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Swiss Accident Investigation Board SAIB

Aviation Division

Final Report No. 2158 by the Swiss Accident Investigation Board SAIB

concerning the serious incident involving the AVRO 146-RJ100 aircraft, registration HB-IXP, under flight number LX 5187

on 20 July 2011

at Zurich-Kloten airport

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Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass die Besatzung nach dem Ausfall eines einzelnen Systems die verbliebenen Systeme nicht zweckmässig einsetzte und eine sichere Führung des Flugzeuges zeitweise nicht mehr gewährleistet war.

Dabei hat die Untersuchung die folgenden Faktoren ermittelt, welche zum schweren Vorfall geführt haben:

- Die Besatzung hatte eine grundsätzlich unzutreffende Vorstellung des dem Systemausfall zugrunde liegenden technischen Problems.
- Dem Copiloten gelang es nicht, nach dem Ausfall von *autopilot, autothrottle* und *flight director* das Flugzeug manuell weiterzuführen.
- Der Kommandant konnte das Flugzeug nur eingeschränkt mit Hilfe der Notinstrumente fliegen.
- Die Zusammenarbeit der Besatzung (*crew resource management* - CRM) war mangelhaft.
- Die Besatzung führte keine ausreichende Situationsanalyse durch.
- Ein im Simulator geübtes Fliegen nach *standby instruments* und nach *raw data* konnte im Ernstfall nur teilweise umgesetzt werden.

General information on this report

This report contains the Swiss Accident Investigation Board's (SAIB) conclusions on the circumstances and causes of the serious incident which is the subject of the investigation.

In accordance with Art 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the accident investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All times in this report, unless otherwise indicated, follow the coordinated universal time (UTC) format. At the time of the serious incident, Central European Summer Time (CEST) applied as local time (LT) in Switzerland. The relation between LT, CEST and UTC is:
LT = CEST = UTC + 2 hours.

For reasons of protection of privacy, the masculine form is used in this report for all natural persons, regardless of their gender.

Contents

Final Report

Synopsis

Owner	Swiss International Air Lines Ltd. Postfach, 4002 Basel, Switzerland
Operator	Swiss European Air Lines AG Malzgasse 15, 4052 Basel, Switzerland
Manufacturer	British Aerospace (regional aircraft) Ltd.
Aircraft type	AVRO 146-RJ100
Country of registration	Switzerland
Registration	HB-IXP
Location	Zurich-Kloten airport
Date and time	20 July 2011, 09:52 UTC

Investigation

The serious incident occurred on 20 July 2011 at 09:52 UTC. The notification was received at 15:40 UTC on the same day by the Aircraft Accident Investigation Bureau (AAIB), who opened the investigation at approximately 17:00 UTC. The AAIB informed the United Kingdom authorities via the usual reporting channels about the serious incident. The United Kingdom investigating authority offered the AAIB its support, but did not designate an authorised representative.

The present final report is published by the Swiss Accident Investigation Board (SAIB).

Summary

On 20 July 2011, at 08:53 UTC, the AVRO 146-RJ100 aircraft, registration HB-IXP, took off under flight number LX 5187 and radio call sign "Swiss five one eight seven" on a ferry flight from Nuremberg to Zurich.

Shortly after take-off, at a height of approximately 400 ft above the ground, when the aircraft was still under manual control, the autothrottle (AT) and the flight director (FD)[1] failed simultaneously. These could subsequently be regained, together with the autopilot (AP).

After an otherwise uneventful flight, the crew assumed that all systems were available without any restrictions. LX 5187 then received clearance for an approach on runway 14. When lined up on the localiser and at an altitude of 4000 ft AMSL, at 09:51:40 UTC the autopilot, the autothrottle and the flight director failed. A few seconds later the acoustic alert "bank angle" for a high bank angle sounded.

At 09:52:04 UTC, the red ATT (attitude) and HDG (heading) warnings appeared on the commander's electronic flight instrument system (EFIS) and the navigation data disappeared. On the copilot's EFIS displays the indications remained stable and allowed the aircraft to be controlled manually.

The copilot no longer trusted his indications; the commander took over control of the aircraft using standby instruments and also continued to conduct radio communications. Shortly af-

[1] The flight director (FD) is a graphic symbol on the primary flight display (PFD) of this aircraft. By means of this display, an attitude change command is given in order to bring the aircraft onto the pitch or bank angle as specified by the flight guidance computer (FGC). If the autopilot is engaged, these commands are implemented directly, without any involvement of the pilot.

terwards, he reported to air traffic control that there were navigation problems and that no heading indication was available. During the subsequent flight phase, significant oscillations in attitude occurred and the rate of climb and descent, as well as the aircraft's airspeed, varied considerably. The air traffic control officer (ATCO) guided the aircraft with left/right instructions into a position for a repeated approach. In addition, arriving and departing traffic on Zurich Airport was halted in order to provide flight LX 5187 with optimal support.

In accordance with the abnormal checklist, the crew switched the EFIS selector to the "BOTH 2" position and at 09:58:52 UTC reported that they would shortly have the indications available again.

A little later the ATCO gave clearance for an approach on runway 14 and the crew, who had reengaged the AT and the FD, reported at 10:03:21 UTC that they were *"fully established"*. The approach was carried out manually.

The subsequent final approach and landing were uneventful.

Causes

The serious incident is attributable to the fact that after the failure of a single system the crew did not use the remaining systems appropriately and safe control of the aircraft was at times no longer guaranteed.

The investigation identified the following factors which led to the serious incident:

- The crew had a fundamentally unfounded picture about the technical problem causing the system failure.
- After the loss of the autopilot, autothrottle and flight director, the copilot did not manage to continue to control the aircraft manually.
- The commander was able to fly the aircraft only to a limited extent with the aid of the standby instruments.
- Crew resource management (CRM) was unsatisfactory.
- The crew did not carry out a sufficient analysis of the situation.
- An exercise which had been practised in the simulator using standby instruments and raw data could only be partially implemented in the actual case.

Safety recommendations

In the context of the investigation, three safety recommendations were issued.

According to the provisions of Annex 13 of the ICAO, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which has to decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, establishment or individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

In the Ordinance on the Investigation of Aircraft Accidents and Serious Incidents (OIAASI), the Swiss legislation provides for the following regulation regarding implementation:

"Art. 32 Safety recommendations

[1] DETEC, on the basis of the safety recommendations in the SAIB reports and in the foreign reports, addresses implementation orders or recommendations to the FOCA.

[2] The FOCA informs DETEC periodically about the implementation of the orders or recommendations pronounced.

[3] DETEC informs the SAIB at least twice a year on the state of implementation by the FOCA."

1 Factual information

1.1 Pre-history and history of the flight

1.1.1 General

For the following description of the pre-history and the history of the flight, the recordings of the radio communication, the flight data recorder, radar data and the statements of the crew members and air traffic control officers were used. During the flight, excluding the approach and landing in Zurich, the copilot was acting as pilot flying (PF) and the commander was acting as pilot not flying (PNF).

The flight took place under instrument flight rules. It was a ferry flight.

1.1.2 Pre-history

On 19 July 2011 at 12:54 UTC, the AVRO 146-RJ100, registration HB-IXP, and under flight number LX 1191, taxied for take-off in Nuremberg (EDDN) on a scheduled flight to Zurich (LSZH). After setting the take-off power, at a speed of approximately 60 knots the "master caution", "HYD" and "LO QTY"[2] displays appeared. The crew aborted the take-off and taxied back to the stand, where they shut down the engines at 13:00 UTC.

The subsequent investigation revealed a leak in the hydraulic system. The fault could be remedied by replacing a seal and the aircraft was again released for operation on 20 July 2011 at 06:05 UTC. For operational reasons, the airline decided to fly the aircraft without passengers to Zurich on the same day.

On the night of the 19 to 20 July 2011 it rained heavily in Nuremberg and when the crew took over the aircraft they noticed that the cabin floor was wet in the entrance area. According to the operator, failures of the flight guidance system (FGS) occurred often under such conditions. This was known to crews.

1.1.3 History of the flight

On 20 July 2011 at 08:53 UTC, the AVRO 146-RJ100 aircraft, registered as HB-IXP, took off under flight number LX 5187 and radio call sign "Swiss five one eight seven" on a ferry flight from Nuremberg to Zurich.

Shortly after take-off, at a height of approximately 400 ft above ground, the autothrottle (AT) and the flight director (FD) failed simultaneously. The aircraft was being controlled manually in this phase. The copilot continued the climb and after retracting the flaps (clean up) the commander dealt with the failure of the AT and FD. The commander later testified that this was a known problem, especially after the aircraft had been on the ground for a long period of time in heavy rain. This would have led to a failure of the active flight guidance computer (FGC).

In accordance with the airline's operating procedures, the crew had selected FGC 2 as the active FGC for the take-off[3]. The commander then switched to FGC 1 and it was possible to reengage the AT, FD and AP.

