained inspectors, the industry may become essentially self-regulating."

On 8 December, the FOCA informed its superior authority, the General Secretariat (GS) of the Federal Department of Environment, Transport, Energy and Communications of the personnel shortage in the technical area ascertained by the ICAO. GS DETEC allowed the FOCA to take on personnel indefinitely, even though at the time there was a block on recruitment in the federal administration.

The number of FOCA inspectors for aviation company operational affairs developed from 6 on 31 December 2000 as follows:

- 31 December 2001: 8 inspectors
- 31 December 2002: 11 inspectors

1.17.2.4 Regulations on duty time

When this report was drawn up, JAR-OPS 1 had not yet defined any flight and duty time limitations and rest requirements in subpart Q. With reference to crew time, therefore, at the time of the accident the provisions of paragraph 4.7 of the Decree on Operating Rules in Commercial Air Transport (Verordnung über die Betriebsregeln im gewerbsmässigen Luftverkehr - VBR I) were in force. In the operations manual part A (OM A), section 7, these statutory conditions were described, amended where necessary in individual cases and finally approved by the FOCA.

The following provisions of VBR I are significant for the flight involved in the accident:

- 4.7.1.3: "Crew time accumulated with other aviation companies must be included in the calculation."
- 4.7.1.4: "Both the operator and crew member are responsible for compliance with crew times".
- 4.7.3.7: "The duration of primary or secondary activity in the last 10 days before a flight is deemed to be flying duty time".
- 4.7.3.1.1: "Subject to paragraphs 4.7.1.2, 4.7.3.1.2 and 4.7.3.2-4.7.3.10 the flying duty times of flight crew members are limited as followed:" for a minimum flight crew according to AFM of 2 pilots and a maximum of 4 landings, the maximum flying duty time is 14 hours.
- 4.7.4.1: "Between two flight duty times, each crew member must have rest time which must immediately precede the flying duty time. The rest period is calculated according to the longer of the two flying duty times and, subject to paragraphs 4.7.1.2 and 4.7.3.4 shall be at least:" 12 hours for a flying duty time of more than 14 hours.

1.17.2.5 Relationship of Crossair to the supervisory authority

Relations between the FOCA and Crossair were multi-layered. As far as the accident is concerned, the following points are significant:

- The FOCA checked whether the Crossair training guidelines on crew resource management (CRM) complied with JAR. The effectiveness and implementation of the training in flight operations was not monitored by the FOCA.
- Audits of Crossair flight operations had not been conducted at the time of the accident. An initial flight operations audit took place on 28 August 2002, after Crossair's name had been changed to Swiss International Air Lines Ltd.
- According to their own statements, employees of Process LV are aware of the papers used as a basis for Crossair flight operations, but are not aware of the actual practice.
- Several FOCA employees worked on a parttime basis as pilots with Crossair.
- According to statements from FOCA personnel, nothing in principle had changed in the Aviation Operations (LV) Process between the accident to Crossair flight number CRX 498 on 10 January 2000 and the accident to Crossair flight number CRX 3597 on 24 November 2001.
- Coordination meetings took place two to three times a year in which from the Crossair side, senior employees from flight operations, maintenance, quality management and flight safety took part. The FOCA was in each case represented by responsible personnel from the departments in charge of flight operations, air transport operations, maintenance and airworthiness. As the minutes of these meetings from 1996 to 2001 prove, the performance of crew members or pilots' qualifications were never a topic of discussion.
- There is no indication that the activity of the experts employed by Crossair who had been carrying out type ratings and performance checks such as line and route checks on behalf of the FOCA had been checked by the FOCA.
- The difficulties and failures which occurred in the conversion course to the type MD 80 were not known to the FOCA.

1.17.3 Horizon Swiss Flight Academy flying school

The Horizon Swiss Flight Academy flying school was founded in 1979 and had a permit as a flight training organization (FTO) in accordance with JAR-FCL requirements. It offered training to acquire private pilots' licences (PPL), commercial pilots licences (CPL) and air transport pilots (ATPL) licences. The company operated at the time of the accident type Katana DV 20, Piper Archer and Piper Seneca aircraft.

At the time of the accident the commander of the accident aircraft had an older version of a working contract which did not regulate the coordination between his flight instructor activities with Horizon Swiss Flight Academy and the flight activities within other companies. According to the flying school all their instructors had been made aware of their responsibility to respect their flight duty times.

1.17.4 Air traffic control

1.17.4.1 General

Since 1 January 2001 the military and civil air traffic services have been combined into a single body, which handles all Swiss airspace. In order to give expression to this merger, which is unique in Europe, the Swisscontrol company changed its name and became skyguide. Since 1996 the company has been organised as a company limited by shares in private law and has been financially independent of the Confederation.

Commercial exploitation of Swiss airspace and foreign airspace delegated to Switzerland includes, in particular, the organisation and implementation of air traffic control.

1.17.4.2 Approach control

Skyguide provides this service for approaches and departures in the approach control unit. Depending on the volume of traffic, approaching aircraft are guided in up to three different sectors (Approach Sector East, Approach Sector West and Final Sector) and departing aircraft are guided in a single sector (Departure Sector). In addition, a coordinator is available to support the above-mentioned sectors.

According to the skyguide sector occupancy plan, 4 working positions should have been occupied in the approach control unit at the time of the accident (21:07 UTC). In fact, one working position was occupied.

1.17.4.3 Aerodrome control

Aircraft which take off or land or which have to cross runways are controlled by skyguide, from aerodrome control, which is located in the control tower. For this purpose, skyguide, depending on the volume of traffic, operates the four control positions ADC 1, ADC 2, GRO and clearance delivery (CLD) at up to four different workstations. A duty manager is responsible for monitoring the operation of the service in the control tower and in approach control.

According to the skyguide sector occupancy plan, at the time of the accident 4 working positions should have been occupied in the control tower. In fact, 2 working positions were occupied. According to the sector occupancy plan, the supervisor was required until 22:00 UTC.

1.17.5 Airport Zurich AG (Unique)

1.17.5.1 General

Airport Zurich AG (Unique) is a licensee of the Confederation and operates Zurich airport. Within this function it performs the following tasks related to flight operations: apron control, apron service, duty office, safety zone protection and cantonal reporting point for limiting obstacles, security, fire-fighting and safety, plus maintenance services including winter services, environmental protection and flight noise management.

With regard to skyguide, the duty officer is the Unique contact concerning deviations from the runway utilisation concept.

1.17.5.2 Apron control

Airport Zurich AG (Unique) is responsible for control of aircraft and vehicles on the ground in the apron area, on the taxiways to the south of runway 28 and to the east of runway 16, on certain sections of taxiways to the north of runway 28 in the area of the new dock midfield and in the area of the "Romeo" and "Romeo 8" taxiways, as well the "Whiskey" parking positions.

1.17.5.3 Role of Unique in implementing the state agreement between Switzerland and Germany

With regard to the attempted conclusion of a state agreement between Switzerland and Germany to regulate the use of south German airspace for approaches to and departures from Zurich-Kloten airport, at the beginning of 2001 two commissions – a working group and a control group – were set up under the leadership of Flughafen

Zurich AG (Unique). In the subsequent few months, these two bodies looked at the consequences on flight operations.

Both bodies were chaired by Unique employees. Furthermore, the managements of Swissair, skyguide and the FOCA, in some cases with additional consultants, were represented on both bodies.

An important part of the forward drawn measures of the already mentioned state agreement which was finally concluded was the condition that immediately after this agreement had been concluded, approaches from 22:00 LT to 06:00 LT had to take place on runway 28. This under the assumption that the actual meteorological conditions would allow an approach in accordance with the minima laid down in the AIP Switzerland. These forward drawn measures entered into force on 19 October 2001.

On the occasion of the above-mentioned meetings to draw up the runway utilisation concept, in particular concerning approaches on runway 28, the appropriateness or quality of the standard VOR/DME approach 28 which was envisaged for application was not a topic. The only documented statements concerned the fact that it was a non-precision approach, which might be critical for larger aircraft types. In particular, the question of a possible increase in the approach minimums was not discussed.

1.17.5.4 Influence of Unique on traffic handling

According to the Aviation Law, the aerodrome owner has to submit operating arrangements to the FOCA for approval. The amendment to these regulations applied for by Unique with reference to the state agreement to be completed with Germany was approved on 18 October 2001 by the Federal Council concerning the above-mentioned approaches to runway 28.

Thus it was in principle up to the Unique airport authority to monitor compliance with the runway utilisation concept (*Pistenbenützungskonzept* - PBK). On the other hand, skyguide, as the company responsible for air traffic services, was responsible for implementing the PBK. Skyguide was obliged to obtain approval from the Unique airport authority (duty officer) in the event of any desired deviation from the PBK.

This structure led to a situation in which skyguide’s actual possibilities of specifying take-off and landing runways according to purely operational criteria were made more difficult.

Until the entry into force of the state agreement on 19 October 2001, the standard VOR/DME approach 28 was put into operation by air traffic control only sporadically, in situations with a pronounced westerly wind.

1.17.6 MeteoSwiss

1.17.6.1 General

MeteoSwiss is a federal office which reports directly to the head of the Federal Department of the Interior (EDI). According to the law on climatology and meteorology dated 18.6.1999, various key tasks are entrusted to MeteoSwiss. Among other things, MeteoSwiss is obliged to provide meteorological information for flight operations and flight safety on Swiss territory.

According to the Federal Council decree on the air traffic control service (VFSD), MeteoSchweiz provides the civil aviation weather service and is the meteorological authority as defined by the ICAO, Annex 3. The Federal Department of Environment, Transport, Energy and Communications looks after the details in agreement with the EDI.

The more precise delineation of MeteoSwiss' tasks regarding aviation is contained in the DETEC decree on the civil aviation weather service.

Supervision is provided by the FOCA.

1.17.6.2 Aviation weather process

Since the reorganisation of 1998 MeteoSwiss has process-based structures. Various centres of competency and coordinating bodies are superimposed on the three divisions: Weather, Climate and Support. The Aviation Weather Process is located within the Weather Process.

The Aviation Weather Process provides the aviation weather service for the entire territory of Switzerland in accordance with the standards and recommendations of the WMO (World Meteorological Organization) and the ICAO.

1.17.6.3 Aviation weather service at Zurich airport

The weather service tasks on Zurich airport are provided by an advisory and observation service. The advisory centre in the operations centre is manned from 04:45 LT to 22:15 LT; the observation station is manned over 24 hours.

The key tasks of the advisory service are:

- provision of meteorological documentation for flight planning
- personal consultations
- issue of forecasts for aviation for the whole of Switzerland (GAMET)
- issue of warnings for the whole of Switzerland (SIGMET, AIRMET)
- issue of local warnings for the airports (storms, lightning, inversions, windshear)

It is the observation centre's task to permanently monitor weather at Zurich airport. Weather reports are routinely issued every 30 minutes in METAR and QAM code. If there are any significant changes between two observation times, a special internal airport report is drafted and forwarded.

The observation station is located in the northern part of the airport in the area of the thresholds of runways RWY 14 and RWY 16. Recording of the weather parameters is carried out by visual observation and measuring instruments which are installed on the airport and in close proximity to it. In addition to conventional measuring instruments (thermometer, hygrometer, barometer and anemometer), the following measuring instruments are also available:

- transmissometers for determining runway visibility (three instruments respectively along the main landing runways 14 and 16, two instruments along runway 28)
- ceilometer for determining the cloud base (one instrument respectively in the areas of runways 14 and 16, middle marker 16, outer marker 16 and near Bassersdorf, approximately 1 km to the south of the axis of runway 28)
- lightning detection system
- inversion measurement chain AMETIS1 to detect inversions and associated slowly evolving windshear (sensors on adjacent hilltops)
- cloud projectors and TV cameras.

1.18 Additional information

1.18.1 Training equipment

Crossair did not own its own flight simulator for the AVRO 146-RJ100. Training was carried out on third-party RJ 100 simulators. The following simulators were used by Crossair for pilot training:

- RJ 100 simulator in Berlin, certificated according to JAR-STD 1A Level DG, could be equipped with the GNS-X navigation management system if necessary.
- RJ 100 simulator in Istanbul, certificated according to JAR-STD 1A Level D (DGCA) and Level C (FOCA). The GNS-X was permanently installed.
- RJ 85/100 simulator in Brussels, certificated according to JAR-STD 1A Level DG. This simulator had a GNS-X.
- RJ 100 simulator belonging to BAe in Woodford. This simulator was sold in the USA.

Computer based training (CBT), which dealt with the functions of the aircraft systems and performance was available at Crosscat.

Furthermore, Crossair owned a CBT without interactive functions for the FMS GLNU 910, which was installed in the AVRO RJ 100 Mk II.

In the 16 RJ 85/100 (HB-IX*) aircraft, the GNS-X navigation system was used; in the four RJ 100 Mk II (HB-IY*) aircraft, the more modern Collins GNLU 910 system was installed.

The commander and the copilot of HB-IXM were trained mainly on the simulator at the Turkish Airlines flight training centre in Istanbul. This training equipment was fitted with the GNS-X which corresponded to the configuration of the aircraft involved in the accident.

1.18.2 Entry of flight obstacles in approach charts

No flight obstacles were entered in the approach sector for runway 28 in the approach chart 13-2 dated 10 November 2000 in the Jeppesen route manual, which the flight crew were using.

In the approach chart LSZH AD 2.24.10.7-1 of the Swiss AIP, which describes standard VOR/DME approach 28, two illuminated obstacles are marked in the approach sector using the customary symbols (cf. appendices 7 and 8).

1.18.3 Relevant safety recommendations from earlier investigations

1.18.3.1 Introduction

The following safety recommendations from earlier investigations by the Aircraft Accident Investigation Bureau address problem areas which occurred in comparable form in the present accident involving Crossair flight number CRX 3597.

1.18.3.2 Accident to Alitalia flight AZA 404 at Stadlerberg, Zurich

On 14 November 1990 an Alitalia McDonnell Douglas DC 9 crashed on its approach to runway 14 at Zurich airport. Forty-six people lost their lives in this accident. During the approach, due to a technical defect in the navigation system, the aircraft prematurely left the assigned altitude of 4000 ft QNH and about three minutes later collided with the Stadlerberg mountain.

In the final report, the Aircraft Accident Investigation Bureau expressed the following safety recommendations, among others:

Safety recommendation Nr. 9

"The duties of the Approach Traffic Control should be expanded to include the task of warning in the event of an altitude undershoot of the Minimum Safe Altitudes. In this respect, a warning system similar to that used in the USA (minimum safe warning system) which gives an automatic aural and acoustic warning when an aircraft undershoots an altitude should be added to ATC equipment."

Safety recommendation Nr. 13

"The installation of an area microphone recording system for the Air Traffic Controller stations (similar to the aircraft CVR area mike) should be evaluated."

1.18.3.3 Accident to Crossair flight CRX 498 near Nassenwil, Zurich

On 10 January 2000 a Crossair Saab 340B took off on a scheduled flight to Dresden. Two minutes and 17 seconds later, after losing attitude control, the aircraft crashed onto a field near Nassenwil/ZH.

The accident involved two crew members who before working in Switzerland had flown for foreign operators. With regard to the validation of licences from countries with unknown training structures, the Aircraft Accident Investigation Bureau recommended:

"The JAR-FCL proficiency check must in all cases be carried out by an inspector from the supervisory authority. In the process, the above-mentioned key points must be checked. This check must in no case be delegated to an operator, but it may be part of the operator proficiency check."

The accident showed that the crew members had not complemented each other ideally. The AAIB therefore recommended:

"Deficits in the linguistic and operational areas must be remedied by appropriate and individual training. Careful crew pairing must ensure that any existing deficits in a crew do not accumulate.

During the proficiency training courses, candidates' individual difficulties must be addressed using appropriate methods (e.g. unusual attitude training, communication training). During the proficiency check, the result of this individual training must be checked."

1.19 Useful or effective investigation techniques

1.19.1 Analysis of non-volatile memories

1.19.1.1 Introduction

Honeywell is a substantial supplier of avionics systems for the Avro 146 RJ 85/100. A query to this company indicated that the EFIS symbol generator, the digital air data computer (DADC) and the digital flight guidance computer (DFGC) contain non-volatile memories. In order to obtain additional information, an attempt was made to read the following circuit card assemblies (CCA) in the presence of an AAIB representative.

1.19.1.2 Digital air data computer

Circuit card assembly A7 comprises the CPU and the non-volatile memory in which failure messages are stored.

The read-out showed that neither during the flight involved in the accident nor during any of the nine preceding flights had a failure been stored in the DADC.

1.19.1.3 EFIS symbol generator unit

Circuit card assembly A2 contains the symbol generator CPU and the non-volatile memory in which failure messages are stored.

Several failures were recorded which had apparently been stored in the non-volatile memory as the accident unfolded. The following statement was made by Honeywell concerning the period before the accident:

“Thus, no Symbol Generator faults were recorded during the flight indicating a failure that would contribute to displaying incorrect flight information to the crew at the time of the crash”.

1.19.1.4 Digital flight guidance computer

Circuit card assemblies A3 and A18 each comprise a CPU and a non-volatile memory in which failure messages are stored.

According to the DFDR recordings, digital flight guidance computer (DFGC) number 2 was active during the flight involved in the accident. It was possible to confirm this fact using the recovered memory data.

No failure was recorded during the accident flight between the take-off in Berlin and the initial contact with the trees.

After the contact with the trees, events were recorded which were due to the aircraft’s deceleration and later by the power failure which occurred. The DFGC were backed up by the onboard battery. It was therefore possible that events which concerned the power failure were recorded in the DFGC.

2 Analysis

2.1 Technical aspects

2.1.1 Flight guidance system

2.1.1.1 Electronic flight instrument system

2.1.1.1.1 Reliability

An examination of the maintenance documents revealed nothing unusual concerning the operating behaviour of the electronic flight instrument system (EFIS).

2.1.1.1.2 Availability during the flight involved in the accident

On the basis of the CVR recordings, it can be assumed that both pilots originally had the CRS selector on the EFIS control panel in the 'LNAV' position. The copilot's CRS selector was still in this position when the wreckage was recovered. The commander's was in the OFF position. The commander probably switched his CRS selector to the OFF position after the aircraft was aligned on the 275° KLO VOR inbound course, in order to reduce the amount of data on his navigation display (declutter).

After recovery, the EFIS switch on the commander's instrument panel was in the 'NORM' position; the protective cap was intact. This is an indication that both EFIS symbol generator units had functioned.

From the CVR recordings there were no verbal indications of any problems with the electronic flight instrument system.

The non-volatile memories of both EFIS symbol generator units were analysed by the equipment manufacturer. The conclusion was reached that no faults were recorded which might have led to the display of incorrect flight information in the critical phase of the flight involved in the accident.

2.1.1.2 Auto flight system

2.1.1.2.1 Reliability

A check of the maintenance documents revealed nothing unusual concerning the operational behaviour of the auto flight system (AFS).

2.1.1.2.2 Availability during the flight involved in the accident

During the last 30 minutes of the flight the auto flight system was used without interruption to guide the aircraft.

For lateral guidance, the autopilot worked alternately in LNAV1 mode, HDG SEL mode and VORNAV1 mode. In the final phase of the flight, VORNAV1 mode was active. The last selected VOR course was 275°. Analysis of the DFDR data showed that autopilot control was functioning normally in the cited operating modes.

For vertical guidance, the autopilot worked alternately in vertical speed mode and altitude hold mode. In the final phase of the flight, the vertical speed mode was active. The last selected rate of descent was 1200 ft/min. Analysis of the DFDR data showed that autopilot control was functioning normally in the cited operating modes.

Above FL 235 the autothrottle system was in Mach mode; below this it was always in IAS mode. The last selected speed was 116 KIAS. Analysis of the DFDR data showed that control by the autothrottle system was functioning normally in the cited operating modes.

At 21:06:34 UTC the commander announced his intention of initiating a go around. At the same time the autopilot was switched off and the corresponding acoustic warning signal (cavalry charge) could be heard on the CVR. Contact with the trees occurred two seconds later.

Until the end of the DFDR recordings, the autothrottle system remained on and in IAS mode. This is an indication that the TOGA pushbutton on the power levers was not operated.

Examination of the thrust rating panel (TRP) indicated that it is highly probable that at least one bulb in the MCT pushbutton was lit on impact. This is a further indication that the TOGA pushbutton on the power levers was not operated.

Analysis of the non-volatile memories of the two digital flight guidance computers showed that no faults were recorded during the flight up to the first contact with the trees. After contact with the trees, events were recorded which were caused by the deceleration of the aircraft and subsequently by the power failure which began to occur.

2.1.1.3 Navigation management system

2.1.1.3.1 Reliability

Examination of the maintenance documents revealed nothing unusual concerning the operating behaviour of the navigation management system (NMS).

2.1.1.3.2 Availability during the flight involved in the accident

During the last 30 minutes of the flight the navigation management system (NMS) was used twice to guide the aircraft with the autopilot (FDR: LNAV1 mode). The first time it was used on a track of approximately 220° towards RILAX, and the second time after ZUE VOR.

At 20:59:25 UTC the commander stated: “LNAV isch dine, das düemer dän schnell mit em LNAV flüüge, detä...”. LNAV is programmed, then we fly briefly with the LNAV there... It is probable that at this time he had entered the route ZUE, D178F, KLO*, KLO**, RW28. KLO* and KLO** are waypoints generated by the pilot.

At 21:00:06 UTC the commander reported: “LNAV isch engaged, da simer praktisch druffe”. LNAV is engaged, we’re practically on it. At this time, the aircraft was on the VOR inbound course 125° ZUE. It is probable in this situation that the commander also was activating the direct to ZUE function just prior to the engagement of the LNAV mode.

The approach was continued in LNAV mode until 21:04:15 UTC, the time at which the autopilot turned the aircraft onto inbound course 275° KLO (VOR capture).

Analysis of the DFDR data showed that autopilot control in LNAV1 mode was progressing normally. Shortly before the accident the autopilot was working in VORNAV1 mode.

When the wreckage was recovered, the CRS selector on the commander’s EFIS control panel was in the ‘OFF’ position. It is probable that the commander had selected VOR 2 or 1 as a 2nd course. This allowed him to monitor autopilot control of the aircraft along the VOR course.

On recovery, the LNAV switch was found to be in the LNAV 1 position. There are no indications that this position was selected as the result of a technical failure. It is more probable that the commander had switched to LNAV 1 out of habit, because he was pilot flying.

2.1.2 Aircraft control

The DFDR recordings of the primary flight controls, aileron, elevator and rudder could not be analysed. The DFDR data on the secondary flight controls could, however, be analysed satisfactorily and from an operational point of view these were within the normal limits.

The flight-path related data (such as: altitude, airspeed, heading, latitude, longitude, ground speed, wind, roll and pitch) were recorded correctly until the first contact with the trees and could be analysed. The progression of the flight path permits the conclusion that the primary flight controls were functioning correctly.

2.1.3 Navigation equipment

2.1.3.1 Inertial reference system

2.1.3.1.1 Reliability

Analysis of the maintenance documents revealed nothing unusual concerning the inertial reference system (IRS).

2.1.3.1.2 Availability during the flight involved in the accident

Until a few seconds before the first contact with the trees, the aircraft was being flown using the autopilot. The control behaviour indicates that the data provided by the IRS was being processed correctly by the autopilot.

From the CVR recordings, there were no indications of any problems of any kind with the flight parameters generated by the IRS and displayed by the EFIS.

2.1.3.2 VHF navigation system

2.1.3.2.1 Reliability

Analysis of the maintenance documents revealed nothing unusual concerning the operating behaviour of the VOR system.

2.1.3.2.2 Availability during the flight involved in the accident

During the last 30 minutes of the flight involved in the accident, the VOR system was used twice to control the aircraft using the autopilot (FDR: VORNAV1 mode). The first time on an inbound course of 125° to VOR/DME ZUE, and the second time on an inbound course of 275° to VOR/DME KLO. Both the FDR recording and the radar plot indicated typical control behaviour by the autopilot in VOR mode, with relatively large deviation from the VOR course after the VOR capture.

After the accident the VOR/ADF switch on both distance bearing indicators (DBI) was in the ADF position. The indications of the VOR bearing on these instruments were therefore not available.

On the CVR there were several indications that the VOR was switched on on the EFIS navigation display (presumably as 2nd course on both sides). Neither the commander nor the copilot mentioned any problems whatsoever with the VOR system.

2.1.3.3 Distance measuring equipment

2.1.3.3.1 Reliability

Analysis of the maintenance documents revealed nothing unusual concerning the operating behaviour of the distance measuring equipment (DME).

2.1.3.3.2 Availability during the flight involved in the accident

During the approach, there were two indications from the pilots which imply that the two DME systems were functioning correctly:

At 21:04:23 UTC the copilot reported: “Jetz simer acht Meile” (D8KLO). We’re now at eight miles. At this time, both VOR/DME systems were on the frequency of KLO VOR/DME (114.85).

A comparison with the radar plot at this time revealed that the two distances matched. If one assumes that the copilot had the course selector (CRS) on his EFIS control panel set in the LNAV position (the result of the investigation of the wreckage), he must have read off the DME distance on his distance bearing indicator (DBI). Since the two distance indications for DME 1 and DME 2 are right next to each other, he would surely have noticed any difference.

At 21:05:27 UTC the commander mentioned: “Sechs Meile drüü drüü isch checked” Six miles three three (3300)... is checked (D6KLO /3360 ft). A comparison with the radar plot revealed that CRX3597 passed point D6KLO at 21:05:21 UTC at an altitude of 3240 ft QNH. The reason for the slight delay in the commander’s statement is probably attributable to the fact that at 21:05:21 UTC the copilot was beginning to talk with ATC, which was subsequently acknowledged.

There were no indications on the CVR that the DME system would have given rise to complaints in the subsequent progress of the flight.

2.1.3.4 Air data system

2.1.3.4.1 Reliability

Analysis of the maintenance documents revealed nothing unusual concerning the operating behaviour of the air data system.

2.1.3.4.2 Availability during the flight involved in the accident

The read-out from the non-volatile memory showed that neither during the flight nor during the nine preceding flights had any failure been stored in digital air data computer DADC 1. DADC 2 was destroyed by the impact and by the fire and could not be analysed.

The FDR recordings indicated plausible altitude and speed values throughout the approach.

The ATC Transponder (mode C) was transmitting the correct altitude until the last radar scan.

The multiple references to indicated altitudes by both pilots recorded on the CVR were compared with the data recorded in the DFDR. They matched.

It can therefore be assumed that correct air data parameters were available to the pilots during the approach.

2.1.3.5 Radio altimeter

2.1.3.5.1 Reliability

Analysis of the maintenance documents revealed nothing unusual concerning the operating behaviour of the radio altimeter system.

2.1.3.5.2 Availability during the flight involved in the accident

There was no indication on the CVR recording of a failure of the radio altimeter display during the flight.

The radar altitude of both radio altimeter transceivers was recorded by the FDR. The recorded values appeared plausible, taking the topography into account.

The two acoustic warnings 'five hundred' and 'minimums' responded normally, proving that radio altimeter system 1 was functioning up to the accident. The 'minimums' warning responded 300 ft above ground. This decision height was set beforehand as standard by the crew. Comparison with the barometric height, taking the topography into account, indicated a match.

2.1.3.6 ATC transponder system

2.1.3.6.1 Reliability

Analysis of the maintenance documents revealed nothing unusual concerning the operating behaviour of the air traffic control (ATC) transponder system.

2.1.3.6.2 Availability during the flight involved in the accident

The radar plot indicates plausible data throughout the approach. The pressure altitude recorded by the FDR matches that on the radar plot.

The radar on the Holberg recorded the last response (radar return) from flight CRX 3597 at 21:06:32 UTC. The radar return due at 21:06:36 UTC was not detected.

2.1.4 Maintenance

Analysis of the maintenance records dating back to the C2 check in May 2000 provided the following results:

- There are no indications that the periodic checks prescribed by the aircraft manufacturer and the authorities were not carried out within the specified intervals.
- The components subject to lifetime control were within the specified operating times at the time of the accident.
- In comparison with the Avro 146 RJ 85/100 fleet as a whole, HB-IXM exhibited an average occurrence of faults.
- The high incidence of faults on the auxiliary power unit (APU) had been known on the entire Avro 146 RJ 85/100 fleet since the introduction of the aircraft type.
- The prescribed calibration of the standby altimeter and the two air data computers was not carried out in accordance with FOCA regulations.
- Various parameters of the flight control position on the DFDR could not be analysed. This problem had already been noted during a parameter check on 27 March 2001 and had not been rectified.

2.1.5 Airworthiness

There is no indication that aircraft HB-IXM was not in an airworthy condition at the time of the accident.

2.1.6 Possibilities of survival

The severity of the impact was attenuated by the topography, the direction of the flight path and the tree cover.

On contact with the trees, the radome was separated, the right side of the fuselage was torn open and presumably the wiring between the onboard batteries and the electrical distribution system was damaged. This may have been the reason for the sparks which were observed by the passenger travelling in seat 14 B.

On impact, the fire which had broken out shortly after the initial contact with the trees developed within seconds into a high-temperature conflagration. Because of this intense fire, the accident was survivable only by chance.

There is no indication that the surviving members of the cabin crew could have increased the chances of survival.

Deployment of the police and rescue forces was rapid and efficient.

2.2 Human, operational and organizational aspects

2.2.1 The “SHEL” model

The origin of aircraft accidents can often be explained by the complex interaction of human, technical, operational and environmental factors. In terms of the evaluation, therefore, a systematic approach has been chosen which not only describes the obvious errors but also analyses the basic situation and ascertains the fundamental causes of primary errors.

In order to make relationships clearer and clarify the flight crew’s behaviour and decision-making processes, the “SHEL” model recommended by the International Civil Aviation Organisation in “Human Factor Digest No. 7” has been applied. This tool is a model for considering the interaction of people with other people and technical equipment in a specific working environment. The four letters “S-H-E-L” are an abbreviation of the four components of the model:

S – software	Non-material part of the system which consists mainly of procedures, checklists, rules and regulations.
H – hardware	Technical systems such as the aircraft, equipment, etc.
E – environment	The environment includes all external factors such as the weather, other aircraft, air traffic control, operators and the supervisory authority.
L – liveware	The human being, with his variations and limits is aligned at the centre of the model. Several L elements may interact with each other (commander, copilot, etc.)

For the investigation of the present aircraft accident, the commander and copilot are taken as the central starting points for the liveware (L) element. The type of interaction of the two flight crew members constituted another important subject of investigation. Furthermore, the relationships between the flight crew and the aircraft (L-H) and the interface between flight crew and procedures (L-S) were considered. As a final point, the effect of the environment on the flight crew procedures was examined (L-E). This environment, in addition to the weather and air traffic control, also included the operator and the supervisory authority. The appended summary of the progress of the flight was used as a basis for the chronological sequences (cf. appendix 1).

2.2.2 Commander (L)

2.2.2.1 Previous history

The first indications of the limits to the commander's capabilities and of his difficulties in accepting these are to be found in his incomplete school education and the rejection of his candidature for pilot's pre-training, even after a third application for re-evaluation. These repeated attempts at re-evaluation indicate for the first time the commander's great determination to achieve his goals in aviation.

Even as early as 1979, when the commander started working for Crossair, his in excess of 4000 flying hours meant he was considered as experienced. Before that, he had already flown charter flights on smaller aircraft for several years and achieved a rating which qualified him to teach trainee pilots in visual and instrument flight. As can be seen from the documents, the commander's talent clearly lay in the area of visual flying. He completed the conversions to the corresponding aircraft types without any problems. On the other hand, he twice failed the test for obtaining instrument flight rating, before passing at the third attempt. The difficulties with instrument flying, which were noted by various experts from the Federal Office for Aviation on the occasion of periodic check flights, were still present when he himself trained pupils, flew regularly and thus maintained a good training status. He completed his first conversion to a transport aircraft shortly after joining Crossair. The course took place at an international training centre. The commander took the examination to acquire the type rating before an expert from the Federal Aviation Office and passed with a "below average" mark, despite his flying experience. Once again, basic weaknesses in instrument flying and an inadequate comprehension were noted.

A short time later, the Federal Aviation Office transferred the acceptance of performance checks such as line, simulator and route checks and of qualifications after conversions to experts employed by the operator. To date, this corresponds to current practice. Assessment of the commander's performance was now increasingly more favourable and in 1982 Crossair rated his flying performance as above average. Apart from individual cases, up to the beginning of 1996 few reliable facts were provided on the checklists and the commander's performance was mostly judged to be good (cf. appendix 9).

In the two conversion courses to the MD 80 aircraft type, difficulties were revealed which had been noted right at the start of his career. The commander received several additional lessons in the simulator, without making adequate progress. The assessment, which noted a lack of overall comprehension and basic problems in controlling the aircraft, was appropriate and corresponded to the commander's performance as previously noted. The investigation found that the conversion course to the MD 80 was highly demanding but was conducted fairly with regard to the participants.

During the time the commander flew on the Saab 340, some performance problems became obvious beside the mostly positive qualifications. The responsibles of the airline did either not recognize these problems or they did not react appropriately to them. The decision to requalify the commander again onto the Saab 340 without a deeper analysis of the reasons for failing the MD 80 transition course, must be seen under this aspect. Afterwards his performance on the Saab 340 was again generally assessed as good. With the decommissioning of the Saab 340, Crossair tried to find a new aircraft type to which the commander could be assigned, since he wished to continue flying. Without further clarification, the Avro RJ 85/100 was selected as the most suitable aircraft for him. Thus the commander was assigned to a conversion course for the aircraft type involved in the accident. Since the instructors and experts on this course were people who applied the same benchmarks and principles as in the Saab 340 fleet, the qualifications turned out to be similarily positive. The circumstance that, according to the available documentation, the commander apparently worked virtually without fault is in contradiction to earlier assessments by experts who did not originate from the operator.

A certain aversion to more complex technical systems runs like a thread through the commander's career. Inappropriate use of navigation aids was noted above all at the beginning of his flying career and manifested itself in the problems encountered using the digital flight guidance system on the MD 80. The commander's instrument setting which was found permits the conclusion that during the flight involved in the accident the navigation instruments were not used optimally either. It is considered, however, that this was not relevant to the accident.

2.2.2.2 Behaviour during the flight involved in the accident

The commander's behaviour was unanimously described as very quiet and self-controlled. Copilots saw him as an authority figure, above all because of his very great flying experience and because of his almost unshakeable calmness. This image is also reflected by the recordings of the cockpit voice recorder virtually throughout the flight involved in the accident. The commander appeared somewhat irritated only in two situations: at 20:48:39 UTC he spontaneously uttered a swear word when he learned that – contrary to his assumption – it would be necessary to make an approach to runway 28: "Ou, Sch*****, das äno, ja guet ok" - Oh, sh*****, that as well, fine, ok. This may be an indication that this short-term change in the approach did not please him. On the second occasion, at 21:06:25 UTC, approximately 10 seconds before the aircraft came into contact with the first obstacles, a developing displeasure may have been the reason for the spontaneous utterance: "Sch*****, zwei Meile hät er gseit, gseht er d'Pischte" - Sh*****, two miles he said, he sees the runway.

The flight was proceeding more or less normally until approximately 90 seconds before the aircraft collided with the wooded hillside. Certain decisions and actions which occurred before this did indeed influence the way the accident unfolded, but did not in themselves necessarily have to lead to a fatal outcome. These preparatory actions and decisions are discussed in greater detail below.

The first indication that the approach was not taking place on the specified glide path presented itself to the commander at 21:05:21 UTC, when the aircraft was at an oblique distance of 6 NM from VOR/DME Kloten. According to the approach profile, a minimum altitude of 3360 ft QNH was specified for this position. Actually, the altitude of HB-IXM at this time was only 3240 ft QNH. As the CVR recordings prove, the commander did in fact check the altitude at a distance of 6 NM from VOR/DME Kloten, but did not notice the deviation of 120 ft, or assessed it as tolerable. At 20:05:27 UTC he stated: "Sächs Meile drü drü isch checked" - Six miles three three (3300)... is checked.

At this time the commander must still have been aware of the distance to the aerodrome. The rate of descent, however, was neither changed nor addressed.

Then the commander referred several times to the minimum height for the approach, even before it was reached. About 15 seconds before the aircraft had reached the minimum descent altitude (MDA) of 2390 ft QNH, the commander mentioned that he had ground contact: “Ground contact hämmer, hä” – we have ground contact. This shows that in this phase he was looking outside for at least some of the time. The following comment indicates that he had at least partly understood the weather report transmitted by Crossair flight number CRX 3891 at 21:04:34 UTC: “Mä hät gseit, Pischte hät er spaat gseeh da...” – It was said that he saw the runway late here. At this time, HB-IXM was at an oblique distance of approximately 4.8 NM from VOR/DME. The commander – unlike at 21:05:27 UTC – carried out no further checks on the distance. This was probably the beginning of an at least partial loss of awareness of the situation.

A short time later, at 21:06:10 UTC, the aircraft reached the MDA of 2390 ft QNH. At the same time the commander stated: “...zwo vier, s’Minimum...ground contact han ich...mer gönd wiiter im Moment...es chunnt füre...ground contact hämmer...mer gönd wiiter” - two four (2400), the minimum ... I have ground contact ... we’re continuing at the moment ... it appears we have ground contact ... we’re continuing on ... The commander was thus aware that he had reached the minimum height for the approach. No reference to the distance to VOR/DME Kloten was made. Although the defined visibility conditions for going below MDA were not present, the commander decided to descend further. The following reasons, among others, may have been critical for this decision:

- The ground was occasionally visible.
- The commander, according to his statement, was expecting that the runway would soon become visible.
- As a result of his long association with the Saab 340, the commander was provably used in Lugano to descend below the minimum descent height, even when he had sight only of the ground and not of the runway. As the incident of December 1995 shows, the commander obviously believed he was capable of carrying out such a procedure even at night and under instrument conditions.

In view of the meteorological conditions, visual contact with the runway was highly improbable, since when it flew through the MDA the aircraft was still at an oblique distance of approximately 4.4 NM (8.1 km) from VOR/DME Kloten and 3.5 NM (6.5 km) from the runway threshold.

At 21:06:22 UTC a radar altitude of 500 ft RA was reached and the ground proximity warning system reported: “Five hundred”. This call-out may have caused the commander some displeasure, since he immediately responded: “Sch*****, Zwei Meile hät er gseit, gseht er d’Pischte” - Sh*****, two miles he said, he sees the runway. Once again the commander recalled the report from the aircraft which had landed immediately before him. The commander had correctly understood the distance of 2 NM to VOR/DME Kloten at which CRX 3891 had seen the runway. Since at this time HB-IXM was still at a distance of 3.1 NM to the threshold, visual contact with the runway was still not possible. But even in the following seconds the commander spoke only of the altitude which the aircraft was just flying through. At 21:06:31 UTC the commander read off the altimeter: “Zwöi Tuusig” – two thousand. Since he had always expressed his perceptions throughout the entire flight, it can be assumed that in this phase he was still observing the information provided by the altimeter. He was apparently no longer checking the DME distance. Hence his awareness of one essential parameter relating to monitoring the approach had been lost. It is highly probable that in this phase the commander was trying to re-establish visual contact with ground. Since he did not mention further visual references, it must be assumed that he no longer had any.

One second later, at 21:06:32 UTC, the GPWS called out “minimums”, as 300 ft RA had been reached. After another second, the commander asked hesitantly: “...go around mache?” - ...make a go around? If, instead of the question, a go around had been initiated at this time, it might just have been possible to avoid the collision with the trees, as shown by the tests in the simulator.

At 21:06:34 UTC the commander finally decided to initiate the go around, possibly because the obstacles were visible in the light from the landing lights.

2.2.2.3 Medical aspects

The investigation revealed no basis for a medical cause which might have been partially or wholly responsible for the accident. In particular, there were no indications of a sudden incapacity to fly on the part of the commander due to medical reasons (obvious sudden incapacitation).