After an otherwise uneventful flight, at 09:33 UTC the crew joined the RILAX holding pattern at flight level 130 for traffic reasons. In the holding pattern, the commander again selected FGC 2 because he wanted to see whether the problem after the take-off in Nuremberg still existed. Everything was functioning normally and the crew decided to leave FGC 2 as the active FGC.

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[2] The "LO QTY" display stands for low quantity and indicates a low quantity of oil in a hydraulic system.

[3] On days with an even-numbered date, FGC 2 is used, whilst on days with an odd date FGC 1 is used.

At 09:49:25 UTC, after leaving the RILAX holding pattern, the crew of LX 5187 received the following clearance from the Zurich final air traffic control officer (ATCO): *"Swiss five one eight seven, left heading one six zero, intercept localizer one four."* Thirty seconds later the crew received clearance to descend to 4000 ft QNH and to follow the beam of the runway 14 instrument landing system (ILS).

At 09:49:52 UTC the system captured the localizer and followed it. At 09:51:17 UTC, the ATCO instructed the crew to reduce their speed to 160 knots; the crew acknowledged immediately. They then extended the flaps to the 18 degree position. A few seconds later, at 09:51:40 UTC, the inertial reference unit 1 (IRU 1) began to output an erratic bank angle signal and at the same time the AP, FD and AT failed. Since the commander was convinced that the Nuremberg take-off scenario was being repeated, he immediately switched back to FGC 1 and ordered the copilot to continue flying without the autopilot. At this time the aircraft was flying under instrument meteorological conditions (IMC) in level flight at 4000 ft QNH. In order to reduce speed the throttles were in idle and the interception of the glide slope was eminent. A few seconds later the acoustic warning "bank angle" sounded. The copilot stated that, irritated by this acoustic warning, he had looked over at the commander's instruments to make sure that his own instruments were in order. On the commander's side, an unstable bank angle was displayed on the primary flight display (PFD) at this time. At this moment, the copilot's PFD indicated a bank angle corresponding to level flight.

At 09:52:04 UTC the warning messages ATT and HDG appeared on the commander's EFIS displays in red. Just a few seconds later, at 09:52:16 UTC, the ATCO asked the crew: *"Swiss five one eight seven, established?"* and the latter confirmed immediately with *"affirm"*.

The commander stated that they both then looked at the standby horizon and believed this was indicating a somewhat *"surreal"* flight attitude.

The ATCO observed that the aircraft's radar symbol was moving away from the approach centerline to the east and was showing a continuation of the descent. Immediately after the *"affirm"* report from the crew, the ATCO therefore gave the instruction: *"I see you left of the centerline, turn immediately right and climb immediately to four thousand feet."* At this time the aircraft was located 0.45 NM to the east of the approach centerline at a distance of approximately 6 NM from the runway 14 threshold and at an altitude of 3300 ft AMSL. With reference to the glide slope, it was therefore flying approximately at the nominal glide angle. According to his own statements, by means of this instruction the ATCO intended to bring the aircraft back onto the approach centerline. The crew then answered that they had a navigation failure, whereupon the ATCO, with a view to a repositioning, instructed to crew to climb immediately to an altitude of 5000 ft QNH and to fly a heading of 100 degrees (cf. Annex 1).

Since the copilot told the commander that he no longer trusted his attitude indications, the latter took control of the aircraft during the climb. According to his statements, he then used the standby instruments. In order to let the copilot acquire an overall view and work through the corresponding checklist, the commander subsequently also handled the radio communications. He informed the ATCO at 09:53:05 UTC as follows: *"OK, we have a problem with our heading indications so please give us a left and a right ah indication."* The ATCO obeyed this request immediately. He also monitored compliance of the flown altitude and in the event of deviations immediately gave appropriate correction instructions.

At 09:53:35 UTC, retraction of the flaps began from the 18 degree position to zero degrees. Between 09:53:40 UTC and 09:54:08 UTC the aircraft descended at an average rate of descent of almost 2500 ft/min, and then climbed again until

09:54:32 UTC at an average rate of climb of approximately 2600 ft/min. At the same time the engine power levers were set to a power lever angle (PLA) between 45 and 70 degrees and the airspeed varied within a range of 160 to 240 knots (cf. Annex 2).

By agreement with the other ATCOs, the ATCO in the interim did not allow any further approaches at Zurich airport and kept the frequency clear in order to provide optimal support to the crew of LX 5187. At 09:55:24 UTC the crew reported: *"At ah five thousand two hundred feet at the moment and PAN, PAN, PAN, PAN, PAN, PAN, Swiss five one eight seven. Lost our primary navigation displays."* Since it was impossible to estimate how the situation would develop, no further take-off clearances were given by air traffic control.

At 09:55:53 UTC the ATCO informed the crew as follows: *"Swiss five one eight seven, you are now the only traffic on this frequency. Are you able to fly heading?"* The crew replied in the negative, whereupon the ATCO gave the following instruction: *"Roger, left turn until I say stop."* At this time, the aircraft was on a northerly heading at an altitude of 5000 ft QNH.

When the ATCO asked at 09:56:06 UTC: *"Swiss five one eight seven, will you be able to fly the ILS one four?"* the crew replied: *"Stand by, Swiss five one eight seven."* The question asked at 09:57:41 UTC, as to whether LX 5187 was still in a left turn, had to be repeated twice by the ATCO before the question was answered in the affirmative at 09:58:04 UTC by the crew.

In the meantime, the copilot had begun to work through the abnormal checklist for the *"Loss of IRS"* procedure and asked the commander accordingly to set the EFIS selector switch to "BOTH 2" (cf. Annexes 3 and 5). As a result, the indications on the commander's EFIS displays reappeared, the flight director (FD) and the autothrottle (AT) could be reengaged and the crew reported at 09:58:52 UTC: *"Ah we have the system back any moment."* The ATCO promptly informed the crew that they were in the base leg for an ILS approach on runway 14, that they were still 22 miles from touchdown and asked if they could accept that. The crew replied: *"That's perfect"*.

To the ATCO's question at 10:00:14 UTC as to whether the crew of flight LX 5187 wanted a further delay, they replied: *"negative"*. At this time the aircraft was five miles from the localizer. The ATCO then instructed the crew: *"Roger. So continue present heading. Maintain five thousand feet, vectoring ILS one four."*

At 10:00:37 UTC, the ATCO informed the crew as follows: *"I see you again in a left turn, Swiss five one eight seven, make a right turn, start right turn until I say stop."* The crew acknowledged this information and ten seconds later the ATCO instructed the crew to end the right turn. At 10:01:24 UTC, after a preceding clearance to descend to 4000 ft QNH, the ATCO gave the following instruction: *"Swiss five one eight seven, now left heading one seven zero, cleared ILS one four, report established."*

The crew reported at 10:02:36 UTC: *"Established on the localizer. Glide path two dots below"* and at 10:03:21 UTC they confirmed: *"Swiss five eight one seven is now fully established."*

The subsequent final approach and landing were uneventful.

1.1.4 Location of the serious incident

Approach sector East, Zurich-Kloten airport.

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew	Passengers	Total number of occupants	Others
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	2	0	2	Not applicable
Total	2	0	2	0

1.2.2 Nationality of the occupants of the aircraft

The crew consisted of two Swiss citizens.

1.3 Damage to aircraft

The aircraft was not damaged.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 Commander

1.5.1.1 General

Person	Swiss citizen, born 1957
Licence	Air transport pilot licence aeroplane – ATPL(A) according to joint aviation requirements (JAR), first issued by the Federal Office of Civil Aviation (FOCA) on 3 July 1998, valid till 11 May 2016
Ratings	Type rating AVRORJ/BAe146 as pilot in command, valid till 27 May 2012
	Language proficiency: English level 4, valid till 27 May 2013
	Night flying NIT(A)
Instrument flying rating	Instrument flight aircraft IR(A)
	Category III instrument approaches with AVRORJ/BAe146, valid till 27 May 2012
Last proficiency check	Simulator check on 3 May 2011
Medical fitness certificate	Class 1/2, restrictions: VNL (shall have available corrective spectacles for near vision and carry a spare set of spectacles)

	Valid from 28 March 2011 till 25 April 2012
Last medical examination	28 March 2011

1.5.1.2 Flying experience

Total	9430:00 hours
on the incident type	3480:00 hours
during the last 90 days	56:47 hours
of which on the incident type	56:47 hours
as commander	7541:14 hours

1.5.1.3 Crew times

Start of duty in the 48 hours before the serious incident	18 July 2011, off duty 19 July 2011, off duty 20 July 2011, 06:00 UTC
End of duty in the 48 hours before the serious incident	18 July 2011, off duty 19 July 2011, off duty
Flight duty times in the 48 hours before the serious incident	18 July 2011, 0 hours 19 July 2011, 0 hours
Rest times in the 48 hours before the serious incident	from 18 to 19 July, off duty from 19 to 20 July, off duty
Flight duty time at the time of the serious incident	3:52 hours

1.5.1.4 Qualifications

In addition to the qualification documents concerning the years prior to the serious incident, the investigation also had at its disposal documentation on the commander's selection procedure as a pilot and as a candidate for commander. In order to better assess his performance with reference to a promotion to commander, he was assessed in day-to-day operations as a co-pilot by line pilots not trained specifically for this task. Some of the assessments produced in this way exhibit some very contradictory statements about his suitability as a commander.