On the two days preceding the accident, the commander had clearly exceeded the permitted maximum duty times and had slightly undercut the prescribed rest time in the night before the accident. It can thus be assumed that he would tend to be overtired on the day of the accident. The accident happened at the end of a day in which the commander had been awake for 15 hours. As a result of his freelance activity as an IFR instructor before his scheduled flying duty, at the time of the accident he had been on duty for more than thirteen and a half hours. A longer break from work, which might, for example, have allowed recuperation through sleep, was lacking. The bad weather may have further increased the strain throughout the day and led to greater fatigue.

Such tiredness adversely affects concentration and decision-making as well as the ability to analyse complex processes, and the frequency of mistakes increases. This corresponds to the observations during the flight involved in the accident:

- At 20:43:44 UTC, while the commander was carrying out the approach briefing for the runway 14 approach, the copilot made him aware of excessively high speed: “Mer chömed glaub mit de speed ächli in rote Bereich ine.” I believe that our speed is going somewhat into the red. The commander had obviously paid too little attention to this parameter during the approach briefing.
- During the second approach briefing, for runway 28, the commander described his plan shortly after 20:52 UTC as follows, among other things: “Wämer dä turn macht bi Ko...Komma Sächs Meile, Sächs Komma Föif Meile left turn and dänn dä Aaflug da gemäss Profil...” If you make the turn at poi... point six miles, six point five miles, left turn and then the approach according to the profile. He was describing a left turn. Actually, the approach to the extended centre line makes a right turn. The commander was describing what he saw on the approach chart – without picturing the flight path graphically: the extended centre line on a course of 275° goes to the left on an approach chart which has north at the top.
- The commander may possibly also have judged the deviation from the standard glide path at 6 NM oblique distance from /DME Kloten as not sufficiently great to necessitate a correction because he was overtired.

- The fact that the commander did not reduce the rate of descent appropriately as horizontal speed decreased, resulting in the glide path becoming increasingly steep, may also be attributable to overtiredness.

From the above points it must be concluded that his tiredness fulfils the criteria for an adverse effect on his flying capability (subtle incapacitation).

2.2.3 Copilot (L)

2.2.3.1 General

The copilot followed a direct training route to commercial pilot with instrument rating and possessed a frozen ATPL, since he had already attended a theory course for air transport pilots and had passed the corresponding examinations. His total flying experience was low, at only 500 hours. However, he had slightly greater flying experience than the commander on the aircraft type involved in the accident, since he had started his assignment to the Avro RJ 85/100 about two months earlier.

The copilot was unanimously described by witnesses as sensitive and friendly. During the Crossair pilot selection procedure, it was found that the copilot tended to subordinate himself. He was described as lively, but not aggressive, seeking harmony.

These characteristics are in themselves not an obstacle for a successful career as a pilot, if personality development is taken into account in flight operations and in training.

2.2.3.2 Medical aspects

The investigation revealed no basis for a medical cause which might have been partially or wholly responsible for the accident. In particular, there were no indications of a sudden incapacity to fly on the part of the copilot due to medical reasons (obvious or subtle sudden incapacitation).

2.2.4 Interaction between the commander and the copilot (L-L)

2.2.4.1 General

The commander had about forty times more total flying experience than the copilot and was substantially older than him. In this case, this led to a distinct gap in authority between the flight crew members. The fact that the copilot already had experience of the commander as a flying instructor during his instrument flight training at the flying school Horizon Swiss Flight Academy probably played only a secondary role in this connection, since a total of only two joint training flights had been made. However, the disparity in authority was widened further by the fact that from 20:37:25 UTC, for about two minutes, the commander lectured the copilot in detail about the interpretation of a runway report, thereby placing him in the position of a pupil. Since the copilot had just deciphered the runway report for Zurich-Kloten more or less completely and correctly, the explanation was actually not necessary. Even during the commander's explanations the copilot conveyed a rather uninterested impression.

2.2.4.2 Continuation of the flight below the minimum approach altitude

Upon reaching the minimum descend altitude the commander decided to continue the descent although he had no visual contact to the approach lights or to the runway. From the viewpoint of error analysis this was a mistake where procedures were deliberately not adhered to. Among other things, the copilot's duty was to monitor the commander's work and to detect and prevent errors, if possible at the first signs. As the accident shows, this did not happen in the present case for the following reasons:

- During the approach briefing for standard VOR/DME approach 28 between 20:51:56 UTC and 20:53:05 UTC a discussion on the information on the approach chart did in fact take place. However, an actual concept for configuring the approach was neither developed nor communicated. It was not determined in what respect one should deviate from the standard procedure, while configurating the aircraft, how deceleration was to take place and at what distance from the runway the instrument approach was to be terminated. The absence of such a plan of action made it more difficult for the copilot to be able to assess the actual events in good time.
- The decision to configure the aircraft for landing only after the final approach fix and to constantly change this configuration throughout the final approach made it more difficult for both crew members to monitor the aircraft's glide path and to predict its chronological development. This monitoring was non-existent or only partial, as evidenced by the fact that at 21:04:36 UTC the commander selected a rate of descent of about 1000 ft/min, which suited the current speed of the aircraft of 160 kt. Subsequently this rate of descent was not adapted to the decreasing horizontal speed. The result was that the glide path of HB-IXM became increasingly steep in comparison with the nominal glide path and the aircraft descended below this path (cf. appendix 10).
- For the copilot too, the first indication that the approach was not on the envisaged glide path presented itself at 21:05:21 UTC, when the aircraft was at an oblique distance of 6 NM from VOR/DME Kloten. The commander mentioned this point, but did not react to the deviation in altitude which had accrued. At this time the copilot was still busy with the last points of the check for approach and thus in an unfavourable initial position to monitor the commander. In the following seconds, the copilot was again busy with tasks and was making contact with Zurich apron control.
- A short time later, at 21:05:36 UTC, there began another sequence of activities which occupied both crew members and made monitoring of the glide path angle of the approach more difficult. Commander: "Flaps 33" – copilot: "Speed checked, flaps 33 selected", commander: "Final check" – copilot: "Final check, confirm three greens" – commander: "Is checked". Commander, with reference to the approach speed (V_{ref}+5 kt): "Hundert sächzäh (116)" – copilot: "Full flaps...set" – commander: "Checked" – copilot: "Cabin report received" – commander: "Received" – copilot: "Landing clearance to go" – commander: "Isch to go" – copilot: "Jawohl".
- When the activities described were completed, HB-IXM was at approximately 3.9 NM to the threshold and still about 200 ft above the MDA. The remaining 15 seconds till the minimum height for the approach was reached were probably insufficient for the copilot to be able to reconstruct a complete picture of the current situation.
- The recordings of the cockpit voice recorder prove that communication and cooperation between the commander and the copilot took place calmly and professionally. The pronounced calmness which the commander exhibited almost continuously had very probably created in the copilot the impression of an experienced superior who was acting prudently and consciously. This may have been one of the main reasons why the copilot did not intervene when at 21:06:10 UTC the commander continued the descent below the minimum altitude for the approach. The fact that he quietly said "Two, Four" when the aircraft flew through the minimum altitude shows that he too was aware of the current altitude of the aircraft. It must remain

open whether he made any connection between this altitude and the distance to the runway.

- During the subsequent 24 seconds which elapsed after flying through the MDA until the initiation of the go around, no speech or actions of the copilot are documented. On the basis of his training and his aptitudes it can be assumed that he was in a position to recognise the descent below the MDA without adequate visual references as an error. However, he made no attempt to prevent the continuation of the flight below the minimum descent altitude.

2.2.4.3 Crew resource management

The commander had only been confronted with training in crew resource management (CRM) in the last few years of his career. Among other things, such training and retraining aims to improve patterns of behaviour and attitudes of crew members in such a way that cooperation is optimised. Experience has shown that this process takes several years. The accident shows that efficient cooperation, which includes optimal use of the crew for mutual monitoring in particular, was present only to an insufficient degree. The copilot too had undergone corresponding training. The accident proves that the course contents had not been translated adequately into everyday practice.

In summary it must be stated that the inappropriate decisions and actions were able to develop into a fatal event only by the combination of the crew members (cf. Safety Recommendation 2002-1).

2.2.5 Interaction between the flight crew and the aircraft (L-H)

2.2.5.1 General

In terms of the consideration of the interaction between crew and aircraft (L-H), the man-machine element was in the foreground. In the process, consideration was given not only to the aircraft itself, but also to its equipment, in particular the approach procedure documentation used during the flight.

The initial prerequisite to be established is that the aircraft HB-IXM was airworthy up to the collision with the first obstacles. In particular, all flight management and navigation equipment was working perfectly. The starting difficulties with the APU during the approach, which led to a second starting attempt, had no effect on the development of the accident. The auxiliary power unit started at 21:00:04 UTC, before the descent for the final approach had begun.

By correctly setting the reference pressure on the altimeters at 20:58:13 UTC and by making a corresponding cross-comparison, the crew established the initial situation for being able to measure correctly a key parameter, altitude above sea level, for carrying out a non-precision approach.

2.2.5.2 Use of flight guidance and navigation equipment

At 20:59:25 UTC the commander mentioned: “LNAV isch dine, das tüemer den schnäll mit em LNAV flüüge detä... uf hundertachtesiebzig (178)” – LNAV is programmed, then we fly briefly with the LNAV there... towards 178. At this time it is highly probable that he had entered the following route: ZUE - D178F - KLO* - KLO** - RW28. The autopilot was working in VORNAV1 mode and an inbound course of 125° to VOR ZUE had been entered.

At 21:00:06 UTC the commander reported: “LNAV isch engaged, da simmer praktisch druffe... dän hämer hundert achtesibzig (178) dä Kurs” – LNAV is engaged, we’re practically on it ... then we have a hundred and seventy-eight as course. At this instant, the autopilot was switched to LNAV1 mode and very probably a DTO to ZUE was entered at the same time. At the same time also, the commander turned his VOR course selector to 178°.

At 21:00:17 UTC the commander selected the VOR/DME frequency of 114.85 MHz (KLO) in the preselect window on his VOR/ILS/DME control panel. At this time, ZUE was still actively selected. It is probable that the commander had selected LNAV as primary course (CRS) and VOR1 as 2nd course on his EFIS control panel. On his EFIS control panel, the copilot had probably selected LNAV as primary course (CRS) and VOR2 as 2nd course. Since the LNAV selector was in the LNAV1 position, “LNAV1” in yellow appeared on both navigation displays (ND).

At 21:01:14 UTC the commander mentioned the following: “Guet, das stimmt überii s’LNAV and de radial, den gan ich mit dem füre uf Chlote, mit em inbound track 275” – Good, that matches, LNAV and the radial, so I’ll go with this on to Kloten, on inbound track 275. On his side, the copilot had a few seconds previously selected a VOR course of 275°. In order to be able to compare the VOR radial with the LNAV track, the commander may have switched his 2nd course to VOR2. He now announced his intention of continuing to fly on as far as Kloten in LNAV mode. A short time later, the commander too had also switched the VOR course on his side to 275°.

At 21:02:32 UTC the aircraft reached waypoint D178F and began, still in LNAV mode, to turn right in the direction of the FAF. In the meantime both pilots had set their VHF NAV equipment to the VOR/DME KLO frequency and checked this.

At 21:03:38 UTC the copilot proposed to preselect the VOR as per the operator’s procedural specifications (PIH AVRO RJ85/100 procedure 15.1, standard GNS-X procedures). The commander was still convinced that it would be better to continue the approach in LNAV mode. However, he then adopted the copilot’s proposal and preselected VOR mode at 21:03:52.

At 21:04:15 UTC the aircraft reached the selected VOR course and captured it (VOR capture). Up to the time of the accident the autopilot remained in VOR mode.

During the step down descent the autopilot was operated alternately in ALT mode and in VertSpd mode. At 21:04:23 UTC, CRX3597 had reached waypoint D8KLO (KLO*) at an altitude of 4000 ft QNH and then began to descend at an initial rate of 1000 ft/min.

At 21:06:34 UTC the autopilot was switched off and a manual go around was initiated.

After the accident the following switch positions were found:

Location	**Control unit/display**	**Position**
instrument panel left	EFIS switch	NORM
		protective cap intact
	EFIS 1 MSTR (lever lock switch)	ON
display dimming panel	knob for weather radar	at the stop, counter-clockwise
instrument panel right	EFIS 2 MSTR (lever lock switch)	ON

EFIS control panel left	bearing selector (BRG)	VOR
	range selector (RNG)	10
	course selector (CRS)	OFF
	format	MAP
EFIS control panel right	bearing selector (BRG)	OFF
	range selector (RNG)	10
	course selector (CRS)	LNAV
	format	MAP

It must be assumed that the commander had set the CRS selector on his EFIS control panel to the OFF position during the final approach in order to declutter the navigation display (ND). In this situation he had very probably selected VOR 2 as 2nd course. Since the DME selector on the VOR/ILS/DME control panel was on HOLD, the commander's HD displayed the VOR deviation in addition to the VOR bearing and VOR course.

It is to be assumed that the copilot had selected the settings which were found for the entire approach and that he had selected VOR 2 as 2nd course. On his VOR/ILS/DME control panel the DME selector was also on HOLD, so that on the ND, in addition to the LNAV presentation, he had available the VOR course and the VOR deviation. However, he did not have the VOR bearing available on the DBI either.

In summary it can be stated with regard to the use of the flight management and navigation equipment:

The pilot's navigation screen can be set up to provide many different displays. By selecting the CRS selector and the 2nd CRS push button, many combinations are possible. No precise statement on the selected display can therefore be made, because these manipulations are not recorded anywhere.

Nonetheless, given the positions of the switches found in the aircraft wreckage it can be stated with a high degree of probability how the displays for the final approach were selected. It cannot be explained why the switch on the control panel was in the LNAV 1 position and not in the SPLIT position, as it would be according to the normal Crossair flight procedure.

The selected presentation seems not to have been optimally either. It is considered, however, that this was not relevant to the accident.

2.2.5.3 Warnings

For about a minute before the go around was initiated, the aircraft maintained a constant rate of descent of 1200 ft/min. The investigation found that the performance parameters of the aircraft throughout the final approach were just outside the envelopes for mode 1 – excessive sink rate and mode 2B – excessive terrain closure rate. This is why no GPSW warning was triggered.

A terrain awareness and warning system (TAWS) would have had more advantages over the ground proximity warning system (GPWS) used in the aircraft involved in the accident. If the aircraft in landing configuration approaches the ground too far away from the runway, a visual and acoustic warning is generated. This is possible because the TAWS has access to a topographical database of the area around the airport. Such a system would have detected the dangerous closing of HB-IXM with the area to the north of Bassersdorf in good time and would have been able to warn the crew accordingly.

It should be mentioned that at the time of the accident no approved installation documents (service bulletin or equivalent) for the retrofit from GPWS to TAWS – which fulfils the requirements of TSO C151, Class A – were available for the AVRO 146-RJ100, Mark I (HB-IXM). According to JAA requirements the retrofit has to be accomplished by 1 January 2005. The AVRO 146-RJ85 fleet is also affected by this retrofit. AVRO 146-RJ100 Mark II were already fitted with a TAWS at delivery of the aircraft. The TAWS installed is a Honeywell enhanced ground proximity warning system (EGPWS) which fulfils the requirements of TSO C151, Class A.

In order to expedite this process, the Swiss AAIB had issued Safety Recommendation 2002-5 early during the investigation.

2.2.5.4 Call outs

The height indications from the synthetic voice at 500 ft RA (“five hundred”) and 300 ft RA (“minimums”) respectively responded normally and triggered certain reactions from the flight crew:

At 500 ft RA uneasiness set in and shortly after the “minimums” call out consideration was given to initiating a go around.

2.2.5.5 Obstacles missing on the approach charts

In approach chart 13-2 dated 13 November 2000 in the Jeppesen route manual which was used by the crew, no flight obstacles were shown in the runway 28 final approach sector. In approach chart LSZH AD 2.24.10.7-1 of the Swiss AIP, which was valid at the time of the accident, two flight obstacles were shown. HB-IXM collided with the most northerly of these two obstacles, a hill with an obstacle light at 1880 ft AMSL. It cannot be excluded that the commander would have reconsidered his decision to descend below the MDA without sufficient visual references if these obstacles had been visible on the approach chart (cf. Safety Recommendation concerning the representation of the terrain profile on approach charts).

2.2.6 Relationship between flight crew and procedures (L-S)

2.2.6.1 General

In the consideration of the relationship between flight crew and procedures (L-S) the application and implementation of general flight rules and the procedures specified by the operator occupied the foreground.

2.2.6.2 Transition from instrument flight to visual flight

At 21:03:36 UTC, when the aircraft was in the right turn onto the approach line for the standard VOR/DME approach 28, the commander mentioned for the first time that he had definite ground contact: “Ground contact hämmer...”- we have ground contact. On the basis of the position of the aircraft he would have been able to see the lights of Kollbrunn to the left below him.

Between 21:05:55 UTC and 21:06:21 UTC the commander again spoke of ground contact and used this circumstance as a justification for descending below the minimum approach altitude. During this period the aircraft was flying over Nürensdorf, and it is probable that the commander saw the lights of this locality.

The crew of flight CRX 3891 who had landed a short time previously on runway 28 reported that they were able to see the runway only at a distance of approximately 2.2 NM to VOR/DME Kloten. On the basis of this report and also with regard to the general weather conditions at Zurich airport at this time, it can very probably be excluded that the crew of Crossair flight CRX 3597 had visual contact with the approach or runway lights during the approach. Hence the criteria for continuing a descent below minimum descent altitude (MDA) laid down in JAR-OPS 1 and the operator's operations manual part A (OM A) were not met. The commander's background of experience and the copilot's training documentation prove that these criteria were known to both crew members, especially as these criteria had already been defined in the earlier procedure specifications, not merely on introduction of JAR-OPS 1 in 1998.

The commander's comments on ground contact show that he was looking outside for at least some of the time. On the basis of the allocation of tasks he was pilot flying and accordingly responsible for controlling the aircraft using instruments. Above all, the statements of the commander between 21:05:55 UTC and 21:06:21 UTC permit the conclusion to be drawn that he was increasingly orientating himself according to the inadequate visual references. This unconscious changeover between instrument flying and visual flying may have made it more difficult for him to determine the actual position of the aircraft in relation to the runway with regard to its altitude. The operator's procedures (cf. section 1.17.1.8, OM A 8.4.7.4.15.2 Co-operation on changeover to visual flying) specify a clear division of duties between pilot flying and pilot not flying for this flight phase. The flight crew did not comply with these instructions.

As the investigation showed, in comparable situations the commander had taken similar decisions and interpreted the operator's specified procedures in his own fashion. It is possible that the copilot had also experienced similar deviations from procedures and this would be a further reason for his non-intervention.

2.2.6.3 Configuration during a non-precision approach

The operator's procedures as well as PANS-OPS specified that the aircraft should be configured for landing before reaching the final approach fix (FAF). The resulting practically unchanged attitude simplifies planning and monitoring of the glide path during the final approach. Without mentioning this during the approach briefing, the commander decided to start the approach faster than specified and to constantly change the configuration of the aircraft during the final approach. This procedure would have required continuous adaptation of the rate of descent to the horizontal speed, but this was not performed (cf. appendices 4 and 10).

2.2.6.4 Altitude setting during a non-precision approach

In the pilots' information handbook and in the AVRO RJ training guidelines, the operator specified that shortly before reaching the final approach fix the go around altitude must be selected on the mode control panel (MCP). The crew had to ensure the step altitudes according to this specification using the autopilot's altitude hold mode. Leaving the respective altitude was initiated via vertical speed mode.

In former times, according to the specifications in the pilots information handbook, the minimum descent altitude (MDA) was set on the MCP during the final approach. This procedure established a safety net, because an automatic level-off at the MDA was executed, without pilot intervention, provided the autopilot was engaged.

The manufacturer of the aircraft type involved in the accident left the setting of the altitude on the mode control panel to the operators.

The crew of the aircraft involved in the accident kept to the valid procedural regulations of the operator with regard to setting the go around altitude. Compared with the earlier Crossair procedure, these regulations have the disadvantage that an additional safety net was removed. It remains an open question whether the commander would have stopped the aircraft's transition to horizontal flight when reaching the MDA if the earlier procedure had been applied.

2.2.7 Flight crews – environment interface (L-E)

2.2.7.1 General

In considering the "flight crew – environment" interface, the behaviour of the preceding aircraft, the weather situation, air traffic control and the configuration of the approach, as well as the operator and the supervisory authority, were in the foreground.