The qualification documentation for the previous four years describe the commander as good to very good. It is attested that he fully understands his role as a commander in terms of crew management. It is explicitly mentioned that he involves the copilot in all decisions, that he complied with the "PPAA" decision-making principle defined by the operator (cf. chapter 1.17. 2) and takes full account of crew resource management (CRM) (cf. chapter 1.17.3). Control management of the aircraft is assessed as calm and coordinated.

No actual weaknesses are listed.

In the general assessment under *"flight operation"* there is a comment in the licence proficiency check (LPC) in May 2011 [translated from German]: "In the OEI GA (one engine inoperative – go around) there was some over-rotation at the beginning. In the subsequent left turn, after an automatic disengagement of the AP, an unstable flight attitude occurred, but this was corrected quickly and purposefully."

In the LPC in March 2008 there is the comment [translated from German]: "Isolated navigation errors because of inadequate recourse to basic navigation in the event of FMS problems." The LPC in April 2007 includes among other things [translated from German}: "He is still excessively unsettled by surprise incidents and in the process loses the overview (control)."

1.5.2 Copilot

1.5.2.1 General

Person	Swiss citizen, born 1974
Licence	Commercial pilot licence aeroplane – CPL(A) according to joint aviation requirements (JAR), first issued by the Federal Office of Civil Aviation (FOCA) on 28 October 1999, valid till 16 June 2016
Ratings	Type rating AVRORJ/BAe146 as copilot, valid till 5 September 2012 Language proficiency: English level 4, valid till 30 August 2014 Night flight NIT(A)
Instrument flying rating	Instrument flight aircraft IR(A) Category III instrument approaches with AVRORJ/BAe146, valid till 5 September 2012
Last proficiency check	Simulator check on 5 June 2011
Medical fitness certificate	Class 1 / 2 without restrictions Valid from 24 August 2010 till 17 September 2011
Last medical examination	24 August 2010

1.5.2.2 Flying experience

Total	1529:13 hours
on the incident type	1058:42 hours
during the last 90 days	172:45 hours
of which on the incident type	172:45 hours

1.5.2.3 Crew times

Start of duty in the 48 hours before the serious incident	18 July 2011, off duty 19 July 2011, off duty 20 July 2011, 06:00 UTC
End of duty in the 48 hours before the serious incident	18 July 2011, off duty 19 July 2011, off duty
Flight duty times in the 48 hours before the serious incident	18 July 2011, 0 hours 19 July 2011, 0 hours
Rest times in the 48 hours before the serious incident	from 18 to 19 July, off duty from 19 to 20 July, off duty

Flight duty time at the time of the serious incident	3:52 hours

1.5.2.4 Qualifications

In addition to the qualification documentation since his employment as copilot by Swiss European Air Lines in June 2009, the investigation also had at its disposal the results of previous aptitude assessments of the copilot.

Since the employment of the copilot, the qualification documentation consistently describe good to very good performance. There are several explicit mentions of the fact that the copilot analyzes situations well and consistently applies the known "PPAA" (cf. chapter 1.17.2).

On the basis of the good to above-average qualifications, on 1 December the copilot was appointed as a Training First Officer. As an additional crew member, a Training First Officer has the primary task of supporting new copilots during the initial training rotations. He had applied for this position in March 2011 and underwent a corresponding assessment in June 2011.

1.5.3 Air traffic control officer

Function	Final approach control (FIN)
Person	Swiss citizen, born 1970
Start of duty on the incident day	05:40 UTC
Licence	Air traffic controller licence based on European Community Directive 2006/23, first issued by the Federal Office of Civil Aviation (FOCA) on 15 November 1996, valid till 20 February 2012
Relevant ratings	APS approach control surveillance
Medical fitness certificate	Class 3, without restrictions; from 20 January 2010, valid till 21 February 2012

1.6 Aircraft information

1.6.1 General

Registration	HB-IXP
Aircraft type	AVRO 146-RJ100
Characteristics	Four engine commercial jet aircraft
Manufacturer	British Aerospace Ltd., Woodford, Cheshire, England
Year of manufacture	1996
Serial number	E3283
Owner	Swiss International Air Lines Ltd., Postfach, 4002 Basel, Switzerland
Operator	Swiss European Air Lines AG, Malzgasse 15, 4052 Basel, Switzerland
Engines	4 Allied Signal LF507-1F
Airframe operating hours	35 623 hours

Number of cycles	32 597
Max. permitted masses	Max. permitted take-off mass 44 999 kg Max. permitted landing mass 40 142 kg
Mass and centre of gravity	Both the mass and centre of gravity were within the permitted limits according to the aircraft flight manual (AFM).
Maintenance	The last scheduled maintenance work (A-check) took place on 14 May 2011 at 32 177 cycles. (On the AVRO 146 RJ100, maintenance work is based on the number of cycles).
Technical limitations	A defective taxi light was entered in the deferred defect list (DDL).
Permitted fuel grade	JET A1 kerosene
Registration certificate	Issued by the Federal Office of Civil Aviation (FOCA) on 11 April 2007 (no. 6), valid till removal from the aircraft register.
Airworthiness certificate	Issued by the Federal Office of Civil Aviation (FOCA) on 11 April 2007, valid till revocation by the competent authority of the country of registration.
Certification	Cat. IIIA RVR 200m / DH 50 ft
Types of operation	LVTO RVR 125 m RVSM RNAV B-RNAV RNP 5 P-RNAV RNP 1.0 Continuing Airworthiness EC2042/2003, Part M Subpart G EFB Class 1 Dangerous goods

1.6.2 System, instruments and displays

1.6.2.1 General

The following sections mention and describe only those systems, instruments and indicators which were used during the serious incident for the guidance of the aircraft and which had a relevant impact.

1.6.2.2 Electronic Flight Instrument System

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

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

The PFD displays the flight attitude and data for flight guidance, as well as the flight director (FD). In addition, the PFD displays selected and pre-selected operating modes of the flight guidance system (FGS). The altitude is displayed on a separate instrument to the right of the respective PFD.

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

Using the EFIS control panel (ECP), in addition to the display format, the parameters to be displayed and their source are determined, as well as the range for the ND.

The EFIS symbol generator (SG) processes data from various sensors such as the IRS, air data computer, radio altimeter, weather radar and radio navigation equipment. It generates the symbols which are displayed on the PFD and ND and monitors and compares incoming signals. Invalid parameters are flagged accordingly. Example 1: if the two inertial reference units (IRU) are delivering different attitude parameters, the ATT warning is displayed in yellow in both PDFs. Example 2: if one IRU is delivering invalid attitude parameters, ATT is displayed in red on the corresponding side.

Using the EFIS selector on the commander's instrument panel, in the event of failure of an EFIS symbol generator (SG) it is possible to switch to the intact SG (cf. Annex 3). This then supplies the signals to all four DUs.

EFIS 1 is powered via the ESS 115 VAC bus, whilst EFIS 2 is powered via the 115 VAC2 bus. Each EFIS can be switched on and off separately using an EFIS master switch.

1.6.2.3 Inertial Reference System

The AVRO 146-RJ100 is equipped with two inertial reference systems (IRS). Each IRS contains one inertial reference unit (IRU). Both IRU are controlled by a common mode select unit (MSU), which is mounted in the console on the copilot‘s side.

The IRU is used to calculate attitude and navigation data. The navigation data includes among other things the position of the aircraft, the along track velocity and the true/magnetic heading. Three laser gyros and three accelerometers serve as sensors. The accelerometers measure acceleration along the three axes of the aircraft. The laser gyros are arranged so that they sense rotation around these axes. In the computer of the IRU a virtual platform is formed. This platform is constantly updated during flight using the data supplied by the laser gyros.

The flight attitude reference data is fed to the electronic flight instrument system (EFIS), the flight guidance system (FGS) and the enhanced ground proximity warning system (EGPWS), among other things. The navigation data is used by the flight management system (FMS) and the EFIS.

The MSU has one rotary switch and one status annunciator for each IRS. The functions OFF, ALN, NAV, and ATT can be selected using the rotary switch:

- OFF – IRS is switched off.
- ALN – in this position alignment of the virtual platform begins (align mode). In this phase the aircraft must not be moved. The NAV OFF light on the MSU lights up during this process.
- NAV – the rotary switch on the MSU can be set to the NAV position after alignment has been completed successfully. The NAV OFF light on the MSU

is now extinguished. The rotary switch can also be set directly to the NAV position. In this case the IRU automatically switches from align mode to navigation mode, once alignment is completed and the NAV OFF light goes out.

- ATT – in attitude mode, in flight, the IRS can only supply attitude and compass data to the EFIS. The compass data is only available if this has previously been entered in the multifunction control display unit (MCDU).

Using a selector switch on the commander's instrument panel, it is possible to toggle between true heading and magnetic heading. The switch is usually in the 'MAG' position and is secured by a protective cap (cf. Annex 3).

In the event of an IRU fault, the warning messages ATT or HDG are displayed on the corresponding EFIS displays. The ATT/HDG switch can be used to switch to the intact IRU (cf. Annex 3).

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

1.6.2.4 The flight guidance system

The flight guidance system (FGS) on the AVRO 146 RJ100 includes essentially two flight guidance computers (FGC), a mode control panel (MCP), a thrust rating panel (TRP), as well as a number of servos to implement the control commands of the FGC. The FGC SELECT switch in the overhead panel determines which of the two FGCs is active. The remaining FGC is then available as a hot spare.

The FGC 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
- elevator trim, flap trim compensation
- yaw damper and turn-coordination
- aural and visual altitude alerting
- built-in fault monitoring and maintenance test system

The FGC generates flight director commands 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 localizer beam
- capture and holding of a glide slope beam
- tracking of a flight plan calculated by the flight management system
- commands for takeoff and go around
- windshear recovery guidance

Flight director commands are displayed on the EFIS primary flight display (PFD) and are actioned by the pilot. If the autopilot is engaged, the commands calculated by the FGC are executed directly via servos.

On the mode control panel (MCP), the airspeed, mach, heading, clearance altitude and vertical speed are selected. Flight director/autopilot modes are also selected or preselected on the MCP. These are displayed on the primary flight displays (PFD) for confirmation. Flight director (FD), autopilot (AP) and autothrottle (AT) are armed or activated respectively on the MCP.

The two FGCs receive, among other things, signals from both IRS (attitude, heading). The incoming signals are constantly compared. For autopilot operation, valid signals from IRS 1 and IRS 2 must be present.

Using the pushbuttons NAV1 or NAV2, the autopilot is engaged and at the same time a selection of the sources for navigation data is made. The autopilot can be disengaged using a pushbutton on the left and right control stick.

For different configurations of the aircraft, the FGC calculates a maximum and a minimum permissible speed. Limit values are also programmed for attitude. One of the tasks of the autopilot is to keep the aircraft within the predetermined speed/attitude envelope.

The autothrottle function of the FGC is used to control engine power. This enables an airspeed (speed/mach) or a defined thrust rating to be maintained.

If the AP/FD is engaged, the autothrottle mode depends on its vertical mode. The autothrottle maintains the selected speed if the AP/FD is in one of the following vertical modes: vertical speed, altitude hold or glide slope. The autothrottle maintains the thrust selected on the thrust rating panel (TRP) in the following vertical modes: take-off, go-around or level change climb. The autothrottle reduces thrust for: level change descent or autoland flare.

The speed to be maintained is selected on the mode control panel (MCP). On the TRP, the following thrust ratings can be selected: TOGA MAX, TOGA REDU, CLIMB MAX, CLIMB NORM and MCT.

The autopilot, flight director and autothrottle can be used individually or in any combination.

Flight guidance system FGS 1 is powered by the ESS 115 VAC, 28 VDC1 28 VDC, EMERG 28 VDC ESS, ESS/BATT bus. FGS 2 is powered by the 115 VAC2, 28 VDC2, EMERG 28 VDC and ESS/BATT bus.

1.6.2.5 Bank angle warning

HB-IXP is equipped with an enhanced ground proximity warning system (EGPWS). This generates different warnings which are useful for situational awareness. Among other things, the EGPWS monitors roll attitude and issues an acoustic warning "bank angle", if this exceeds a specific value. The response threshold depends on the height above ground.

The bank angle reference is provided by the inertial reference system (IRS). IRS 1 and IRS 2 are connected to the EGPWS. In the normal case, IRS 1 supplies the attitude reference signals. If IRS 1 fails completely, the EGPWS automatically switches to IRS 2. This situation is indicated in the cockpit by the red ATT and HDG warning messages on the commander's EFIS display.

1.6.2.6 Distance Bearing Indicator

The AVRO 146 RJ100 is equipped with two distance bearing indicators (DBI). One DBI respectively is located on the left next to the EFIS navigation display (ND).

The DBI displays the following navigation data: magnetic heading, DME 1 distance, DME 2 distance, bearing 1 and bearing 2. The bearing can be switched optionally between VOR and ADF.

The heading information on the commander's side normally originates from IRS 2. In case of failure of the ESS DC bus, switching takes place automatically to IRS 1. The copilot's DBI always takes the heading from IRS 1.

The heading on the DBI always refers to magnetic north. The ATT HDG transfer switch has no effect on the DBI heading. A failure of the heading information is indicated by a red warning flag with the inscription HDG.

1.6.2.7 Instruments for an emergency

In an emergency, i.e. if both inertial reference systems (IRS), or both air data computers (ADC), or both electronic flight instrument systems (EFIS) or the corresponding power supply fail, so-called standby instruments are available.

The standby attitude indicator is available as the attitude reference. This is located on the left instrument panel and is powered from the EMERG DC BUS to drive the internal gyro. The EMERG DC BUS can be supplied from the battery in an emergency. The standby attitude indicator can additionally display the localizer deviation and the glide slope deviation from ILS 1.

The standby compass is used to display the magnetic heading. It is mounted between the two front windscreens and does not require any power, except for interior lighting.

The combined standby altimeter/airspeed indicator is used to display altitude and airspeed. This is located on the left instrument panel and is connected to the auxiliary pitot/static system. For internal lighting, the altimeter vibrator and heating of the auxiliary pitot tube, the instrument is powered from the EMERG DC BUS. The EMERG DC BUS can be supplied from the battery in an emergency.

1.6.3 Technical measures immediately after the serious incident

After the serious incident involving flight LX 5187 the following entry was made by the crew in the Tech Log:

"T/O FCG 2 / AT 1000 FT FGC 2 U/S / CHANGE TO FGC 1 / INFLIGHT CHANGE AGAIN TO FGC 2 → NORMAL OPS AGAIN WITH FGC 2. AT 7 NM AT+A/P DISCONNECT / LEFT PFD BLACK + "ATT" RED / CHANGE TO FGC 1 / ALL DIFF. INDICATIONS BETWEEN LEFT+RIGHT+STDBY HORIZON. FGC 2 U/S + IRS FAULT SUSPECTED."

On the basis of this entry, IRU 1 and the standby horizon on aircraft HB-IXP were removed and taken to the workshop.

The shop findings were as follows:

- The standby horizon (P/N H341AZM, S/N 9214) did not exhibit any faults.
- The IRU (P/N HG2001BC02, S/N 94070284) indicated a fault only after various tests (cf. chapter 1.16).

1.7 Meteorological information

1.7.1 General meteorological situation

A trough extended at high altitude from the North Sea to Slovenia. At midnight its axis was advancing directly over Switzerland and swung round slowly to the east during the morning. Below 3000 metres maritime polar air flowed from Ireland over the Bay of Biscay to the north side of the Alps. The centre of the low which determined the weather persisted in the morning between Prague and Warsaw.

1.7.2 Local weather and visibility

In the morning rain, and sometimes light drizzle, fell occasionally. In the second half of the morning, Zurich-Kloten airport and the runway 14 approach sector remained dry in the lee of the Black Forest. Visibility was at least 10 km from 09:00 UTC onwards. By 12:00 UTC, according to the LSZH SYNOP report (WMO 06670), it increased to 25 km.

1.7.3 Wind conditions

Between 09:00 UTC and 11:00 UTC the Schaffhausen wind profiler indicated wind from WSW at 20 to 30 knots below 800 m AMSL. Above this, a homogeneous wind field prevailed up to 3000 m AMSL. The wind was blowing from 270 degrees at an average speed of 25 to 30 knots. According to LSZH METAR reports, the wind at ground level was blowing from 220 to 240 degrees at just under 10 knots. After 10:00 UTC, there was a temporary trend to a variable direction between 190 and 270 degrees at an average speed of 9 knots.

Wind shear prevailed mainly below 1000 m AMSL. It consisted of directional and speed shear.

1.7.4 Cloud

The sky was heavily overcast throughout the morning. From 08:50 UTC to 09:20 UTC the ceiling was at 2000 ft AGL. By 09:50 UTC, it had risen to 2500 ft AGL. From 10:20 UTC, the main cloud base was at 3000 ft AGL. By 09:50 UTC there was 2-4/8 at 1200 ft AGL. The base then rose to 1500 ft AGL. In addition, 1-2/8 was observed at 800 ft AGL.

1.7.5 Aerodrome weather reports

In the period from 09:20 UTC up to the time of the serious incident the following meteorological aviation routine weather report (METAR) for Zurich airport were valid:

METAR LSZH 200920Z 23009KT 9999 FEW008 SCT012 BKN020 13/11 Q1011 TEMPO BKN012=

METAR LSZH 200950Z 23009KT 9999 FEW008 SCT012 BKN025 13/11 Q1011 NOSIG=

In clear text, this means:

On 20 July 2011, shortly before the 09:50 UTC issue time of the aerodrome weather report, the following weather conditions were observed at Zurich-Kloten airport:

Wind	from 230° at 9 kt
Meteorological visibility	Over 10 km

Cloud	1-2/8 at 800 ft AAL 3-4/8 at 1200 ft AAL 5-7/8 at 2500 ft AAL
Temperature	13°C
Dewpoint	11°C
Atmospheric pressure	1011 hPa, pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere.
Land weather forecast	No significant weather changes are expected in the two hours following the weather observation.