2.2.7.2 Preceding aircraft

A few minutes ahead of the aircraft involved in the accident, two aircraft of the same airline, flight numbers CRX 3891 and CRX 3797, landed on runway 28 after the same approach. The commander realised that at least flight number CRX 3891 was able to land before him. It cannot be excluded that this fact generated a certain pressure to succeed or at least encouraged the hope that a landing was possible under the prevalent weather conditions.

2.2.7.3 Weather situation and weather minima

The weather situation at the time of the accident permitted an approach on runway 28 according to the weather minima in force at the time.

However, the prevaling meteorological visibility and the cloud in the approach sector of runway 28, according to the weather report from CRX 3891, permitted an approach only if the aircraft flew horizontally at the MDA until a distance of approximately 2.2 NM before VOR/DME Kloten. The final approach from the viewpoint of this position corresponds to a glide path of about 6° (cf. appendix 11).

This can be described as steep and inappropriate for larger aircraft and conceals a general risk with regard to an unstabilised final approach at low altitude.

At the time of the accident, a minimum runway visual range of 2000 m was published for standard VOR/DME approach 28 for aircraft in categories C and D. With such visibility conditions, the first approach lights could be detected at a distance of 2.3 NM to VOR/DME Kloten at the earliest (cf. appendix 11, point P-3). This position corresponds to a distance of 2 km from the beginning of the approach lights.

The minimum visibility for non-precision approaches is in a fundamental relationship to the MDA. Applying the recommendations of the ICAO (Doc. 9365-AN910, manual of all weather operations) to the case of VOR/DME approach runway 28, the result is a minimum visibility of 4000 m for category C aircraft.

In this context, it is worth noting the relationship of the visual descent point (VDP) to minimum horizontal visibility. In the case of standard VOR/DME approach 28 this VDP, according to the definition, would be the point of intersection of the PAPI glide path (3.7°) with the MDA. This intersection is located at an oblique distance of 3.3 NM from VOR/DME Kloten, or 2.4 NM (4.4 km) before the threshold of the runway (cf. appendix 11, point VDP). In order to be able to see the approach lights from this point, which extend for 650 m, the computed minimum visibility of 4200 m would accordingly be required. The simulator tests have shown that for a minimum horizontal visibility of 5000 m the approach lights become visible only 0.2 NM after overflying the VDP.

2.2.7.4 Air traffic control

2.2.7.4.1 Use of personnel

According to the skyguide sector occupancy plan, at the time of the accident four working positions should have been occupied in approach control and in aerodrome control respectively. In fact, approach control only had one working position occupied and the aerodrome control unit was occupied by two working positions.

After the landing of the first of three aircraft which were on the standard VOR/DME approach 28, the supervisor decided to reduce the team of aerodrome control tower to two ATCOs. He himself handed over his function to the GRO, left the control tower shortly after 21:03 UTC and set off for home after a brief stay in the office.

The supervisor position, which is indicated until 22:00 UTC according to the sector occupancy plan, was therefore no longer occupied by a trained supervisor. The GRO ATCO who took over the task was not trained as a supervisor and had only limited experience of this activity.

Difficult weather conditions prevailed, which for instance could have made decisions necessary such as changing of a runway or initiating the forwarding of a pilot report. For that reason presence of a trained supervisor would have been appropriate.

If the remarkable reduction of occupied working stations in the aerodrome control unit and in the approach control did have further negative impact, as for example attending CRX 3597 by approach control during the final part, must be open.

2.2.7.4.2 Selection of the approach procedure

According to the provisions of the Law on Aviation, the aerodrome owner has to submit the operating regulations to the FOCA for approval. The amendment applied for by Unique with reference to the state agreement to be concluded with Germany was approved by the Federal Council concerning the above-mentioned approaches on runway 28 on 18 October 2001 and entered into force on 19 October 2001.

These transitional agreements made it impossible to grant clearance to aircraft over German territory for flight levels below FL 100 between 21:00 UTC and 05:00 UTC, regardless of whether these aircraft were flying under their own navigation or were controlled by radar.

Thus between the above-mentioned times, on the basis of the prevailing weather and the published minimums for runway 28 it was not permitted to make ILS approaches on runways 14 or 16. Accordingly, Zurich approaches had to be conducted on standard VOR/DME approach 28.

Until the entry into force of the transitional arrangements in the state agreement of 19 October 2001, the standard VOR/DME approach 28 was used by air traffic control only sporadically, where there was a pronounced westerly wind. Except for precipitation, typical westerly situations are generally characterised by good visibility and a relatively high cloud base.

2.2.7.4.3 Execution of standard VOR/DME approach 28

The standard VOR/DME approach 28 is not flown with radar vectors but under the aircraft’s own navigation.

At 21:03:01 UTC, APP ATCO (A) handed over the aircraft to Zurich Aerodrome Control 1 (Zurich tower) at the beginning of the right turn onto the extended centre line of 275° towards VOR/DME KLO, approximately 11 NM to the east of the airport, without verifying that flight CRX 3597 was on final approach track. At 21:05:21 UTC, CRX 3597 reported for the first time on the ADC 1 frequency: "Tower gueten Abig, CRX 3597, established VOR/DME runway 28" - Tower good evening, CRX 3597, established VOR/DME runway 28.

APP ATCO (B), who took over the task of monitoring CRX 3597 from APP ATCO (A), still had a number of departures to deal with at the same time. He indicated (cf. section 1.8.4) that he saw the aircraft on his radar screen. He consciously noticed its altitude only at approximately 6 NM, when he noted an altitude of approximately 3600 ft. The ATCO stated that no further altitude checks were carried out by him, since the aircraft was under its own navigation.

2.2.7.4.4 Radar monitoring

In reference to radar monitoring of the standard VOR/DME approach 28 skyguide released an instruction to supervise the lateral track and to give heading corrections if necessary. The investigation found that the understanding of the interviewed ATCOs regarding the extent and the practical execution of radar monitoring for the standard VOR/DME approach 28 differed. Despite this, it is a fact that the requirements for the radar monitoring of flight CRX 3597 were fullfilled.

2.2.7.4.5 Minimum safe altitude warning system

After an Alitalia aircraft collided with Stadlerberg (a hill in the approach path of runway 14) on 14 November 1990, the AAIB issued a safety recommendation to monitor a minimum safe altitude by introducing a warning system. Although non-precision approaches are well suited to such a warning system, given their discrete altitude steps, such equipment was not installed in the approach sector 28. Hence a further safety net which might possibly have prevented the accident was lacking.

On 11 April 2002, the AAIB submitted an interim report to the Federal Office for Civil Aviation, which proposed, among other things, safety recommendation 2002-7 relating to the installation of an MSAW in the approach sector of runway 28 (cf. section 4.1.4).

In its letter of 31 October 2002, the supervisory authority (FOCA) demanded from skyguide the installation of an MSAW for the approach sector to runway 28.

2.2.7.5 Configuration of the approach

As the corresponding details show (cf. section 1.16.2), the standard VOR/DME approach 28 deviates in certain areas from PANS-OPS standards. These deviations are not directly causally related to the accident.

If the actual visibility corresponds to the minimum of 2000 m in force at the time of the accident, the approach lights can be detected at a distance of 2.3 NM DVOR KLO at the earliest (cf. appendix 11, Point P-3). Since a final approach from this point according to such visibility would require an approach angle of about 6° in relation to the threshold of the runway, there is a danger of an unstabilised approach close to the ground.

2.2.7.6 Airline

No documentation was available concerning an aptitude check when the commander joined the operator in 1979. The suitability of a pilot at that time was deduced from possession of a corresponding licence and professional experience, calculated exclusively based on his flight experience in flight hours. In addition, a discussion in person took place, though no aptitude check was specified.

At that time, with a total flying experience in excess of 4000 hours, the commander was already experienced. During the examination for the SA 226 TC Metroliner II type rating, the official expert from the Federal Aviation Office stated certain shortcomings concerning the commander's performance. Shortly afterwards, the supervisory authority transferred periodic crew checks to experts who were employed by the operator as pilots. Until the commander started the first conversion course for the MD 80 aircraft type, negative points of criticism were seldom entered on his checksheets (cf. appendix 9). The checksheets corresponded to the stipulations of the Federal Office for Aviation (today's Federal Office for Civil Aviation), but were not very reliable in terms of content. In the context of both conversion courses to the type MD 80, the flying instructors and experts, some of whom came from a different aviation environment, noted deficiencies concerning the commander's performance. The above-mentioned difficulties related to fundamental elements of flying capabilities and were not primarily associated with the MD 80 aircraft type. When the commander finally converted to the Avro 146 RJ 85/100 aircraft type, he was partially trained and examined by flying instructors who applied the same standards and principles as in the Saab 340 fleet. This familiar environment was also cited by senior personnel from the operator as a reason why the commander underwent conversion to this jet aircraft without any problems.

This different assessment of the commander's performance permits the conclusion that certain experts and flying instructors from the operator applied different benchmarks and did not recognise the deficits which were present. The operator also did not really manage to put the various occurrences during the commander's career into a broader context, to recognise common features and basic patterns or to take appropriate measures.

If one compares the procedures applied by Crossair to select the copilot with the corresponding guidelines of JAR-FCL 3 (cf chapter 1.17.1.5.1), the following points emerge, among others:

- The entire area of modes of behaviour critical to success and possible psychical deficits was not raised.
- Operational aptitudes were not raised in a standardised manner; there was a lack of reliable and standardised aptitude tests. These factors were assessed as part of a simulator exercise. Flight simulators are of only limited suitability in this context and the data acquired in this way are not very dependable.
- The aspects of a pilot's personality which are important for decision-making and for coping with stress were not systematically recorded.
- The external psychodiagnostic report concentrated on the aspects of social behaviour and enterprise. The typical characteristics and aptitudes of a pilot according to JAR-FCL 3 were dealt with only marginally; however, the dimensions of the two main characteristics are neither clearly defined nor cleanly separated. Thus for example the description of behaviour "*bleibt sich selber* - is his own person" and "*bleibt sich selbst* - remains himself" occur identically under the dimensions "emotional compatibility" and "individualist". As a result, the dimensions become difficult to understand and impossible to delineate.
- The instruments used were akin to those of a selection system for management and corresponded only in part to a requirement profile for pilots. It could not be demonstrated that the individual personality and performance aspects of candidates could be recorded independently. Furthermore, there is a lack of evidence that the proc-

ess was examined for objectivity and optimised. This is important in so far as any selection procedure includes a specific number of subjective influences which must be recognised and checked if distortions are to be avoided. There are neither standards relating to the procedures nor checks on reliability and measurement accuracy. The degree of standardisation, reproducibility and verifiability of the measurements must therefore be described as low. Since objectivity is a condition for reliability and the latter in turn is a prerequisite for validity studies, the selection procedure therefore meets none of the quality criteria required by JAR-FCL 3.

- The Crossair selection procedure also deviates from the methodical specifications of JAR-FCL 3 in that no formalised criteria for decisions were laid down in order to decide whether an applicant would be accepted or rejected.

With regard to clarifying aptitude, the office for pilot selection established, among other things, that the copilot still had little self-assurance and tended to behave in a submissive fashion in dealings with authority. These personality traits indicated a need for training and support in the area of self-confidence and readiness to intervene. The fact that the copilot did not intervene to stop the aircraft descending below the minimum approach altitude allows the assumption that despite completing training in crew resource management, the corresponding deficits continued to exist.

As the investigation showed, the flight involved in the accident was not an isolated case in which procedure was not followed. The reasons for this observation lie, among other things, in the rapid growth of the company, which brought with it a continuous change of responsible personnel and structures. In an attempt to operate in a cost-effective manner, certain specifications tended occasionally to be interpreted broadly. The operator did not manage to generate the necessary safety awareness in all its flight crews.

Crossair's flight safety department was moderately equipped with personnel resources for a company with more than 80 aircraft. In addition its incorporation into the flight operations support division was not optimal, since the flight safety officer had access to the fleets only via several superiors. The flight safety department was not involved in training or performance problems, or in violations of procedures by crews. It was not until shortly before the accident that a confidential reporting system was introduced. The result of all this was that the flight safety department was not very helpful in contributing to an improvement in the above-mentioned circumstances.

2.2.7.7 The supervisory authority

Consistent monitoring of the operator by the supervisory authority (the Federal Office for Aviation and later the Federal Office for Civil Aviation) might under certain circumstances have provided an opportunity for recognising that deficits existed with regard to the pilot's performance. Thus, for example, after the conversion to the SA 226 TC Metroliner an inspector from the Federal Office for Aviation noted shortcomings which, until the MD 80 transition course, were recognised in individual cases only by the experts of the airline.

It might also have been recognised that the operator's crews deviated not seldom from prescribed procedures.

Up to the time of the accident, Crossair was never the subject of an operational audit by the FOCA. Likewise the activity of the operator's experts working on behalf of the FOCA was not monitored. This circumstance was the result of a shortage of personnel resources. Only on 28 August 2002 was Crossair, now renamed Swiss International Air Lines Ltd., subjected to an operational audit.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- There is no indication that the aircraft HB-IXM was not in an airworthy condition at the time of the accident.
- The ground proximity warning system (GPWS) issued no warnings because throughout its flight path the aircraft was outside the envelopes of mode 1 – excessive descent rate and mode 2B – excessive terrain closure rate.
- The navigation aids on the ground used for the approach were functioning normally.
- No minimum safe altitude warning (MSAW) system was present in the approach sector for runway 28.

3.1.2 Crew

- According to the documentation available, the crew possessed valid pilots' licences.
- The investigation found no indications of a medical cause for the accident.
- The operator did not carry out any extensive aptitude checks with regard to the commander.
- The commander did not pass two conversion courses for the MD 80 aircraft type due to inadequate performance.
- The commander's career shows that he did not always strictly adhere to standard operating procedures.
- The operator's aptitude check describes the copilot as tending to be submissive, striving for harmony and lively, but not aggressive.
- On the day before the accident the commander's flight duty time was 15 hours and 31 minutes.
- The commander's rest time before the day of the accident was 10 hours and 59 minutes.
- At the time of the accident, the commander's flight duty time was 13 hours and 37 minutes.
- Inter-company monitoring of crew times between the Crossair operator and the Horizon Swiss Flight Academy flying school was not performed.
- On the day before the accident the copilot's flight duty time was 10 hours and 15 minutes.
- The copilot's rest time before the day of the accident was 18 hours and 49 minutes.
- At the time of the accident, the copilot's flight duty time was 4 hours and 47 minutes.

3.1.3 Flight progress

- In accordance with the operator's procedures, after leaving the initial approach altitude of 4000 ft QNH the flight crew set the go around altitude of 6000 ft QNH on the autopilot's mode control panel.
- The procedures in the pilot information handbook specify that the crew should configure the aircraft for landing before the final approach fix (FAF).
- The crew configured the aircraft for landing after the final approach fix without having this briefed.
- The changes to the ATIS reports referring to the meteorological visibility and the ceiling were not forwarded by the APP air traffic control officer (A) to the flight crew of CRX 3597.
- The supervisor decided, on the basis of the operating concept and the weather conditions, to bring the standard VOR/DME approach 28 into operation from 21:00 UTC.
- The APP air traffic control officer (B) had some departing aircraft to handle in addition to the approaching CRX 3597.
- In the approach control office and in the aerodrome control tower the workstations were not occupied in accordance with the duty plan.
- The recordings of the CVR and the radio transcriptions prove that immediately before reaching the minimum descent altitude (MDA) the copilot was occupied by tasks.
- The operator's procedures specified a clear division of tasks between pilot flying and pilot not flying for this flight phase. The flight crew did not comply with these specifications.
- The commander deliberately violated the minimum descent altitude (MDA) for the standard VOR/DME approach 28.
- The copilot made no attempt to prevent the continuation of the flight below the minimum descent altitude.
- None of the crew members had visual contact with the runway or with the approach lights. Therefore the conditions for going below the minimum descent altitude (MDA) and continuing the final approach visually were not met.
- At 21:06:36 UTC, during the transition from a controlled descent to a go around, the aircraft came into contact with the trees on a hill and then crashed into the wood.
- The air traffic control officer at the position GRO raised the highest alarm level at 21:10:32 UTC, 4 minutes after having given the landing clearance.
- The supervisor had left his workstation about three minutes before the accident and had transferred the duty of the daily OPS management to the air traffic control officer GRO.
- The air traffic control officer GRO had no training as a supervisor. He had three years professional experience as an air traffic control officer.
- The rescue and fire-fighting measures were timely and appropriate.
- The accident was survivable only by chance.

3.1.4 General conditions

- The operating procedures applied for non-precision approaches by Crossair at the time of the accident corresponded to the specifications of the Federal Office for Civil Aviation and the Joint Aviation Requirements JAR-OPS 1 respectively.
- The intermediate approach segment of standard VOR/DME approach 28 was 3.5 NM at the time of the accident.
- For an approach with the geometry of standard VOR/DME approach 28, the PANS-OPS standards of the International Civil Aviation Authority (ICAO) specify a length of 7 NM for an intermediate approach segment.
- The ICAO norms specify that in a non-precision approach in which the intermediate approach segment exhibits a slope, before the final approach fix (FAF) a horizontal section at least 1.5 NM long must be incorporated. The slope of the intermediate approach segment may be 5% maximum.
- If a descent is carried out with the maximum specified slope of 5%, a horizontal section of 0.2 NM is possible on the standard VOR/DME approach 28 before the final approach fix (FAF).
- Some of the deviations of the standard VOR/DME approach 28 from ICAO specifications were noted during a periodic check in the year 2000 but not published.
- The final approach segment of the standard VOR/DME approach 28 has a slope of 5.3% from the final approach fix (FAF) to the point at an slant distance of 6 NM from VOR/DME KLO. The final approach segment from this point to a position 50 ft above the runway threshold has a slope of 6.3%. In the Swiss AIP a slope of 5.3% was indicated for the entire final approach segment.
- The minimum visibility which applied at the time of the accident for a standard VOR/DME approach 28 for category C and D aircraft was 2000 m runway visual range according to the Swiss AIP.
- At the time of the accident, meteorological visibility of 3500 m was observed at Zurich airport.
- In the ATIS information NOVEMBER weather report at 20:50 UTC the main cloud base was indicated at a height of 1500 ft AAL.
- The cloud information in METAR reports relate to the airport area and the immediate environment; the cloud information in QAM reports (ATIS) relate to the former middle marker position on runway 16.
- At the time of the accident the main cloud base in the area of the accident was 1000 ft AAL, according to pilots' statements.
- The intersection point of the PAPI glide path (3.7°) with the minimum descent altitude was at a slant distance of 3.3 NM from VOR/DME KLO, or 2.4 NM (4.4 km) ahead of the runway threshold. In order to be able to see the approach lights from this point, a computed minimum visibility of 3700 m would be necessary.
- About three minutes before the accident, Crossair flight CRX 3891 landed on runway 28 and the crew reported that they had seen the runway at a distance of 2.2 NM to VOR/DME KLO. At this point this aircraft would have been at a distance of about 1700 m from the runway 28 approach lights.

- The range of hills with which the aircraft came into contact was entered in the Swiss AIP. However, this obstacle was missing on approach chart 13-2 of the Jeppesen route manual, which the flight crew were using.
- The procedure applied by Crossair for copilot selection corresponded only in part to the guidelines of the Joint Aviation Requirements flight crew licensing JAR-FCL 3.
- The Crossair operator’s concept for training flight crews in crew resource management (CRM) corresponded to the specifications of JAR-OPS and JAR-FCL.
- The flight safety department had at its disposal 80% of one full-time equivalent post.
- The flight safety department was not informed in the case of performance problems with flight crew members.
- Between 1995 and the time of the accident, more than 40 incidents are known in which crews developed their own procedures or did not comply with prescribed procedures.
- Documents on inspections of Crossair by the competent Air Transport Operations Process (Luftverkehrsbetriebe - LV) of the Federal Office for Civil Aviation are not available.
- The activity of the experts employed by Crossair, who were commissioned by the FOCA to carry out type ratings and proficiency checks such as line checks and route checks, was not monitored by the FOCA.

3.2 Causes

The accident is attributable to the fact that on the final approach, in own navigation, of the standard VOR/DME approach 28 the aircraft flew controlled into a wooded range of hills (controlled flight into terrain – CFIT), because the flight crew deliberately continued the descent under instrument flight conditions below the minimum altitude for the approach without having the necessary prerequisites. The flight crew initiated the go around too late.

The investigation has determined the following causal factors in relation to the accident:

- The commander deliberately descended below the minimum descent altitude (MDA) of the standard VOR/DME approach 28 without having the required visual contact to the approach lights or the runway
- The copilot made no attempt to prevent the continuation of the flight below the minimum descent altitude.

The following factors contributed to the accident:

- In the approach sector of runway 28 at Zurich airport there was no system available which triggers an alarm if a minimum safe altitude is violated (minimum safe altitude warning – MSAW).
- Over a long period of time, the responsible persons of the airline did not make correct assessments of the commander’s flying performance. Where weaknesses were perceptable, they did not take appropriate measures.

- The commander's ability to concentrate and take appropriate decisions as well as his ability to analyse complex processes were adversely affected by fatigue.
- Task-sharing between the flight crew during the approach was not appropriate and did not correspond to the required procedures by the airline.
- The range of hills which the aircraft came into contact with was not marked on the approach chart used by the flight crew.
- The means of determining the meteorological visibility at the airport was not representative for the approach sector runway 28, because it did not correspond to the actual visibility.
- The valid visual minimums at the time of the accident were inappropriate for a decision to use the standard VOR/DME approach 28.

4 Safety recommendations and safety actions taken

4.1 Safety recommendations of 11 April 2002

4.1.1 Crewpairing – Composition of flight crews

4.1.1.1 Safety deficiency

The commander had extensive flying experience, but had only limited experience on aircraft with modern flight guidance systems and on jet-turbine powered aircraft or on the aircraft type involved in the accident. He was paired with a young copilot who had little overall flying experience and who also had few flying hours on jet-turbine powered aircraft or on the type involved in the accident. The accident permits the conclusion that the crew members did not complement each other appropriately.

The JAR-OPS 1 regulations adopted by Switzerland specify that both pilots must have a minimum flying time on the corresponding aircraft type before they are allowed to fly together. This minimum experience was present in this case. The AAIB is therefore of the opinion that the purely quantitative criteria for “inexperienced crews” are not sufficient. Consequently, additional qualitative criteria should be applied which ensure that crews – regardless of their flying experience – reliably master a specific operation or new, complex systems of an aircraft. Only when this qualification has been acquired after building up a certain experience (e.g. at the time of a line check or simulator check) is the pilot deemed to be “experienced” and able from that time onward to be paired with “inexperienced” crew members.

4.1.1.2 Safety recommendation 2002-1 (no. 33)

The Federal Office for Civil Aviation should investigate whether criteria can be laid down according to which not only the flying experience of the individual crew members is taken into account for the composition of a flight crew. In particular, the extent to which guidelines concerning qualitative criteria can be laid down and appropriate control procedures drafted for their application should be examined. This should be performed in order to ensure that until the necessary aptitudes are demonstrated, crew members newly assigned to a specific aircraft type or to a specific operation are guided and supported by an experienced crew member.

The Federal Office for Civil Aviation should if necessary propose to the Joint Aviation Authority (JAA) an amendment of the relevant specifications in JAR OPS 1.

4.1.1.3 Comment by the Federal Office for Civil Aviation dated 6 May 2002

“The criteria addressed with regard to the composition of a flight crew concern so-called human factors, i.e. self-esteem, discernment, knowledge of one’s own limits and much more. These factors are ‘soft’ and, moreover, subject to personal fluctuations. They cannot be absolutely quantified or qualified. Accordingly, we do not believe that in this respect officially concretised specifications and checks which go beyond the current conditions imposed by JAR-OPS are expedient. Primarily, the operator must have a net which is sufficiently fine-meshed in order to be able to detect any critical compositions and avoid them if possible. In this context, it is not possible, for example, to rely on experience in terms of flying hours alone; a “top-gun” pilot can have a bad day or may, in a given crew composition, actually increase the risk of conflicts. Furthermore, it must also be possible to record and control short-term changes in the composition of a crew.

In our opinion the route to take is one of dialogue with those responsible, say by using examples to highlight and reinforce safety consciousness, and by inspiring the network (procedures, including CRM training) and adapting it if necessary. The systematic development of personality skills (non-technical skills) and their incorporation in the system is the main factor for further improving flight safety.

The JAR-OPS 1 regulations in this area are adequate and in our opinion do not need to be adapted".

4.1.2 Examination of pilots' performance

4.1.2.1 Safety deficiency

The commander of the aircraft involved in the accident was employed for more than 20 years on piston-engined and turboprop aircraft. From 1987 to 2001 he flew Saab 340 aircraft for the same airline. During this period he tried several times to convert to faster and larger aircraft. Two MD 80 transition courses had to be aborted because of inadequate aptitude. Therafter the commander was reassigned to the Saab 340. With the withdrawal of the Saab 340 from the Crossair fleet a new aircraft had to be found for the commander and he was subsequently converted to the Avro RJ 85/100 aircraft type in spring 2001.

The accident permits the conclusion that the crew carried out the approach procedure without being adequately aware of the overall situation and of the spatial and chronological sequence of the procedure (a lack of situational awareness). There are various indications that the actions of the crew were influenced by overconfidence and complacency. In particular, the approach was deliberately continued below the minimum descent altitude.

The investigation makes it possible to conclude that Crossair may possibly be employing other pilots whose career includes peculiarities, gaps or deficiencies in aptitude which make it essential to check their performance, knowledge and working methods.

4.1.2.2 Safety recommendation 2002-2 (no. 34)

The Federal Office for Civil Aviation should check the criteria, regulations and procedures which govern the selection and conversion of pilots of aircraft with piston engines or turboprop propulsion systems to aircraft with jet engines or aircraft with modern equipment (e.g. Saab 2000, Embraer and Airbus).

4.1.2.3 Comment by the Federal Office for Civil Aviation dated 6 May 2002

"In principle we assume that the type of propulsion system and the equipment of an aircraft should not be a decisive criterion for the selection of a pilot to be converted. On the other hand, conversion must ensure that the specific characteristics of a propulsion system are known and understood. Conversion to modern, integrated electronic equipment must in addition meet the requirements that the basic philosophy, the fundamental method of operation of the systems and their limits are imparted comprehensibly and forcefully.

The requirements of the results of conversion (with regard to aircraft type, equipment, etc.) are in our opinion adequately described and defined. The extent to which an operator wishes to lay down its own criteria for the selection of pilots to be converted must remain within his discretion.

However, the fact that the conversions in question generally also involve becoming acquainted with a different operating environment seems to us to be more important than the cited technical characteristics. In this case, training or retraining must clearly go beyond mere conversion. JAR-OPS specifies that the following elements related to human factors or interaction (CRM, cockpit/crew resource management) are important in the context of a conversion: "human error and reliability, error prevention and detection, philosophy of the use of automation (if relevant to the type), case-based studies". The division of roles between the operator and the authority is explained in the same way as the comments on safety recommendation 2002-1, mutatis mutandis."

4.1.2.4 Safety recommendation 2002-3 (no. 35)

The Federal Office for Civil Aviation should check the performance and knowledge of those Crossair pilots and if necessary those of other operators whose career includes peculiarities, gaps, or particular incidents. This check should not be limited to looking through a pilot's dossier, but should include long-term observation and at least random checks on performance on scheduled flights. Appropriate measures should be taken for pilots with inadequate performance, in cooperation with airline management and psychomedical experts.

4.1.2.5 Comment by the Federal Office for Civil Aviation dated 6 May 2002

"Here, even more clearly than in the two preceding recommendations, it is essential for the responsibilities between the authority and the operator to be clearly regulated. Knowledge of the development of their pilots' aptitudes is plainly a prerequisite for implementing the safety philosophy of a company. Fleet managers must know their people in order to be able to arrange for any measures to be taken. The necessary tools to be applied (qualifications, evaluation of operational feedback, results of training, etc.) is a matter for the operator. This also includes the need for findings and knowledge to flow back into training and further training, where appropriate.

The role of the authority also involves ensuring that such tools exist and that they are applied. Only in special cases should the authority become directly active, e.g. through inspections."

4.1.3 Altitude setting during a non-precision approach

4.1.3.1 Safety deficiency

At 21:04:23 UTC the commander ordered the copilot to set a go around altitude of 6000 ft on the mode control panel. The copilot confirmed this instruction.

The Crossair operator specifies the following, in the pilots' information handbook (PIH) as part of the standard flight procedures, and in the AVRO RJ training guidelines for the phase shortly before reaching the final approach fix, which in Zurich is at a height of 4000 ft AMSL:

The go around altitude must be preselected on the mode control panel (MCP). (In Zurich this is 6000 ft AMSL). The pilot must ensure compliance with the step altitudes by means of the ALT HOLD mode. Departing from each of these altitudes is initiated by selecting vertical speed mode. The target rate of descent (ROD) must be addressed.

Compliance with the minimum descent altitude (MDA) is ensured, as with the intermediate steps, by ALT HOLD mode. On this page, in addition, Crossair published a rule of thumb for determining the visual descent point (VDP).

4.1.3.2 Safety recommendation 2002-4 (no. 36)

The Federal Office for Civil Aviation should check the extent to which the Crossair standard flight procedure needs to be adapted. In particular it should be checked whether, during a non-precision approach, the minimum descent altitude (MDA) should be set on the mode control panel instead of the go around altitude (the current Crossair procedure).

4.1.3.3 Comment by the Federal Office for Civil Aviation dated 6 May 2002

"We are in agreement with the recommendation."

4.1.4 Terrain awareness and warning system

4.1.4.1 Safety deficiency

Compared with the simple ground proximity warning system (GPWS) used on the aircraft type involved in the accident, a terrain awareness and warning system (TAWS) has several advantages. For example, the crew is warned if the aircraft in landing configuration comes too close to the ground at too great a distance from the runway. This is possible because the TAWS can access a topographical database of the area surrounding the airport.

Such a system would have been able to detect the dangerous proximity of the aircraft to the terrain in the area around Bassersdorf and warned the crew accordingly.

For aircraft commissioned since 1 January 2001, the legislation specifies the mandatory installation of a TAWS. All other large aircraft without TAWS which were in service before this date must be equipped accordingly by 1 January 2005.

4.1.4.2 Safety recommendation 2002-5 (no. 37)

The Federal Office for Civil Aviation should examine measures which ensure that large aircraft without a terrain awareness and warning system are retrofitted with such a system as quickly as possible.

4.1.4.3 Comment by the Federal Office for Civil Aviation dated 6 May 2002

“We are in agreement with the recommendation.”

4.1.5 Weather observation system

4.1.5.1 Safety deficiency

A few minutes before CRX 3597 crashed, two other aircraft from the same airline flew a standard VOR/DME approach 28. The first of these two preceding aircraft, flight number CRX 3891, filed the following weather report on the apron control frequency after the landing: "Just for information, the weather for runway 28 is pretty minimum, so we had runway in sight about 2.2 DME distance away". At this point this aircraft would have been at a distance of about 1700 m from the approach lights of runway 28 and about 2400 m from the threshold of the runway.

On the other hand, ATIS transmitted the following weather report from 20:50:00 UTC as part of the NOVEMBER information:

METAR 242050Z 16002KT 3500 –SN FEW006, BKN015, OVC022, 00/M00 Q1024 8829//99 TEMPO 5000.

Thus there were substantial differences between the weather conditions observed at Zurich airport and the actual conditions in the approach sector of runway 28.

4.1.5.2 Safety recommendation 2002-6 (no. 38)

The Federal Office for Civil Aviation should check whether the current system of weather observation from runway 16 and the configuration of the measuring instruments is appropriate, above all in critical weather conditions, for providing a weather report which contains information which is as applicable for runway 28 as it is for runways 14/16. Especially when the weather for the runway 28 approach sector is worse or more changeable than for the airport as a whole, crews should be provided with a specific weather report.

Until an improved weather observation system is introduced, the increased minimums imposed for the approach to runway 28 after the accident should be maintained.

4.1.5.3 Comment by the Federal Office for Civil Aviation dated 5 December 2003

"The value from ceilometer Bassersdorf to judge the ceiling shall be replaced by a local report along the respective runway axis."

4.1.6 Installation of a minimum safe altitude warning system (MSAW) for the approach sector of runway 28 in Zurich-Kloten

4.1.6.1 Safety deficiency

According to the standard VOR/DME approach 28 in Zurich-Kloten, as described on instrument approach chart ICAO AIP LSZH AD 2.24.10.7 – 1, the minimum descent altitude (MDA) was 2390 ft QNH. It is specified that an approaching aircraft should fly below the MDA or the obstacle clearance altitude (OCA) only when there is visual contact with defined elements of runway 28.

At approximately 3.5 NM from the threshold of the runway, i.e. 4.4 NM VOR/DME Kloten, flight CRX 3597 flew below the OCA/MDA of 2390 ft AMSL and then went on to descend continuously. Finally, the aircraft collided with a wooded rise at a distance of about 2.7 NM from the runway threshold.

After the accident to Alitalia flight AZA 404 on 14 November 1990 the approaches to runways 14 and 16 were equipped with a minimum safe altitude warning (MSAW). The MSAW system notifies the air traffic controller by means of a visual warning on the radar screen and an acoustic warning if an aircraft descends below a safe altitude during its approach. Thus the air traffic controller can warn the crew of the aircraft concerned.

The approach to runway 28 was not equipped with an MSAW system.

If an MSAW system had been present, it is highly probably that it would have triggered the alarm at a time which would still have allowed air traffic control to warn the crew in good time. In the present case, this alarm would have to have responded after CRX 3597 descended below the recommended glide path, but at the latest on leaving the OCA/MDA prematurely. Even in the most unfavourable case, there would still have been approximately 20 seconds to warn the crew of their dangerously low altitude.

4.1.6.2 Safety recommendation 2002-7 (no. 39)

The Federal Office for Civil Aviation should arrange for the approach sector of runway 28 to be equipped with a minimum safe altitude warning system which provides an automatic visual and acoustic warning of critical altitude violations. The ATC operating regulations must then be complemented by regulations on warning crews in the case of such critical altitude violations (analogous to the MSAW already installed for the approach sectors of runways 14 and 16).

4.1.6.3 Comment by the Federal Office for Civil Aviation dated 5 December 2003

(On 31 October 2002 and on 23 December 2002 respectively, the FOCA instructed skyguide in writing to install an MSAW on the approach sector of runway 28.)

“The MSAW 28 is in operation.”

4.1.7 Entry of flight obstacles in the Jeppesen Route Manual

4.1.7.1 Safety deficiency

In the approach chart (13-2, 10 NOV 00) in the Jeppesen route manual which was used by the crew, the flight obstacles in the approach sector of runway 28 are not entered. These obstacles are designated in the published approach chart of the AIP (LSZH AD 2.24.10.7-1).

4.1.7.2 Safety recommendation 2002-8 (no. 40)

The Federal Office for Civil Aviation should use its influence to ensure that obstacles below approach pathes are entered in broadly distributed publications such as the Jeppesen route manual, for example.

4.1.7.3 Comment by the Federal Office for Civil Aviation dated 5 December 2003

"Lido and Jeppesen have been instructed by the FOCA to adhere to this recommendation."

4.2 Safety recommendations dated 2 October 2003

4.2.1 Definition and publication of a visual descent point

4.2.1.1 Safety deficiency

The visual descent point (VDP) is the point at the minimum descent altitude (MDA) of a non-precision approach from which a normal visual approach to the runway is possible. If a glide path indicator, e.g. a precision approach path indicator (PAPI) is present, the VDP is the intersection point of this glide path with the MDA. In the case of a non-precision approach, only the missed approach point (MAP) is defined.

4.2.1.2 Safety recommendation no. 94

The FOCA should check the extent to which a visual descent point (VDP) should be added to the approach charts for non-precision approaches.

4.2.1.3 Comment by the Federal Office for Civil Aviation

The comment by the FOCA is pending.

4.2.2 Published minimum visual ranges for non-precision approaches

4.2.2.1 Safety deficiency

The investigation has shown that the minimum visual ranges in force at the time of the accident for the standard VOR/DME approach 28 are not appropriate. In addition, distinct differences were found to exist between the JAR and ICAO recommendations.

A minimum visual range can only be termed appropriate if it makes it possible to carry out the final approach with the necessary visual references from the visual descent point (VDP).

4.2.2.2 Safety recommendation no. 95

The Federal Office for Civil Aviation should check the extent to which the valid minimum visual ranges for non-precision approaches should be adapted, so that a final approach with the necessary visual references is possible from the visual descent point.

4.2.2.3 Comment by the Federal Office for Civil Aviation

The comment by the FOCA is pending.

4.2.3 Representation of the terrain profile on approach charts

4.2.3.1 Safety deficiency

Many aerodromes in Switzerland have rises in the terrain in their immediate environment which are clearly above the reference height of the aerodrome.

Obstacles on approach can be made more apparent by using a side-view representation of the terrain along the approach path.

4.2.3.2 Safety recommendation no. 96

The Federal Office for Civil Aviation should check whether the terrain profile along the approach path should be entered in the approach charts for all categories of instrument approach.

4.2.3.3 Comment by the Federal Office for Civil Aviation

The comment by the FOCA is pending.

4.2.4 Crew times

4.2.4.1 Safety deficiency

On the day before the accident, the commander was on duty for 15 hours 31 minutes, because he had already completed two IFR training flights before flying the four sectors for the operator. The prescribed rest time was not complied with. At the time of the accident, the commander had already been on duty for 13 hours and 37 minutes because he had made three IFR training flights prior to the accident flight. The flying duty records show that this combination of training activity and assignment as an air transport pilot on the same day was not a rarity. No inter-company check on crew times was carried out.

As the accident shows, the commander of the aircraft involved in the accident exhibited signs of fatigue in his behaviour.

4.2.4.2 Safety recommendation no. 97

The Federal Office for Civil Aviation, together with the operator, should check how a complete check on total flying duty time and rest time can be guaranteed.

4.2.4.3 Comment by the Federal Office for Civil Aviation

The comment by the FOCA is pending.

4.2.5 Improving the quality system of the operator

4.2.5.1 Safety deficiency

The investigation showed that even before the accident there were crews who did not follow guidelines and procedures. The operator's efforts in the area of flight safety as well as the monitoring measures of the Federal Office for Civil Aviation were not adequate to detect and prevent these occurrences.

4.2.5.2 Safety recommendation no. 98

Within the framework of the quality systems required according to the provisions of the Joint Aviation Authorities (JAA) JAR-OPS 1.035 on the commercial carriage of persons and goods in aircraft, the Federal Office for Civil Aviation should demand procedures from the operators which indicate and eliminate deficits in the behaviour and working practices of flight crews by means of internal company measures and should monitor these procedures.

4.2.5.3 Comment by the Federal Office for Civil Aviation

The comment by the FOCA is pending.

4.2.6 Acceptance of qualifications and capability checks

4.2.6.1 Safety deficiency

The investigation showed that for a long period the operator did not manage to determine the actual capabilities of a crew member. The experts responsible for administering skill tests, proficiency checks and line checks who were employed by the operator and who carried out these tests on behalf of the Federal Office for Civil Aviation, were in the majority not able to detect deficits and weaknesses, so these were able to have an influence on the accident.

4.2.6.2 Safety recommendation no. 99

The Federal Office for Civil Aviation should arrange for qualifications and proficiency checks to be administered, at least on a random sample basis, by inspectors or independent experts from the Federal Office.

4.2.6.3 Comment by the Federal Office for Civil Aviation

The comment by the FOCA is pending.

4.3 Measures taken since the accident to improve flight safety

4.3.1 Comment by Swiss dated 14 February 2003

The operator Crossair, whose company name had since been changed to Swiss International Air Lines Ltd., indicated that it had taken the following measures subsequent to the accident to CRX 3597:

Quote:

1. “Approach and Landing Accident Reduction” (ALAR)

An analysis to assess the potential for reducing approach and landing risks carried out immediately after the accident on 24 November 2001 was commissioned by the “Emergency Director” competent at that time. The criteria applied were defined by the independent “Flight Safety Foundation”.