1.7.6 ATIS reports for Zurich airport

On 20 July 2011 Zurich airport broadcast the following arrival ATIS (automatic terminal information service) from 09:20 UTC to 09:50 UTC:

“THIS IS ZURICH ARRIVAL INFORMATION FOXTROTT.

LANDING RUNWAY 14 ILS APPROACH .

MET REPORT ZURICH.
0920.
WIND 220 DEGREES 7 KNOTS.

VISIBILITY 10 KILOMETRES OR MORE TOUCH DOWN ZONE 10 KILOMETRES OR MORE.

CLOUD FEW 8 HUNDRED FEET SCATTERED 1 THOUSAND 2 HUNDRED FEET BROKEN 2 THOUSAND FEET.

TEMPERATURE 13.

DEWPOINT 11.

Q.N.H 1011.

TREND TEMPORARY BROKEN 1 THOUSAND 2 HUNDRED FEET.

TRANSITION LEVEL 75.

GLIDE PATH I.L.S RUNWAY 28 UNSERVICEABLE.

AIRMET 2. VALID BETWEEN 0600 AND 1000.

GENEVA AND ZURICH AREA SWITZERLAND F.I.R MODERATE ICING OBSERVED ALPS AND NORTH OF ALPS BETWEEN FLIGHT LEVEL 80 AND FLIGHT LEVEL 140 STATIONARY WEAKENING.

AIRMET 3. VALIS BETWEEN 0600 AND 1000.

GENEVA AND ZURICH AREA SWITZERLAND F.I.R MODERATE TURBULLENCE FORECAST BETWEEN 3 THOUSAND FEET AMSL AND FLIGHT LEVEL 130 STATIONARY INTENSITY NO CHANGE.

ZÜRICH INFORMATION FOXTROTT.”

1.7.7 Terminal aerodrome forecast

At the time of the serious incident, the following terminal aerodrome forecast (TAF) applied:

LSZH 200525Z 2006/2112 23009KT 8000 FEW010 SCT020 BKN040 TX16/2015Z TN12/2006Z TN09/2104Z TEMPO 2006/2016 4000 SHRA BECMG 2018/2021 SCT050 PROB30 TEMPO 2103/2106 2500 BCFG TEMPO 2110/2112 SHRA=

In clear text, this means: on 20 July 2011 at 05:25 UTC the following weather conditions were forecast for Zurich-Kloten airport for the period from 06:00 UTC to 21 July 2011 at 12:00 UTC:

Wind	from 230° at 9 kt
Meteorological visibility	8000 m
Cloud	1-2/8 at 1000 ft AAL 3-4/8 at 2000 ft AAL 5-7/8 at 4000 ft AAL
Temperatures	20 July 2011 maximum 16° at 15:00 UTC 20 July 2011 minimum 12° at 06:00 UTC 21 July 2011 minimum 9° at 04:00 UTC
Conditional forecast	On 20 July 2011 intermittent fluctuations are to be expected between 06:00 UTC and 16:00 UTC; in individual cases, for less than one hour, in total less than five hours, visibility will be 4000 metres with rain showers. Between 18:00 UTC und 21:00 UTC cloud cover will be 3-4/8. With a 30% probability, on 21 July between 03:00 UTC and 06:00 UTC visibility of 2500 metres with isolated banks of fog is to be expected.

1.8 Aids to navigation

1.8.1 General

All navigation aids were in normal operation at the time of the serious incident and were fully available.

1.8.2 Radar monitoring of approaches

According to the workstation documentation, it is the task of the APP/FINAL air traffic control officer (ATCO) to monitor the flight path flown by the crew, as far as possible.

The approach sectors of runways 14, 16 and 28 are equipped with a minimum safe altitude warning system (MSAW). The MSAW is a safety system which triggers a visual and acoustic alarm in air traffic control if predefined minimum altitudes are violated.

From the radar recordings it is clear that the MSAW did not respond at any time.

1.9 Communications

Radio communications between the pilot and ATC took place correctly and without difficulties.

1.10 Aerodrome information

1.10.1 General

Zurich airport is located in north-east Switzerland. In 2010 it handled a traffic volume of some 268 765 landings and departures.

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

1.10.2 Runway equipment

The runways at Zurich airport have the following dimensions:

Runway	Dimensions	Elevation of runway thresholds
16/34	3700 x 60 m	1390/1388 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

At the time of the serious incident a runway length of 3300 m was available for a landing on runway 14.

Zurich Airport is characterised by a system of three runways; two of these runways (16 and 28) cross at the airport reference point. The approach paths of two other runways (16 and 14) intersect approximately 850 metres north-west of the threshold of runway 14. Runways 16 and 14 are equipped with a Category III instrument landing system (ILS) and runway 34 is equipped with a Category I ILS. Runway 28 is equipped with an uncategorised ILS which features increased weather minimums compared to Category I. These runways are therefore suitable for precision approaches.

1.11 Flight recorders

1.11.1 Flight data recorder

Type	Solid state flight data recorder (SSFDR)
Manufacturer	Honeywell
Year of manufacture	1997
Serial number	2494
Part number	980-4700-003
Number of parameters	64
Recording medium	Non volatile memory
Duration of recording	Approx. 50 hours

The flight recorder data was basically recorded in full and could be analysed. One exception were those parameters, in particular pitch and bank angle, which were captured by IRU 1 alone and which were therefore no longer available after it failed.

1.11.2 Cockpit voice recorder

Because the circuit breakers of the cockpit voice recorder (CVR) were not pulled after the flight, the recordings of the flight were overwritten.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

There are no indications of the pilots suffering health problems during the flight.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

Owing to the failure of the flight director (FD) and the autothrottle (AT) after take-off from Nuremberg, the maintenance memory of the FGC 2 was analysed after the landing. This had stored an IRU 1 fault. Likewise, the data recorded in the aircraft at the time of the failure of the FD and AT indicated unstable IRU 1 parameters. During the approach in Zurich, the IRU 1 again caused a failure of the FD, AT and AP.

The IRU 1 was removed after landing and sent to the Honeywell repair workshop in Europe for examination. On the test bench, the IRU exhibited no anomalies.

The IRU was then sent for further investigation to the Honeywell laboratory in Minneapolis. There too, the fault could not be duplicated on the test bench.

Finally the IRU was subjected to a so-called 'burn-in' test. During this test faults occurred and three components were replaced. It cannot be stated with certainty if these three components had a direct influence on the failure of the IRU during flight LX5187.

In the burn-in test, newly manufactured equipment in particular is tested under stringent environmental conditions. It is assumed that "weak" electronic parts will fail under such conditions after a few hours of operation.

1.17 Organisational and management information

1.17.1 The operator

The operator "Swiss European Air Lines" is a wholly owned subsidiary of Swiss International Air Lines. The latter had decided in spring 2005 to hive off regional traffic to a separate operating company.

The Federal Office of Civil Aviation (FOCA) gave Swiss European Air Lines approval to operate on 1 November 2005. Swiss European Air Lines makes so-called "wet lease" flights on behalf of the parent company Swiss International Air Lines. All aircraft from the regional fleet of Swiss International Air Lines were transferred to the new company.

1.17.2 Operating procedures to deal with faults

In the operator's operation manual B (OM B), section 1.03.10 "abnormal procedures" describes which procedures must be adopted in abnormal or emergency situations. Among other things, it states:

"Whenever confronted with an emergency or abnormal situation, the highest priority lies in the proper flying and monitoring of the aircraft. Crew duties must be distributed clearly, basically the following sequence applies:

***P**ower*	*The **PF** takes the initiative, he checks thrust and orders the appropriate setting for operative engines.*
***P**erformance*	*The **PF** checks configuration and minimum/maximum speed.*
***A**nalysis*	*The **PIC** assesses and manages the situation, he checks the time limits and sets priorities.*
***A**ction*	*The **PIC** manages and allocates duties. Action shall be taken according to Abnormal and Emergency Checklist (ACL/ECL) and OM A/OM B operating procedures (e.g. SPORDEC).*

(…)"

Under *"HANDLING OF CAUTIONS AND WARNINGS"* the same section states, among other things:

"<u>GENERAL</u>

*When a warning/caution or advisory situation arises in flight, the **PF** shall as a principle:*

- *Assess the performance situation by starting with **P**ower, **P**erformance.*
- *On ground, PP shall be adapted accordingly*

*The **PNF** shall:*

- *Call out the warning/caution or advisory as indicated on the Central Warning Panel (CWP)/overhead panel or Central Status Panel (CSP).*
- *Reset the warning/caution lights (attention getters) by the order of the **PF**.*

*It is essential that one pilot flies the aircraft, while the other deals with the technical problem. Nonetheless it is very important, that the **PNF** monitors flight progress whilst handling the technical malfunction (checklist work).*

Abnormal procedures shall be started after careful analysis of available information.