2. “Operational Risk Analysis and Control” (ORAAC)

Findings were made from the “ALAR” analysis mentioned under point 1 which include a total of 81 points for action and which led to the establishment of an action plan with the working title “Operational Risk Analysis and Control” (ORAAC). The aim of this action plan was to expose possible weak points in the operation in order to establish good conditions for closing the gaps revealed in the process.

As part of the ORAAC action plan, the following measures, among others, were implemented:

- clarification and/or additions to the pilot “Operation Manuals”
- improvements in the technical equipment of regional aircraft
- adaptations to crew training and further training
- targeted testing of the proficiency of specific crew members “Screening-1” with the adoption of appropriate measures to eliminate deficits which were discovered or (where appropriate) resolution of working conditions.
- institutionalisation of an annual qualification process, conducted across the different fleets and which where necessary triggers effective measures immediately.

It was possible to implement ninety-five percent of all measures specified under ORAAC by the end of 2002.

3. “Flight Safety” and “Flight Crew Training” as a bridging function

In connection with the establishment of SWISS, the competencies of the “Flight Safety” and “Flight Crew Training” functions were extended as a so-called bridging function across both pilot corps, OC-1 (ex-Crossair) and OC-2 (ex-Swissair). As a result, it was possible to ensure that the relevant competencies of both the former operators could be applied and sustained according to “best practice” benchmarks.

4. “SWISS Safety Advisory Board” (SSAB)

In the first half of 2002, the management commissioned an external, internationally recognised team of flight safety experts to check flight safety standards within SWISS.

This team wrote an interim report dated 5 September 2002 and reported its findings with corresponding recommendations directly to the administration board. The implementation of the SSAB recommendations was taken in hand immediately by the “Flight Operations” division (see point 6).

5. "Flight Safety Officer": analysis of current and target situation

On behalf of the flight operations director, the technical office responsible for flight safety carried out an analysis regarding the current potential for further improving flight safety standards. The results were contained in the corresponding report dated 12 September 2002 and handed over to the flight operations director for action. The implementation of the recommendations contained therein was taken in hand immediately, together with those of the SSAB (see point 6).

6. "Flight Safety Program" (FSB)

The findings and recommendations from the SSAB mentioned under point 4, the analysis of the "Flight Safety Officer" mentioned under point 5, plus the internal reports concerning the Werneuchen accident on 10 July 2002 and the OC-1 management seminar on 3/4 September 2002 were assembled into a comprehensive and uniform programme of measures within the framework of the "Flight Safety Program" (FSB).

Implementation of the measures contained therein will be checked on a monthly basis and reported back directly each time to the administration board in the form of a status report.

The following table is a summary of the action plan, with the current status:

Action	Description	Status February 2003
Screening-2	Checking the proficiency of all SWISS pilots and where necessary introduction of corresponding corrective measures with monitoring	Conclusion April/03
Culture - CRM	2-day courses on integrating the two cultures	Management concluded Instructors concluded Basic course by 12/05
Organisation	"Flight Safety" and "Security" are placed directly under the COO	Concluded
Reporting procedure	Monthly report by the "Flight Safety Officer" on the status of flight safety to COO and CEO	Introduced
	"Operations" and "Air Safety Report" redefined and introduced	Concluded
	IT solution to data processing	Conclusion March/03
	Introduction and promotion of a "non-punitive" reporting procedure	Concluded

Flight monitoring	Installation of "Flight Data Monitoring" equipment in regional fleets	EMB-145 from 03/03 Conclusion 12/05
Safety awareness	Courses in "Safety-Awareness" f.a.o. administration board, MD and "vice presidents"	Concluded Conclusion April/03
Safety processes	Harmonisation of processes between pilots and cabin crew to ensure a high standard of safety	Conclusion March/03
Appointment of captains	No new licensing as captain without at least 5 years experience with SWISS plus age at least 25	Implemented
OCC support	Optimisation of support for crews in difficult weather conditions	Implementation in progress Conclusion Oct./03
Flight planning	Increasing systemisation in flight planning	Implemented
Documentation	Integration of information on emergency aerodromes in documentation	Conclusion July/03
Discipline	Special programme to promote discipline	Implementation in progress
Qualifications	Institutionalisation of an annual qualification process to guarantee sustainable pilot quality	Concluded

End quote.

4.3.2 Comment by Swiss dated 8 December 2003

With the comment dated 8 December 2003 Swiss International Airlines delivered an updated version of the action plan:

Quote:

Action	**Description**	**Status December 2003**
Screening-1&2	Checking the proficiency of all SWISS pilots and where necessary introduction of corresponding corrective measures with monitoring	Concluded

Assessment for transition courses	Transition course assessment including the performance before the transition course starts	Introduced
Basic selection	Revising the basic selection within SWISS regarding the guidelines from JAR-FCL 3	Concluded
Culture - CRM	2-day courses on integrating the two cultures	Management concluded Instructors concluded
Organisation	“Flight Safety” and “Security” are placed directly under the COO	Concluded
Flight procedures / SOP / Wordings	Fleet harmonisation	Concluded
Reporting procedure	Monthly report by the “Flight Safety Officer” on the status of flight safety to COO and CEO “Operations” and “Air Safety Report” redefined and introduced IT solution to data processing Introduction and promotion of a “non-punitive” reporting procedure	Introduced Concluded Introduced Concluded
Flight monitoring	Installation of “Flight Data Monitoring” equipment in regional fleets	Evaluation of DFDR data is active, Installation conclusion planned 12/05
Safety awareness	Courses in “Safety-Awareness” f.a.o. administration board, MD and “vice presidents”	Concluded
Safety processes	Harmonisation of processes between pilots and cabin crew to ensure a high standard of safety	Concluded
Appointment of captains	No new licensing as captain without at least 5 years experience with SWISS plus age at least 25	Implemented
OCC support	Optimisation of support for crews in difficult weather conditions	Implemented

Flight planning	Increasing systemisation in flight planning	Implemented
Documentation	Integration of information on emergency aerodromes in documentation	Implemented
Discipline	Special programme to pro-mote discipline	Implementation in progress
Qualifications	Institutionalisation of an annual qualification process to guarantee sustainable pilot quality Qualification data base Retraining and monitoring of instructors	Concluded Concluded Implemented

End quote.

Glossary

AAIB	Aircraft Accident Investigation Bureau (Büro für Flugunfalluntersuchungen)
AAL	above aerodrome level
AC	alternate current
ADC	aerodrome control
ADC	air data computer
ADF	automatic direction finding equipment
ADS	air data system
AFS	automatic flight system
AGL	above ground level
ALN	align
ALT HLD	altitude hold
AMOS	airline maintenance organisation system
AMSL	above mean sea level
AND	attitude nose down
ANU	attitude nose up
AP	autopilot
APA	altitude preselector alerter
APE	approach control east
APP	approach control office
APU	auxiliary power unit
APRON	apron
APW	approach control west
ATA	American Transport Association
ATC	air traffic control
ATCO	air traffic control officer
ATIS	automatic terminal information service
ATPL	air transport pilot licence
ATS	air traffic services
ATT	attitude
BATT	battery
FOCA	Bundesamt für Zivilluftfahrt (Federal Office for Civil Aviation)
BFU	Büro für Flugunfalluntersuchungen (Aircraft Accident Investigation Bureau)
BKN	broken (5-7 eights cloud)
BRG	bearing
B-RNAV	basic area navigation
CA	cabin attendant
CAD	computer aided design
CAM	cockpit area microphone
CB	circuit breaker
CCA	circuit card assembly
CDU	control display unit

CDR	commander	
CEO	chief executive officer	
CFIT	Controlled flight into terrain	
CLB	climb	
CLD	clearance delivery	
COPI	copilot	
CPL	commercial pilot licence	
CPM	cockpit procedure mockup	
CPU	central processor unit	
CRM	crew resource management	
CRS	course	
CRT	cathode ray tube	
CVR	cockpit voice recorder	
DA	decision altitude	
DADC	digital air data computer	
DBI	distance bearing indicator	
DC	direct current	
DDL	deferred defect list	
DEP	departure control	
DFDR	digital flight data recorder	
DFGC	digital flight guidance computer	
DFGS	digital flight guidance system	
DGAC	direction générale de l'aviation civile	
DH	decision height	
DM	duty manager	
DME	distance measuring equipment	
DOC	designated operational coverage	Area in which a specific service is available and in which the frequencies belonging to this service are protected
DTO	direct to	
DU	display unit	
DVOR	doppler VOR	
ECP	EFIS control panel	
EFIS	electronic flight instrument system	
EGPWS	enhanced ground proximity warning system *(*Honeywell *brand name)*	
ELC	engine life computer	
ELEV	elevation	
ELT	emergency locator transmitter	
EMI	electromagnetic interference	
ESS	essential	
FAA	Federal Aviation Authority	Civil aviation authority of the United States of America
FADEC	full authority digital engine control	
FAF	final approach fix	
FD	flight director	
FDR	flight data recorder	
FDAU	flight data acquisition unit	
FDEP	flight data entry panel	
FEW	few	1-2 eighths cloud
FGC	flight guidance computer	
FGS	flight guidance system	

FIR	flight information region	
FL	flight level	
FMS	flight management system	
F/O	first officer	
FOCA	Federal Office for Civil Aviation	
FOM	flight operations manual	
ft	feet	(1 ft = 0.3048 m)
G/A	go around	
GAC	general aviation centre	
GNLU	global navigation landing unit	
GPS	global positioning system	
GPU	ground power unit	
GPU	global position unit	
GPWC	ground proximity warning computer	
GPWS	ground proximity warning system	
GRO	ground control	
G/S	glide slope	
HDG	heading	
hPa	hecto pascal	
IAS	indicated airspeed	
ICAO	International Civil Aviation Organization	
IFR	instrument flight rules	
IGS	instrument guidance system	
ILS	instrument landing system	
IMC	instrument meteorological conditions	
IPG	IFR procedure group	
IR	instrument rating	
IRS	inertial reference system	
IRU	inertial reference unit	
JAA	Joint Aviation Authorities	
JAR	Joint Aviation Requirements	
KIAS	knots indicated airspeed	
kt	knots	(1 kt = 1 NM/h)
LAT	latitude	
LNAV	lateral navigation	
LONG	longitude	
LT	local time	
MAG	magnetic	
MAP	missed approach point	
MCP	mode control panel	
MCT	maximum continuous thrust	
MDA	minimum descent altitude	
MDH	minimum descent height	
METAR	aviation routine weather report	
MHz	megahertz	
MOC	minimum obstacle clearance	
MRT	multi radar tracking	
MSAW	minimum safe altitude warning system	
MSTR	master	

MSU	mode select unit	
ND	navigation display	
NDB	non directional beacon	
NDB	navigation data base	
NM	nautical mile	(1 NM = 1.852 km)
NMS	navigation management system	
NOAA	national oceanic and athmospheric administration	
NVM	non-volatile memory	
OAT	outside air temperature	
OCH	obstacle clearance height	
OM	operations manual	
OVC	overcast	8 eights cloud
PANS-OPS	procedure for air navigation services operations	
PAPI	precision approach path indicator	
PF	pilot flying	
PFD	primary flight display	
PIC	pilot in command	
PLA	power lever angle	
PNF	pilot not flying	
QAM	local weather report	
QFE	station pressure	
QNH	air pressure reduced to sea level, calculated using ICAO standard atmosphere values	
RA	radio altimeter	
RA	radar altitude	
RNAV	area navigation	
ROC	rate of climb	
ROD	rate of descent	
RVR	runway visual range	
RWY	runway	
Rx	receiver	
SCT	scattered	3-4 eighths cloud
SG	symbol generator	
SID	standard instrument departure	
SIGMET	information concerning en-route weather phenomena which may affect the safety of aircraft operations	
S/N	serial number	
SOP	standard operating procedures	
SR	slant range	
SSR	secondary surveillance radar system	
SSCVR	solid state cockpit voice recorder	
STAR	standard instrument arrival route	
SWC	significant weather chart	
TAF	aerodrome forecast	
TAS	true airspeed	
TCAS	traffic alert and collision avoidance system	

TAWS	terrain awareness and warning system
TMM	transmissometer
TOGA	take off go around
TR	type rating
TRK	track
TRP	thrust rating panel
T/S	trouble shooting
TWR	aerodrome control tower
ULB	underwater locator beacon
UTC	universal time coordinated
VAC	voltage - alternate current
VDC	voltage - direct current
VDP	visual descent point
VERT SPD	vertical speed
VFR	visual flight rules
VHF	very high frequency
VMC	visual meteorological conditions
VOR	VHF omnidirectional radio range
VPU	vortac position unit
WO	work order
XPDR	transponder
ZUE VOR	Zurich East VOR

Appendix 1: Chronological sequence of key events

UTC	Event	Comment
20:36:48 – 20:37:23	Copilot decodes runway report	
20:37:25 – 20:39:17	Commander explains a partial aspect to the copilot, copilot answers "Yes" or "Indeed" 12 times, and at the end, "*Jetzt han i grad wider öppis glärnt*."	
20:40:10	ATIS LIMA enters into force: "Landing runway 28, VOR/DME standard approach"	Not known to the crew at this time
20:42:58 – 20:44:05	Approach briefing RWY 14, poss. 16	Crew expectation: landing on runway 14
20:43:44	Copilot makes the commander aware of the excessive speed – the commander apologizes several times	Minor working error as possible effect of tiredness: it is not possible to monitor all parameters at the same time.
20:44:56	ATIS MIKE enters into force, runway report up-dated, but no significant change	Not known to the crew at this time
20:46:20	The copilot asks the commander whether he should inquire whether runway 14 can still be used: "*Söli ämal fragä öbs Vierzähni oder sägemer…s'wird grad eso knapp*"	The statement indicates that the copilot was able to assume, on the basis of the elapsed time, that a change to a different runway was to be expected
20:46:23	The commander answers: "*Ja, s'isch scho s'Vierzähni*" Copilot responds: "*S'Vierzähni*"	The commander reacts only briefly to the copilot's request. The commander is busy monitoring speed between 20:46:04 and 20:46:27: there is obviously a danger that this is again being exceeded.
20:48:22	Copilot calls Zurich arrival and confirms ATIS KILO	Copilot confirms a message which has been invalid since 20:40:10.
20:48:30	ATC: "Crossair 3597, you're identified, it will be a standard VOR/DME approach runway 28 for you"	The change to runway 28 is communicated to the crew for the first time.
20:48:39	Commander: " *Ou, Sch*****[1], das äno, ja, guet ok*."	
20:50	ATIS OSCAR enters into force	
20:51:56 – 20:53:05	Rebriefing in the RILAX holding pattern 20:52:ff the commander discusses the procedure and describes how left a turn is specified:	A spatial presentation of the flight path is omitted, the flight

[1] Expressions which constitute a spontaneous personal assessment of the current situation as well as personal utterances without any direct relation to the accident are identified by *****.

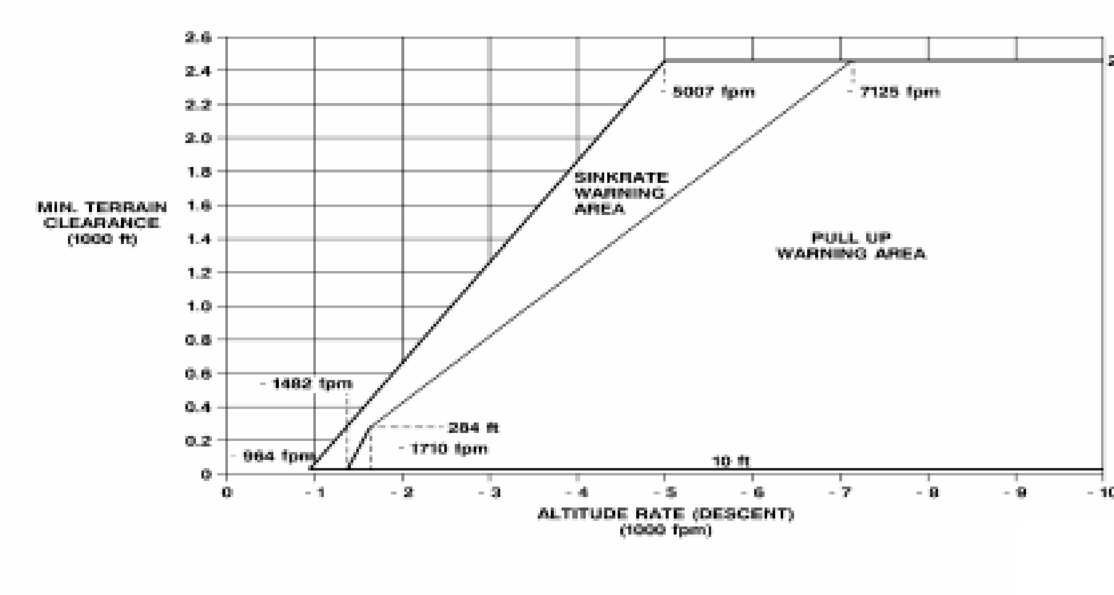
UTC	Event	Comment
	"*Wämer de turn macht bi Ko...Komma sächs Meile, sächs Komma föif Meile left turn*..." 20:53:ff: "*S'NAV setting bitte zweimal Chlote für de approach, bis deet ane isch's up to you*."	path includes a right turn. No description of the actual descent: configuration, VDP, etc. are lacking
20:53:37	Commander: "*Also schön Ziit, mer werded...also würklich well on time sii, hä?*"	Reference to the commander's intention to be able to land on time
20:53:42	Aircraft leaves RILAX holding pattern	
20:55:03	Aircraft flying at a speed of 210 kt, commander lets copilot enquire which speed limits apply. Copilot asks ATC, their reply: "ah, no restriction on speed for the time being" Commander: "*I dem Fall 250, hä?*"	A further reference that time has to be made up. Speed is increased gradually from 20:55:16 to 20:55:46 to 250 kt.
20:56:14	ATC: "... follow ZUE VOR radial 125 inbound" Copilot: "... radial 152, Crossair 3597" ATC: "Aah, radial 125" Copilot: "125, Crossair 3597"	ATC information is 180° incorrect, misunderstanding concerning the wrong information is corrected
20:56:38 – 20:57:10	Commander considers the information, realizes that it refers to "track 125"	No query to ATC, application of common sense
20:58:13	Setting QNH 1024 and altimeter check	Cross-comparison indicates no discrepancy
20:58:40	Copilot asks for APU, commander requests APU start-up, first attempt	APU does not start.
20:58:50	ATC gives clearance for VOR/DME standard approach runway 28	
20:59:25	Commander: "*LNAV isch dine*..."	
20:59:55	Copilot tries again to start APU, 21:00:04: "*Jawohl, jetzt chunnt's guet*"	APU starts.
21:00:56	ATC: "Crossair 3597, reduce speed to one eight zero (180 kt) or less".	Beginning of deceleration, partially with air brake
21:01:39	Commander: "Speed is checked, flaps eighteen (18°)"	
21:02:00	Commander mentions that speed is approx. 160 KIAS	
21:03:01	ATC: "Crossair 3597, tower one one eight one (118.1 MHz) continue your speed reduction to final approach speed" – commander confirms that he is about to decelerate	Transfer to aerodrome control (ADC)
21:03:29	CRX 3891, EMB 145 lands on runway 28	