(…)"

1.17.3 Cooperation in the cockpit

From the experience of numerous accidents in which a lack of cooperation of individual crew members was a causal factor, in the early 'eighties of the last century so-called crew resource management (CRM) was developed as training for flight crews and was subsequently incorporated as a component of the training and ongoing training of commercial pilots. Crew resource management is intended to reinforce the awareness that, in addition to technical understanding on board an aircraft, the interpersonal area is a crucial factor for a safe flight.

In the course of their initial and ongoing training, both pilots took part regularly in such CRM courses and acquired the corresponding knowledge.

1.17.4 Refresher courses in the simulator

In the refresher courses held by the operator in the simulator in the first half of 2011, for example, an exercise was conducted involving a total electrical failure. During this exercise, the commander had only the standby instruments available and using these he had to make an approach on runway 27R at London Heathrow. The commander had completed this refresher on 4 May 2011, just over two months before the serious incident.

In addition, the refresher in the second half of the year 2010 included flying using raw data[4]. An ILS approach with a subsequent go-around had to be flown on runway 23 in Geneva. The operator's chief flight instructor himself wrote information for the pilots (EORE Info dated 16 July 2010), in which he stated the following, among other things:

"In the second semester, the Special Refresher program includes an AEO (all engines operative) raw-data approach into Geneva, whereby both pilots, Captain and First Officer, will have the chance to perform this exercise as pilot flying.

[4] Raw data: in the case of flying using raw data, the aircraft is flown manually and exclusively on the basis of the displays of the primary flight instruments and navigation displays, for example of the instrument landing system. In the process, the pilot must estimate the respective attitude himself in order to achieve a three-dimensional flight path.

The value of up-to-date basic flying skills is beyond any doubt; pilots should also be able to safely fly the aeroplane by instruments without the assistance of the FD (e.g. dual FGC failure).

The purpose of this EORE Info is to provide our flight crews with the recommendations and techniques to successfully master a raw-data approach. (…)"

In what follows, this EORE refers in exceptional detail to the points which must be complied with in order to be able to accomplish an approach and go-around which is as successful as possible. For example, reference is explicitly made to a "pitch & power table" giving attitude and engine performance data and the following is mentioned, among other things:

"Flight crews should be familiar with the approximate pitch for each flight manoeuvre."

Both pilots had completed this refresher. It should be stated that according to the operator's information, refresher exercises are not generally rated, unless extreme weaknesses which require a reaction from the operator are involved.

In the case of the two pilots, this was not the case, according to the instructors conducting the exercise.

1.18 Additional information

On 30 July 2011 on flight LX0771, flown with the same aircraft HB-IXP, a multiple fault occurred with the navigation system after take-off from Brussels. The flight was aborted.

According to the crew's report, at approximately 600 ft above ground the red ATT and HDG warnings appeared on the copilot's EFIS displays. The compass rose on the commander's DBI began to rotate continuously. Both faults were attributed to the inertial reference system (IRS) 2. In accordance with the abnormal checklist (ACL, 14.04), the crew switched the ATT/HDG transfer switch to the "BOTH 1" position, after this action the data on the copilot's EFIS displays normalised. The AP, AT and FD could not be reengaged. This corresponds to normal operation of the system.

At approximately 2300 ft above ground, the vertical speed on the primary flight display (PFD) 1 began to display erroneously and unstably.

The crew discontinued the flight, controlled the aircraft manually using raw data and asked air traffic control for radar guidance for an approach to Brussels. One minute after landing, IRS 1 failed as the aircraft was taxiing.

At the stand, it was possible to align both IRSs normally again. Nevertheless, both inertial reference units (IRU) and the IRS control panel were replaced as a safety precaution.

An analysis of the maintenance memory in the FGC confirmed the failure of IRU 2 at 600 ft, as well as the erratic vertical speed signal on IRU 1.

The analysis of the flight recorder data revealed the following:

All IRU 2 data were initially unstable and IRU 2 finally failed completely.

The vertical speed output of IRU 1 began to be unstable at approximately 500 ft above ground and remained unstable for the rest of the flight.

The shop findings revealed the following:

The fault which occurred during the flight (unstable vertical speed) could not be duplicated clearly in the IRU 1. The Y-laser gyro was replaced anyway.

The IRU 2 was dismantled in the workshop. All printed circuit cards were heavily contaminated by dust and water. Several had to be replaced.

No defect was found on the IRS control panel.

1.19 Useful or effective investigation techniques

Not applicable.

2 Analysis

2.1 Technical aspects

2.1.1 Standby horizon

The crew mentioned that in the first phase after the loss of the EFIS displays on the commander's side the standby horizon indicated a rather unnaturally high pitch attitude. The examination of the standby horizon revealed no relevant faults.

From the recorded altitude data it can be concluded that immediately after the loss of the AP, AT and FD the aircraft descended for over 30 seconds at an average rate of descent (ROD) of nearly 1500 ft/min, followed by a climb for 80 seconds, at an average rate of climb (ROC) of over 1700 ft/min and at greatly increased engine power (cf. Annex 2). Within just one minute, there followed a descent at an average ROD of nearly 2500 ft/min and another climb at an average ROC of over 2600 ft/min. The low mass of the aircraft (no passengers and little fuel) could have contributed to the fact that for a short time a pitch attitude was attained which the crew perceived as unnatural on the standby horizon.

2.1.2 Behaviour of the IRU during the flight

After the take-off in Nuremberg, at approximately 400 ft above ground and while the aircraft was still under manual control, the flight director (FD) and the auto throttle (AT) failed. At this time, the FGC 2 was selected. The flight was continued manually by the copilot. A little later, the commander switched to the FGC 1. The autopilot (AP), FD and AT could be reengaged normally.

An analysis of recorded data found that the failure of the FD and the AT was caused by the inertial reference unit (IRU) 1, which was generating unstable data. A few seconds later the data normalised again, which was the reason why the AP, FD and AT could be reengaged without any problems.

It should be noted that in these circumstances the failure of the FD and the AT would have happened after the take-off even if the FGC 1 had been selected from the beginning, because both FGC receive data from both IRS. If one of the two IRS generates unstable data or if one IRS fails completely, the AT, FD and AP (if engaged) fail, regardless of the selected FGC (cf. chapter 1.6.2.4).

The data generated by the IRU 1 also remained unstable during cruising. The difference between the IRU 1 and IRU 2, however, remained below the threshold of the signal comparator in the active FGC and therefore had no effect. For this reason, this difference was not detectable for the crew.

The commander again switched to the FGC 2 in the RILAX holding pattern. This switchover, as mentioned above, did not result in any change. FGC 2 subsequently remained selected.

At 09:51:40 UTC the data for bank angle reference, generated by the IRU 1, became erratic. This led to the failure of the AP, FD and AT. The immediately effected switch to the FGC 1 again resulted in no change.

Shortly afterwards the acoustic warning *"bank angle"* sounded in the cockpit. This was triggered in the enhanced ground proximity warning system (EGPWS) by the erratic bank angle reference signal from the IRU 1. The actual bank angle was low at this moment.

The phase during which the IRU 1 generated an erratic bank angle reference lasted from 09:51:40 UTC to 09:52:04 UTC. During this time, an unstable and incorrect bank angle was displayed on the commander's PFD. The indications on the copilot side remained stable during this period. Apart from the loss of the FD, the copilot had available all the information for the operation of the aircraft.

Figure 1: Instrument display on the commander's side (The values shown in the figure do not correspond to those which were displayed at the time of the serious incident).

At 09:52:04 UTC the ATT and HDG warning messages appeared in red on the commander's EFIS displays and the corresponding parameters disappeared. The heading display on the DBI left of the ND was preserved throughout, since the corresponding information is supplied by the IRS 2 (cf. figure 1 and chapter 1.6.2.6).

At the same time, on the copilot's side the ATT and HDG displays appeared in yellow, to draw attention to the different signals. The indications to fly the aircraft remained. Only the heading indication in the DBI on the left of the ND showed the red heading flag, because the corresponding information was supplied by the IRS 1 (cf. figure 2 and chapter 1.6.2.6).

In the symbol generator (SG) 2, among other things the ATT and HDG signals are compared. The ATT and HDG displays (yellow) illuminate if these signals are different.

DBI (distance bearing indicator) with red heading flag

The two red bearing flags on the left and right indicate that the VOR bearing pointers, which are referenced to the compass rose, are no longer providing a reliable indication. The distance to the respective VOR/DME station is displayed normally.

Figure 2: Instrument display on the copilot’s side (The values shown in the figure do not correspond to those which were displayed at the time of the serious incident).

After switching the EFIS selector switch to the "BOTH 2" position (cf. Annex 3), the data returned on the commander's EFIS displays. In this switch position the data on the copilot's EFIS displays are copied to the left side. The FD and AT were then reengaged.