UTC	Event	Comment
21:03:36	Commander: “*Ground contact hämmer* ...”	Aircraft flies over Kollbrunn, commander begins to see outside.
21:03:56	Commander again confirms a speed of 160 KIAS	
21:04:23	Crew determines slant range of 8 NM to VOR/ DME KLO and initiates descent	
21:04:31	CRX 3981 transmits to ATC: “Just for your information: the weather for runway 28 is pretty minimum. So we had the runway in sight about 2.2 DME”	This message is at least taken in by the commander, as his reactions at 21:05:59 and 21:06:25 demonstrate.
21:04:34	Commander instructs: “Gear down”	In accordance with Crossair procedures for an NPA, before beginning the final approach (in this case 8 NM), the aircraft should already be configured with gear down and flaps set at 24°.
21:04:37	HB-IXM leaves 4000 ft QNH, 160 kt, descent rate initially 1000 ft/min, later 1200 ft/min	
21:04:47	Commander instructs: “Flaps two four (24°)”	Change in configuration and speed during the approach makes it more difficult to maintain a constant approach angle
21:04:51	Beginning of check for approach, ends at approx. 21:05:00 with the sequence: Copilot: “airchange over” – commander: “*Mache!*”	At the end of the check for approach, when the commander makes the statement at 21:05:02, the copilot is probably still busy with airchange over
21:05:02	Commander states: “... *sechs Meile, drüü, drüü (33) das chunnt guet*”	
21:05:15	Commander: “*Speed 140 chömmer nä, hä*?” Copilot: “*Jawohl, me händ de pack recirc valve*...”	Aircraft is at 3340 ft QNH
21:05:21	“*Tower gueten Abig, Crossair 3597, established VOR/DME runway two eight*”. ATC: “*Crossair 3597, gueten Abe*”.	Aircraft is at 6 NM and is actually at 3240 ft QNH instead of 3360 ft QNH, discrepancy is not noticed
21:05:27	Commander: “*Sechs Meile drüü drüü isch checked* ...” Copilot: “Yes!” Commander: “*S’Minimum isch 2400 grundet*”	Last reference to a distance from VOR KLO by the crew First reference to MDA
21:05:36	Commander: “Flaps three three (33°)” – Copilot: “Speed checked, flaps three three selected” Commander: “Final check” – Copilot: “Final check, confirm three greens” – Commander: “Is checked”	A sequence which occupies both of them now starts

UTC	Event	Comment
21:05:44	Commander: "*Hundert sächzäh* (116 kt)" – Copilot: "Full flaps...set" – Commander: "Checked" – Copilot: "Cabin report received" – Commander: "Received" – Copilot: "Landing clearance to go" – Commander: "*Isch* to go" – Copilot: "Yes!"	Configuration is again changed, both are occupied
21:05:55	Commander: "*Ground contact hämmer, hä?*" – Copilot: "Yes "	HB-IXM is at approx. 2680 QNH ft, approaching the MDA, commander realizes this and looks outside again. In accordance with the division of labour, as PF he should be looking exclusively at the instruments.
21:05:59	Commander: "*Mä hät gseit, Pischte hät er spaat gseeh da...approaching minimum descent altitude...da hämmer echli ground contact*"	Commander remembers the report from CRX 3891, looks outside again. No cross-comparison with the distance is mentioned
21:06:10	Commander: "*...zwo vier, s'Minimum...ground contact han ich...mer gönd wiiter im Moment...es chunnt füre...ground contact hämmer...mer gönd wiieter*" Copilot, meanwhile, quietly: "Two, four"	HB-IXM reaches MDA Copilot indicates MDA
21:06:22	RA callout: "Five hundred"	The aircraft is at 2150 ft QNH
21:06:25	Commander: "*Sch*****, 2 Meile hät er gseit, gseht er d'Pischte*" At this time HB-IXM is at 4 NM DME KLO	RA callout presumably causes first uneasiness. Commander again remembers statement by CRX 3891. However, HB-IXM is still too far from the runway to be able to make visual contact with the approach lights. No further cross-comparison with DME distance takes place.
21:06:31	Commander: "*Zwöi tuusig* (2000)"	
21:06:32	RA callout: "Minimums"	300 ft RA
21:06:33	Commander: "*...go around mache*?" – Parallel with this, ATC with landing clearance, cavalry charge	
21:06:34	Commander: "Go around!" – Copilot: "Go around!"	
21:06:36	Beginning of impact noise, in parallel RA callout: "One hundred"	100 ft RA
21:10:32	ATC raises alarm	

Appendix 2: Oil Indicator as Installed

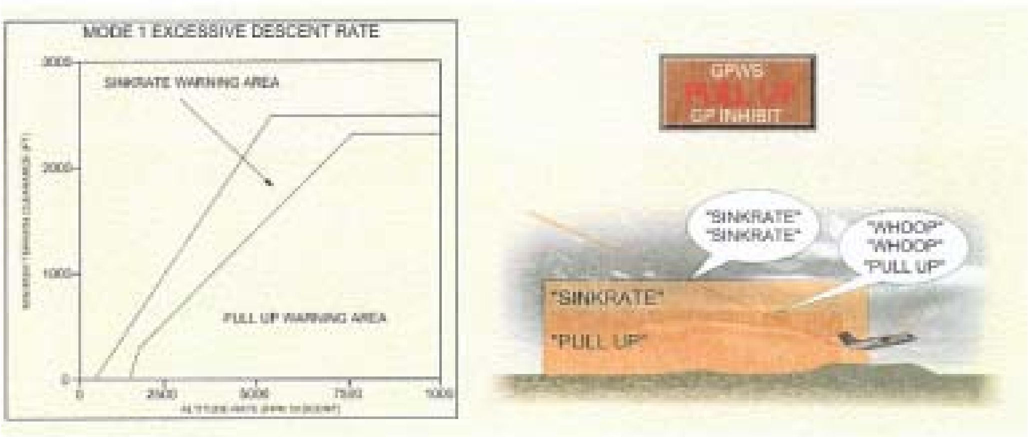
Appendix 3: Warning Envelope of the Ground Proximity Warning System (GPWS)



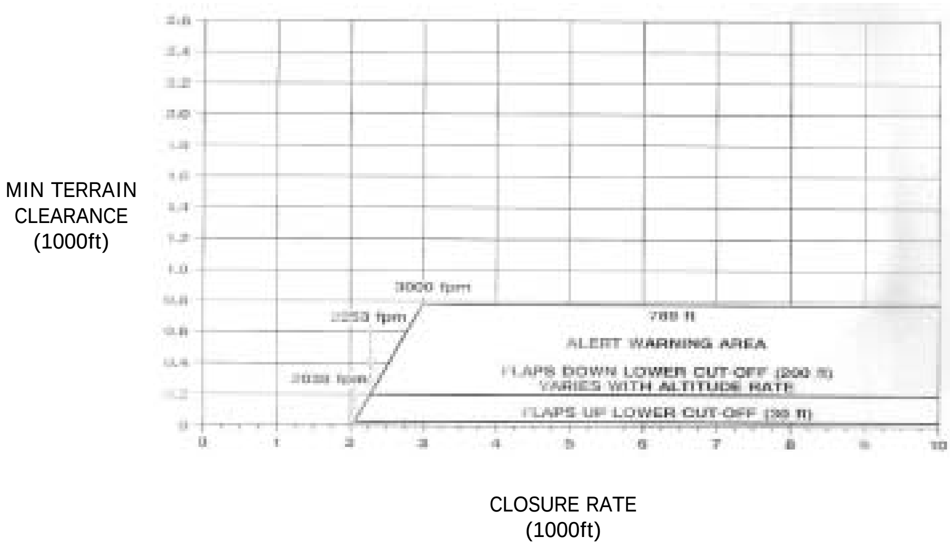
Mode 1. Excessive sink rate

This mode is effective in all aircraft configurations and provides for flight over level ground when the aircraft is losing height at an excessive rate. The GPWC compares the IRS vertical speed (or ADC barometric altitude sink rate if IRS is not available) with the available terrain clearance to determine if a hazard exists. The warning is given to allow time for a gentle recovery manoeuvre. Thus, the smaller the terrain clearance the smaller the sink rate that triggers a warning. Below certain heights, it is assumed that the aircraft is making a deliberate descent and a greater sink rate is tolerated. When using IRS data, the lower limit for this mode is 10 ft. When using ADC data below 30 ft., the GPWS is inhibited to avoid nuisance warnings resulting from ground effect on the static pressure system. This mode has two unique boundaries. The outer boundary advises the pilot that the rate of descent for a given altitude is excessive and the condition should be adjusted.

The warnings are the PULL UP annunciators illuminating and a SINK RATE SINK RATE audible warning. If the second boundary is penetrated, a WHOOP WHOOP PULL UP audible warning sounds.



If the envelope is penetrated, the aural warning "SINK RATE" is given and PULL UP warning light on the glareshield illuminates until the envelope is left. If descent continues and the inner envelope is penetrated, the aural warning "WHOOP WHOOP PULL UP" is given. It can be seen that the PULL UP warning occurs at a higher radio altitude for higher descent rates. This is designed to provide sufficient response time for the pilot to recover.

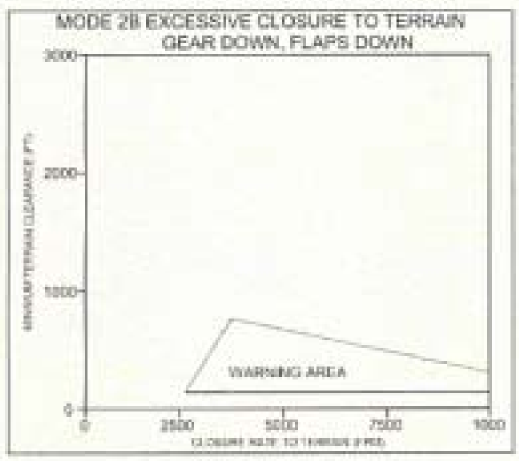


Mode 2. Excessive terrain closure rate

This mode provides for level flight in which the terrain is rising. Terrain closure rate is derived from radio altitude and is compared against terrain clearance. Two sub-modes (mode 2a and mode 2b)are provided to afford adequate protection in cruise while keeping nuisance warnings to a minimum during approach.

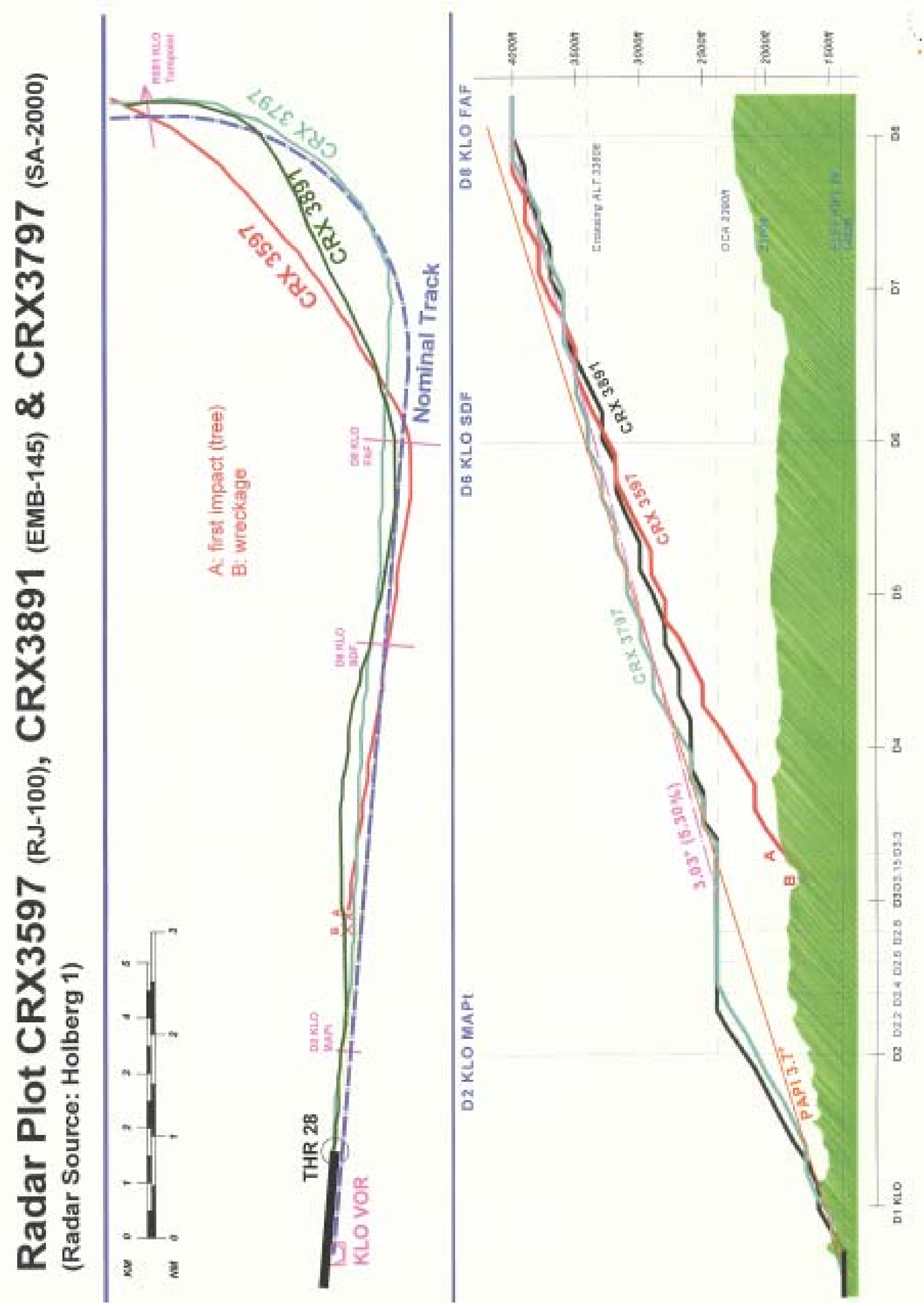
Mode 2b. With the flaps selected to land, this mode operates between 789 ft and 200ft. The slope of the flight path reflects a ground closure rate appropriate to landing. The mode is also active when making an ILS approach with a glide slope deviation less than 1.3 dot. It can be selected by pressing the FLAP WARN OVRD switch.

Mode 2b warnings are red PULL UP annunciators and an audible warning. The warning is cancelled when the aircraft has gained 300ft altitude and is on a safe flight path.



Mode 2b. During an approach with either the flaps in the landing configuration or with the aircraft established on an ILS, the envelope is modified to allow passage over hilly terrain without triggering a warning. The warnings are the same as mode 2a

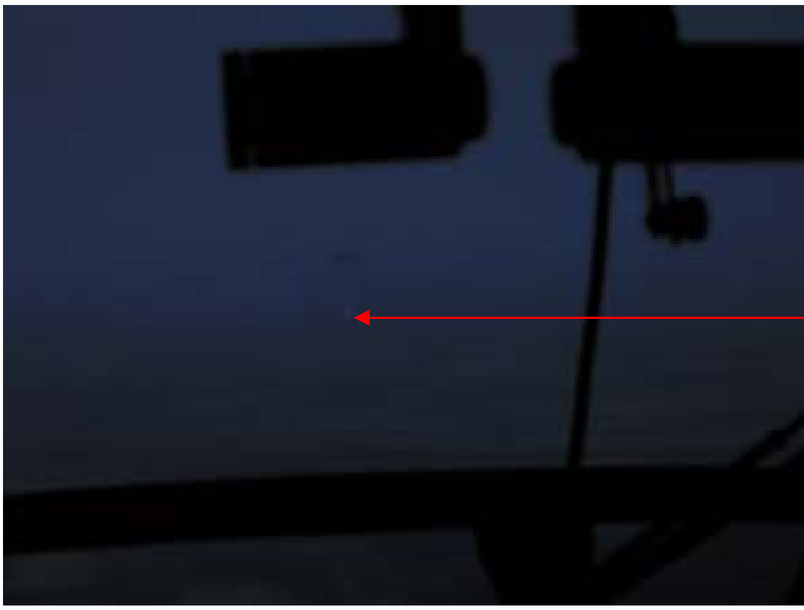
Appendix 4: Approach Profile of Flight CRX 3597



Appendix 5: Simulator Comparison Flights to Runway 28

Runway 28 as seen from the Visual Descent Point (VDP) at 2390 ft AMSL by day with a visibility of more than 10 km

Same condition, but with a visibility of 5000 m



Approach lights

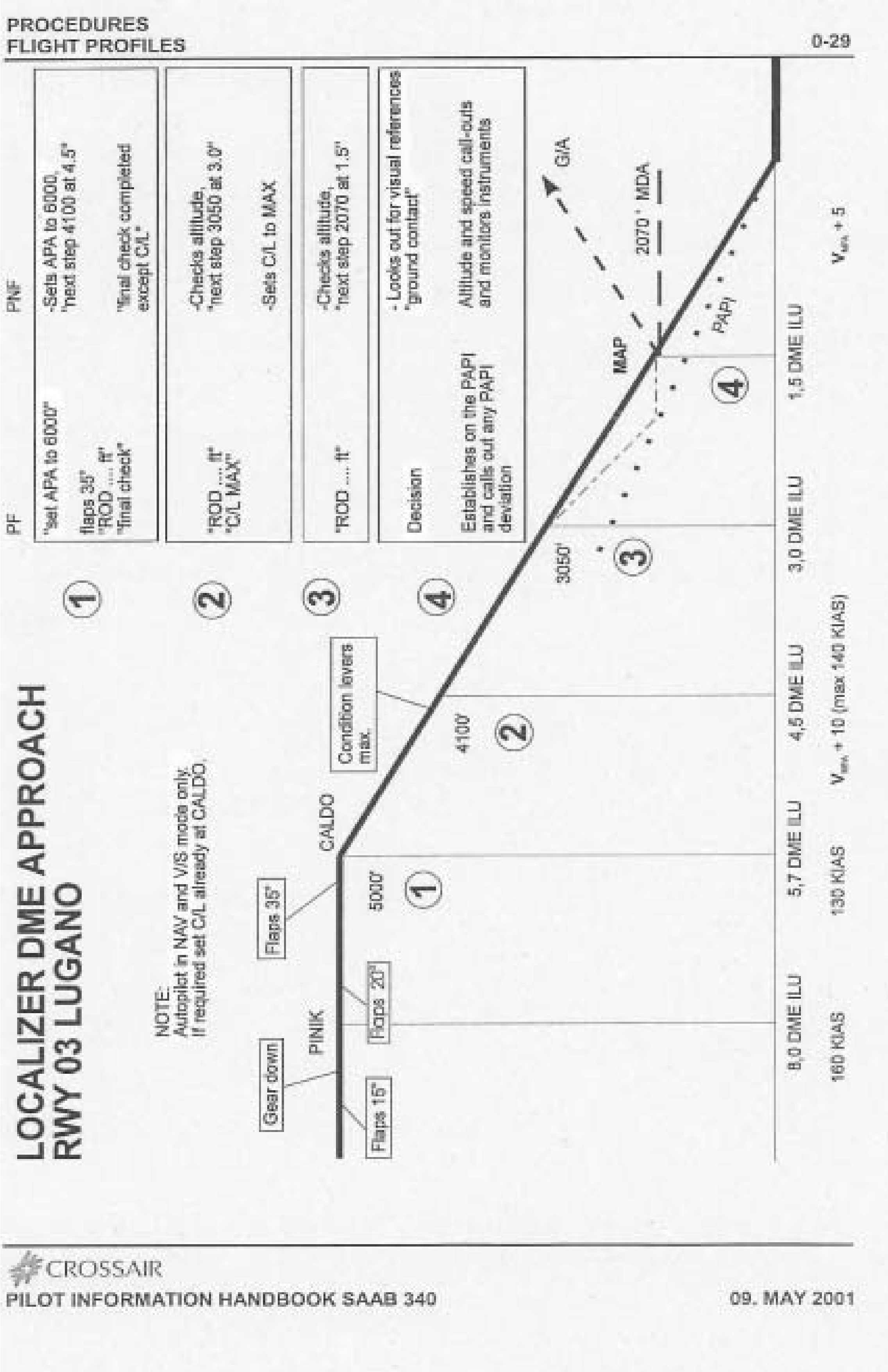
Obviously on this picture one can see that a further reduction of the visibility down to 3500 m makes it difficult to determine the position of the approach lights or the threshold markings. With a visibility of 2000 m it becomes impossible to see the approach lights or the threshold markings.

The following picture was made in reality. The aircraft was located as well approx. 1000 ft (MDA) above the threshold elevation on a three degree approach path. The meteorological conditions were as follows: Broken 2000 ft with a visibility of 5000 m.

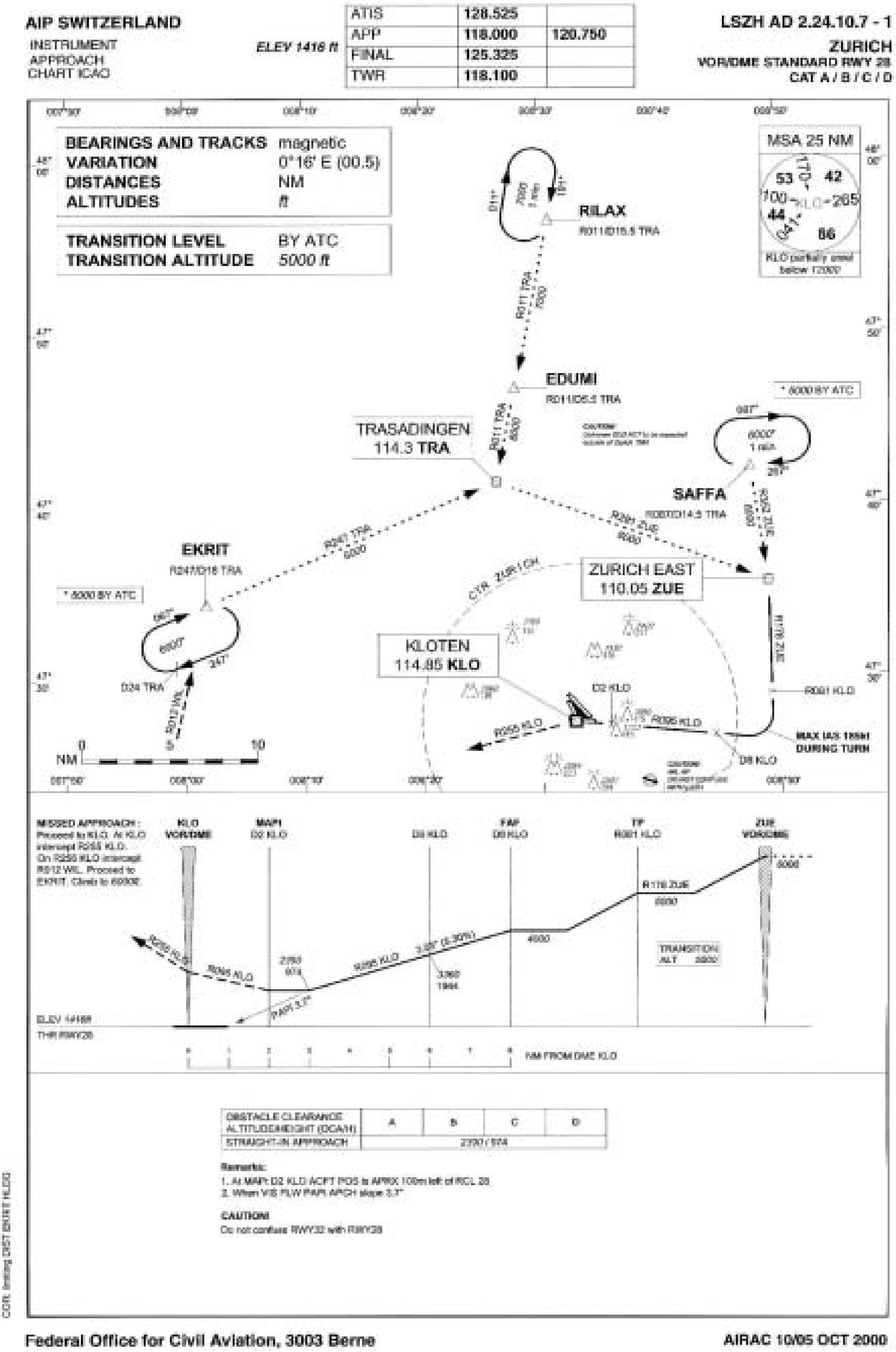
Approach lights

The picture below shows the visual situation as seen by the pilot of an aircraft being at the minimum descent altitude, and approaching the missed approach point with a visibility of 10 km. More or less out of this situation the two preceding traffic CRX3891 (at D2.2 KLO) and CRX3797 (D2.4 KLO) started their final approach descents for landing.

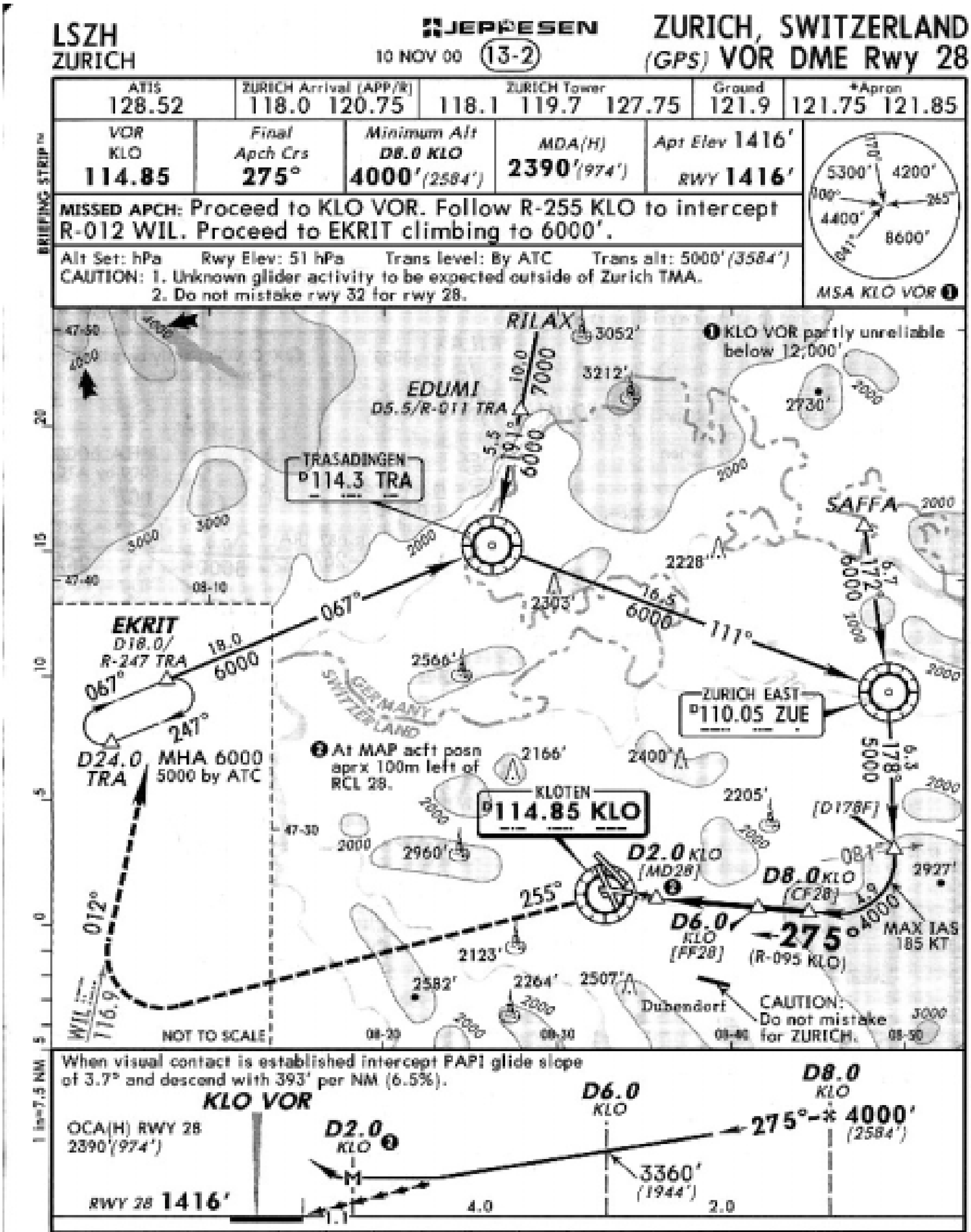
Appendix 6: Localizer DME Approach to Runway 03 in Lugano (today IGS Approach Rwy 01)



Appendix 7: Approach Chart AIP Switzerland LSZH AD 2.24.10.7-1



Appendix 8: Approach Chart 13-2 Zurich, Switzerland, Jeppesen Inc.



Gnd speed-Kts		70	90	100	120	140	160
Descent Gradient D8.0 KLO - MDA	5.3%	376	483	537	644	751	859
MAP at D2.0 KLO							

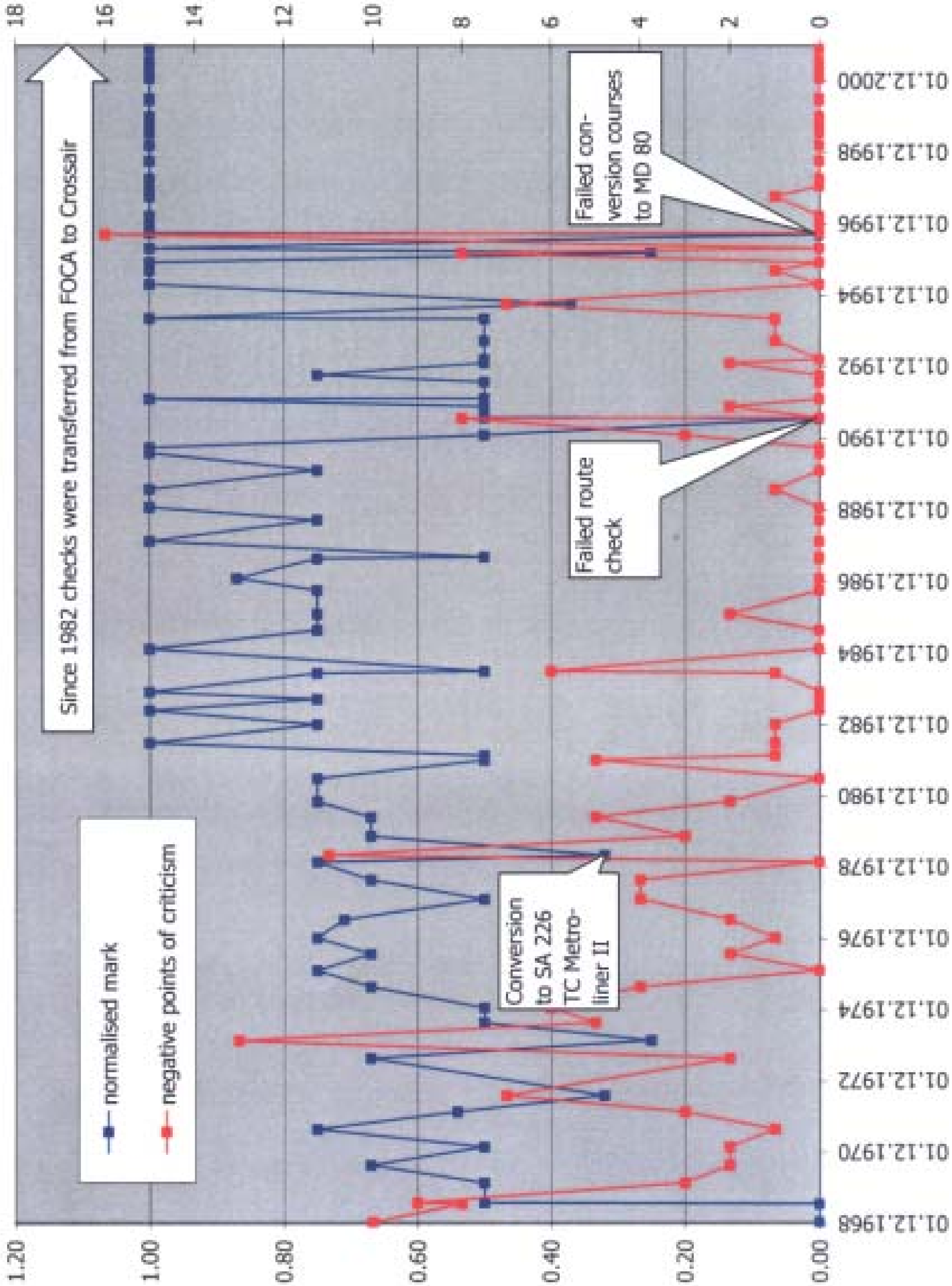
HIALS REIL PAPI — KLO 114.85

JAR-OPS	STRAIGHT-IN LANDING RWY 28		CIRCLE-TO-LAND
	MDA(H) 2390'(974')		
		ALS out	
A	RVR 1500m	A	NOT APPLICABLE
B		B	
C	RVR 2000m	C	
D		D	

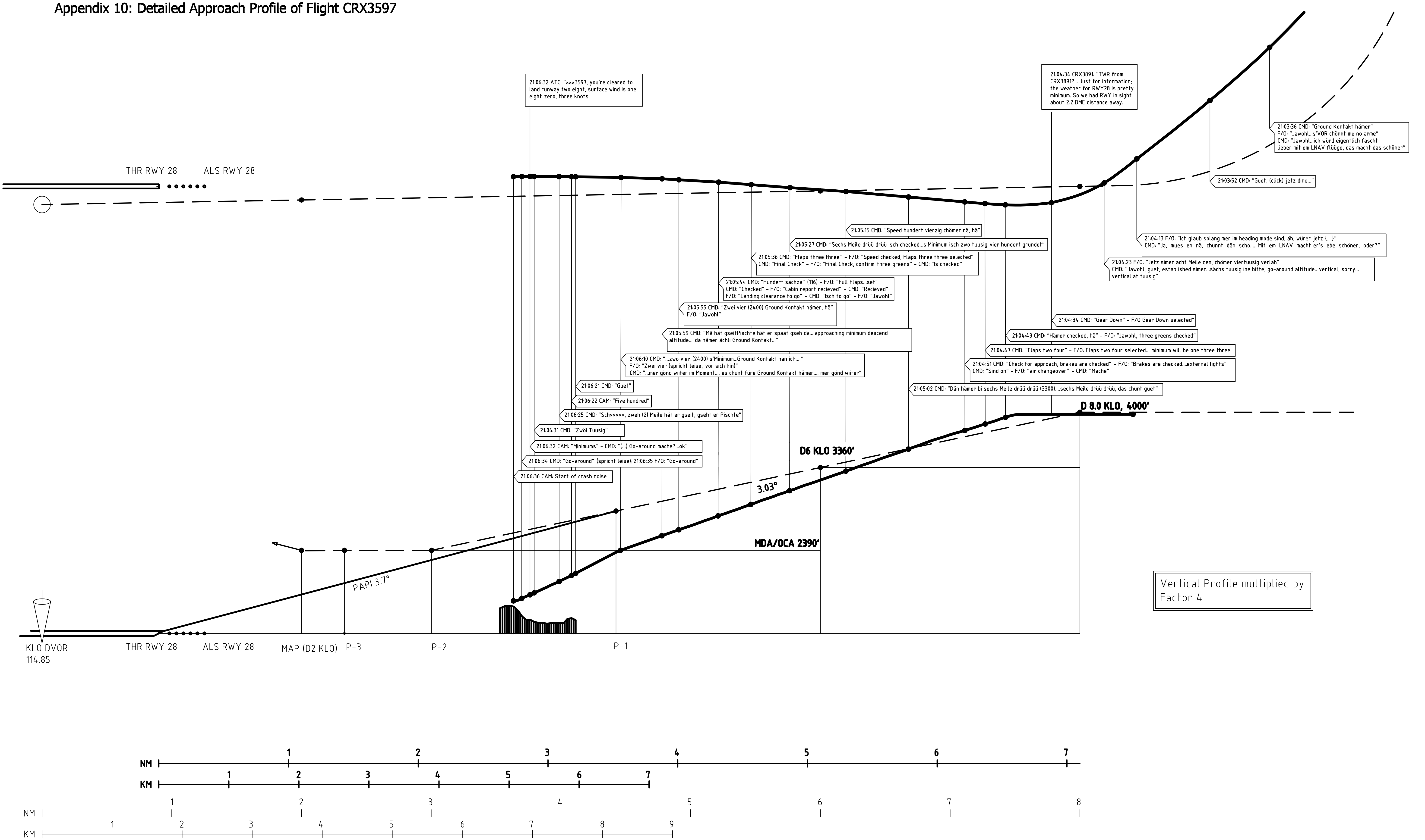
CHANGES: GPS waypoints.

Appendix 9

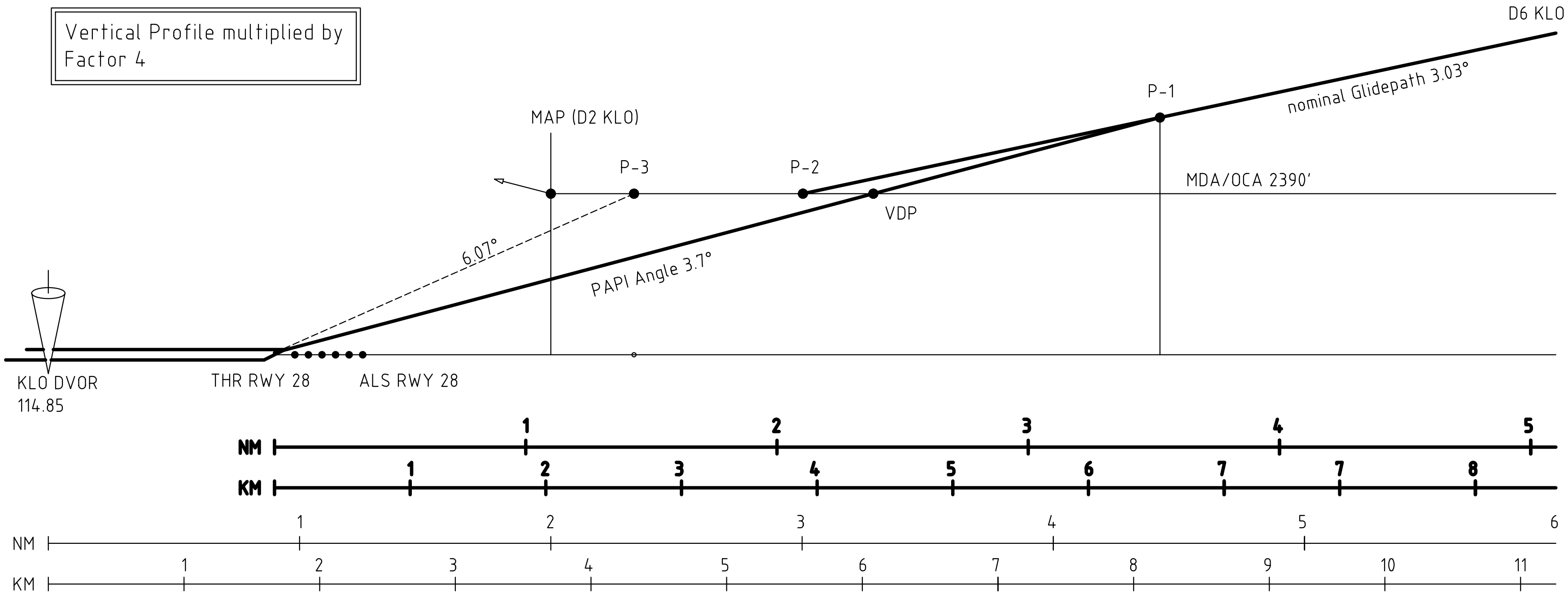
Graphical compilation of the results of the commander's line, route and simulator checks. Since the marking scale varied over time, the marks were normalised so as to make direct comparison possible (blue data series). A value of 0.5 therefore corresponds to average performance. The number of negative points of criticism mentioned on the checksheets has also been entered (red data series).



Appendix 10: Detailed Approach Profile of Flight CRX3597



Appendix 11: Standard VOR/DME Approach - Illustartion of the Final Segment



Point	above MDA	above PAPI	Dist. THR	Dist. ALS	Definition
P-1	140m/459ft	0m/0ft	6527m/3.5NM	5877m/3.2NM	Intersection of the nominal Glidpath (3.03°) and the PAPI Angle (3.7°)
VDP	0m/0ft	0m/0ft	4359m/2.4NM	3709m/2.1NM	Intersection of the PAPI Angle (3.7°) and the MDA/OCA (2390 ft)
P-2	0m/0ft	31m/102ft	3878m/2.1NM	3228m/1.8NM	Intersection of the nominal Glidepath (3.03°) and the MDA/OCA (2390 ft)
P-3	0m/0ft	110m/360ft	2650m/1.4NM	2000m/1.1NM	Point on the MDA/OCA (2390 ft) 2000m in front of the first approachlight along Rwy axis
MAP	0m/0ft	150m/492ft	2037m/1.1NM	1387m/0.8NM	Missed approach point