2.1.3 Analysis of the IRU shop findings

The fault-finding process in the IRU 1, as described in chapter 1.19, provided results only after lengthy and elaborate testing on the manufacturer's premises. However, it cannot be stated with certainty whether these findings were responsible for the failure of the IRU during flight LX 5187.

It seems, according to the statements of the crew, to be general knowledge within the operator that after take-off the AP, AT, and FD may fail if the aircraft has been exposed to heavy rain on the ground for some time with the cabin door open, as was applicable in this case. The crews are therefore of the opinion that switching the FGC generally resolves the problem.

Remarkably, the crew connected the observed failures with the heavy rain which had prevailed before take-off in Nuremberg. They referred to the problems described in a technical information (EORT Info dated 22.12.2009). This technical information does indeed describe the failure of AP, AT and FD, as well as other systems, but refers to defective temperature measurement by the air data systems, not the influence of moisture or water (cf. Annex 4).

The present case, however, permits the conclusion that high humidity and the ingress of water into the IRUs cause these to generate unstable data. This may occur for only a short time and does not necessarily lead to a total failure of the IRUs. However, regardless of the selected FGC the unstable data leads to a failure of AP, AT and FD, as occurred immediately after take-off from Nuremberg.

This thesis is supported by the shop findings relating to aborted flight LX 0771 described in chapter 1.18. In this case traces of dust and water were found on the IRU, on all printed circuit cards.

It is also noted that at the time of the serious incident various problems with the flight guidance system were known. However, until this case the origin seldom resided in the IRS.

The situation described left the crews in the false belief that in case of failure of AP, AT and FD the FGC is the cause in all cases, and that switching to the other FGC will solve the problem.

2.2 Human and operational aspects

2.2.1 Conduct of the crew during the incident flight

When the FD and the AT failed after take-off in Nuremberg, the crew responded on the basis of their experience by switching to the FGC 1. Because they were able to reengage the AT, the FD and somewhat later the AP, they were convinced they had solved the problem. The fact that IRU 1 was responsible for the failure because it was supplying unstable data, could not be known by the crew.

It was quite normal practice for the crew in the later stages of the flight to switch back to the FGC 2, in order to see if all functions were available again. Since this was the case, the commander decided to leave the FGC 2 as the active FGC, because this corresponded to the usual selection for that day. On days with an even-numbered date, the FGC 2 is used, whilst on days with an odd date the FGC 1 is used.

It is obvious that the crew, on the approach on runway 14 in Zurich, when the FD, AT, and AP failed, thought at first that the problem after the take-off in Nuremberg was recurring and was due to the selection of the FGC 2. A few seconds later the indications on the commander's PFD and ND failed and the red ATT and HDG warnings appeared (cf. chapter 2.1.2, figure 1). This was a clear indication that an FGC failure could no longer be there, which the crew apparently did not realise.

The acoustic "bank angle" warning caused by the IRU 1 confused the copilot and he looked at the commander's instruments, which because of the fault which had occurred showed a bank angle which corresponded with the acoustic warning. According to his statement, the PFD on his side showed "wings level" i.e. no bank angle. Now he no longer trusted his own instruments. A comparison with the standby instruments would have shown the crew that their indications corresponded with the display on the PFD on the copilot's side.

Hence all the necessary data was available to fly the aircraft manually on the ILS using raw data (cf. chapter 2.1.2, figure 2). Even a landing would have been possible given the prevailing weather conditions. The flying situation was basically comparable to that which the copilot had experienced on the occasion of the refresher in the year 2010 (cf. chapter 1.17.4).

The fact that the copilot did not make a consistent comparison of the available attitude indications led to a partial loss of situational awareness. This uncertainty meant that the copilot experienced difficulty in controlling the aircraft manually and was subsequently able to support the commander only inadequately. Too little correction was applied for the strong westerly wind and the aircraft drifted away to the east from the ILS localizer. The recorded altitude of this flight phase testifies to a changeable and unstable pitch attitude (cf. Annex 2).

The previously mentioned distrust of the copilot concerning his instrument indications caused the commander to take over control of the aircraft. At this time, however, he no longer had any indications on his EFIS, and this required flying using the standby instruments. Since he could no longer rely on the copilot regarding control of the aircraft, he also continued to handle radio communications. This distribution of work essentially corresponds to the situation when executing an abnormal or emergency checklist.

In this case this distribution of work made the situation significantly more difficult, because it resulted in a temporary overburdening of the commander. This is reflected in particular by the fact that subsequently essential flight parameters varied in some way (cf. Annex 2), which were not consistent with controlled aircraft flying. The question is therefore posed as to whether this work distribution, which also makes more difficult the otherwise customary "closed loop principle", is appropriate in such an emergency.

Essentially it should be noted that controlling an aircraft with the help of only the standby instruments is very demanding, as the instruments, owing to their construction and their layout on the instrument panel can be read only with a certain parallax effect. Also, the size and scaling of the instruments make it difficult to read the attitude, altitude and speed. It is therefore conceivable that some of the fluctuations in flight attitude, altitude and speed which occurred in this serious incident are attributable to the fact that scanning had become more difficult for the commander. Furthermore, the retraction of the flaps at this stage led to a change in the moment of the aircraft, which had to be compensated for via the elevator or trim. Furthermore, considering the low aircraft mass (no payload) the increase of thrust had a remarkable effect.

An analysis of the situation – according to the first "A" of the PPAA principle (cf. chapter 1.17.2) – was not carried out consistently – if at all. It would otherwise have become clear that the copilot had available on his side all the indications required to control the aircraft, with the exception of the flight director (FD) (cf. chapter 2.1.2, figure 2). He was therefore clearly in a better position to control the aircraft.

This behaviour of the crew seems surprising at first glance, because it was confirmed without exception in the qualifications of both pilots by the corresponding instructors that they work consistently in accordance with the procedures of the operator (PPAA and CRM). This discrepancy is attributable on the one hand to the temporary overburdening of the crew due to the situation and on the other hand to the fact that CRM and patterns of action such as PPAA can only be practiced realistically in the simulator to a limited extent.

Notably, the commander reported to the air traffic control officer shortly afterwards that the crew did not have any heading information of any kind. In actual fact, at this time a correct heading was being displayed on the commander's distance bearing indicator (DBI) (cf. chapter 2.1.2, figure 1). The copilot also had a valid heading indication on his EFIS displays. The fact that the crew were not aware of these clearly available displays indicates how confused they must have been at this time.

It is general knowledge to pilots of the AVRO 146 aircraft that the compass on the DBI is supplied crosswise, i.e. the compass in the left DBI is supplied from the IRS 2 and the compass in the right DBI is supplied from the IRS 1. However, it seems that this basic knowledge of the system could not be recalled by the crew because of the stressful situation which had arisen. This knowledge would have helped the crew to undertake a better situation analysis in the serious incident under investigation

As a result of the insufficient situation analysis, the crew put themselves under pressure. This is also confirmed by the radio communication recordings, which show that the ATCO often had to repeat questions or that the readback of instructions by the crew was incomplete.

The reason why the crew analysed the situation inadequately is very probably that after the failure of the autopilot, autothrust and flight director they were convinced that they were confronted with the same problem as after the take-off in Nuremberg. The crew attributed the repeated failure of the FGC functions again to a fault in the flight guidance computer (FGC). This conclusion was not true even on take-off in Nuremberg and led to a preconceived opinion, which had the consequence that the crew, after the failure of the displays on the commander's side, now incorrectly assumed a double failure that means a failure of two independent systems.

The crew then flew for some seven minutes on the assumption that they had no heading information. The statements of the crew and the analysis of the radio communications allow the conclusion that in this phase the commander was getting hardly any support from the copilot. Even though the CVR (cockpit voice recorder) was overwritten and the conversations in the cockpit were therefore not available to the investigation, it can be concluded from the above-mentioned sources that the crew cooperation was deficient, which meant that the failure of a single system could be overcome only with considerable problems.

2.2.2 Qualification and training

The documents relating to the selection and training of the commander, who was employed as a copilot at that time, do not permit any clear conclusions. In particular, the assessments of line pilots which described the prospective commander in day-to-day operations, are not very reliable because they are partially contradictory in their assessment. They date from 1997/98 and therefore do not take into account the personal and professional development of the commander which emerges from later documents.

The copilot's eligibility documentation from 1999, i.e. ten years before his employment by the operator, indicates a certain weakness in data processing and the corresponding interpretation. On the other hand, the eligibility documents from the year 2009 indicate an average to above average result without risk factors.

According to the available qualification sheets from the previous years and the statements made by superiors, the crew consisted of well qualified to very well qualified pilots. No weaknesses are listed in the rating sheets for either pilot. It is attested with reference to both pilots that they work consistently according to "PPAA", undertake clear analyses in the event of faults and also work in accordance with the rules of CRM. This is noteworthy in that on these two points the crew exhibited weaknesses during the serious incident.

It is also worth mentioning in this context that just over two months before the serious incident the commander had to make an approach in the simulator during a refresher, using only the standby instruments, and in addition both pilots had especially practised flying using raw data in the year 2010. As the serious incident indicates, however, the crew exhibited significant weaknesses in relation to this type of control of the aircraft.

The difference in the work of the crew during simulator exercises and their performance in the serious incident is considerable. The reason for this discrepancy is that in simulator exercises crews are prepared in detail for the faults that occur, and these are expected. The effect of surprise, as was present in the serious incident, is largely missing. In principle, this applies to all crews. The question therefore arises as to how recurrent training can be better designed so that what is practised in the simulator can be effectively implemented in a real situation.

2.2.3 Conduct of air traffic control

Air traffic control recognized at an early stage that LX 5187's approach was not proceeding according to plan and immediately ordered a new approach, after assistance in the form of a heading instruction produced no effect. When the crew reported navigation problems, the other approaching traffic was assigned a different frequency. As a further precaution, the approaching and later also the departing traffic at Zurich airport was temporarily halted. In this way air traffic control optimally supported the crew of LX 5187 and contributed to a final resolution of the situation.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for VFR/IFR transport.
- Both the mass and centre of gravity of the aircraft were within the permitted limits according to the AFM at the time of the serious incident.
- The last A-check was carried out on 14 May 2011 at 32 177 cycles.
- During the flight, the IRU 1 generated unstable data and then failed completely.
- The investigation of the standby horizon after the serious incident showed a flawless function.

3.1.2 Crew

- The pilots were in possession of the necessary licences for the flight.
- There are no indications of the pilots suffering any health problems during the flight.
- Both pilots had practised flying using raw data in the simulator in 2010.
- Some two months before the serious incident the commander had carried out an approach in the simulator with the aid of the standby instruments.

3.1.3 History of the flight

- The copilot was pilot flying and the commander was pilot not flying.
- After take-off in Nuremberg at 08:53 UTC, at approximately 400 ft above ground, the autothrottle (AT) and the flight director (FD) failed. The aircraft was being controlled manually in this phase.
- The crew switched from the selected FGC 2 to the FGC 1.
- It was possible to reengage the AT, FD and also the autopilot (AP).
- In the RILAX holding pattern, after 09:33 UTC, the crew switched to the FGC 2. AP, AT and FD functioned normally.
- At 09:49:52 UTC LX 5187 captured the runway 14 localizer and followed it.
- At 09:51:40 UTC, the inertial reference unit 1 (IRU 1) began to output an erratic bank angle signal and at the same time the AP, AT and FD failed.
- A few seconds later the acoustic warning *"bank angle"* sounded, although at this time the bank angle was low.
- The crew switched to the FGC 1. This had no effect on the AP, AT and FD.
- At 09:52:04 UTC the ATT and HDG warnings appeared in red on the commander's EFIS displays and the navigation data disappeared.
- The copilot's EFIS displays remained stable and allowed the aircraft to be controlled manually.
- Shortly afterwards, the aircraft drifted to the left.
- The air traffic control officer gave the crew the following order: *"I see you left of centreline, turn immediately right and climb to four thousand feet."*

- The copilot was confused by the instrument display; the commander then took over control of the aircraft and maintained radio contact.
- At 09:52:24 UTC the crew reported that they had a navigation problem, upon which the air traffic control officer (ATCO) gave repositioning instructions.
- The recordings of the flight data recorder (FDR) show unstable flight in terms of altitude and speed.
- Forty seconds later, the crew reported that they had no heading indication and requested left/right guidance from the ATCO.
- At 09:55:24 UTC the crew sent an urgency message.
- Air traffic control then halted arriving and departing traffic in order to provide full support to the crew of LX 5187.
- Shortly after the crew had set the EFIS selector switch to the "BOTH 2" position, they reported at 09:58:52 UTC: *"… system back any moment."* The FD and AT were engaged again.
- At 10:01:24 UTC the ATCO gave the crew clearance to approach on runway 14.
- The crew reported at 10:03:21 UTC *"fully established"*, and two minutes later an uneventful landing was carried out.

3.1.4 Air traffic control

- The air transport control officer concerned was in possession of all licences necessary for his activity.
- The air traffic controller supported the crew of LX 5187 prudently.

3.1.5 General conditions

- A moderate to strong west wind prevailed and the aircraft flew under instrument meteorological conditions during the serious incident.

3.2 Causes

The serious incident is attributable to the fact that after the failure of a single system the crew did not use the remaining systems appropriately and safe control of the aircraft was at times no longer guaranteed.

The investigation identified the following factors which led to the serious incident:

- The crew had a fundamentally unfounded picture about the technical problem causing the system failure.
- After the loss of the autopilot, autothrottle and flight director, the copilot did not manage to continue to control the aircraft manually.
- The commander was able to fly the aircraft only to a limited extent with the aid of the standby instruments.
- Crew resource management (CRM) was unsatisfactory.
- The crew did not carry out a sufficient analysis of the situation.
- An exercise which had been practised in the simulator using standby instruments and raw data could only be partially implemented in the actual case.

4 Safety recommendations and measures taken since the serious incident

According to the provisions of Annex 13 of the ICAO, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which has to decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, establishment or individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

In the Ordinance on the Investigation of Aircraft Accidents and Serious Incidents (OIAASI), the Swiss legislation provides for the following regulation regarding implementation:

“Art. 32 Safety recommendations

[1] DETEC, on the basis of the safety recommendations in the SAIB reports and in the foreign reports, addresses implementation orders or recommendations to the FOCA.

[2] The FOCA informs DETEC periodically about the implementation of the orders or recommendations pronounced.

[3] DETEC informs the SAIB at least twice a year on the state of implementation by the FOCA."

4.1 Safety recommendations

4.1.1 Improvement of standby instruments

4.1.1.1 Safety deficit

On 20 July 2011 at 08:53 UTC the AVRO 146-RJ100 aircraft, registration HB-IXP, took off under flight number LX 5187 and radio call sign "Swiss five one eight seven" on a ferry flight from Nuremberg to Zurich. On this flight the copilot was pilot flying and the commander was pilot not flying.

During the approach to Zurich airport the inertial reference unit 1 (IRU 1) failed. The copilot was then confused by the sudden appearance of a high bank angle warning *("bank angle"*) and no longer trusted the indications on his electronic flight instrument system (EFIS). The commander therefore took over control of the aircraft. On his side, no indications were available as a result of the failure of the IRU, so he was relying on the standby instruments to control the aircraft. Although he had practiced this kind of aircraft control in the simulator a few months previously, he was able to control the aircraft only to a limited extent using these instruments. Attitude, altitude and speed varied considerably for some minutes.

In the present case, controlling the aircraft solely with the aid of the standby instruments turned out to be very demanding, as the instruments, owing to their construction and their layout on the instrument panel, can be read only with a certain parallax effect. Also, the size and scaling of the instruments make it difficult to read the attitude and airspeed. It is therefore conceivable that some of the fluctuations in attitude, altitude and speed which occurred in this serious incident are attributable to the fact that scanning had become more difficult for the commander. This was confirmed among other things because for several minutes the commander did not notice that he had a correct heading indicator available.

More modern standby instruments, thanks to their design and layout, facilitate reliable reading of the attitude and owing to the integration of heading and speed information make scanning easier.

The AVRO 146-RJ100 aircraft will remain in service, at least with Swiss European Air Lines, for several years and a failure of systems which require control using the standby instruments will become more likely due to increasing age. For this reason, retro-fitting of the aircraft type with improved standby instruments would facilitate control of the aircraft and thus increase safety in the event of system failures.

In the same manner an improvement of aircraft with electromechanical standby instruments should be aimed for at least Europe-wide.

4.1.1.2 Safety recommendation No. 456

"Die zuständige Behörde sollte zusammen mit dem Hersteller des Flugzeugmusters AVRO 146-RJ100 und den betroffenen Flugbetriebsunternehmen eine Nachrüstung mit verbesserten Notinstrumenten prüfen."

[The relevant authority, together with the manufacturer of the AVRO 146-RJ100 aircraft and the operators concerned should verify an upgrade with improved standby instruments.]

4.1.1.3 Safety recommendation No. 457

"Die Europäische Agentur für Flugsicherheit sollte zusammen mit den Betreibern von Luftfahrzeugen, die noch mit elektromechanischen Notinstrumenten ausgerüstet sind, überprüfen, ob deren Auslegung noch den heutigen Erkenntnissen und Anforderungen zur Ergonomie entspricht. Ist dies nicht der Fall, sollte eine Nachrüstung mit verbesserten Notinstrumenten veranlasst werden."

[The European Aviation Safety Agency, together with the operators of aircraft, still equipped with electromechanical standby instruments, should examine whether their design still fulfills the today's requirements with respect to ergonomics. If this is not the case, an update with improved standby instruments should be arranged.]

4.1.2 Improvement of training in relation to behaviour in emergency situations

4.1.2.1 Safety deficit

On 20 July 2011 at 08:53 UTC the AVRO 146-RJ100 aircraft, registration HB-IXP, took off under flight number LX 5187 and radio call sign "Swiss five one eight seven" on a ferry flight from Nuremberg to Zurich. On this flight the copilot was pilot flying and the commander was pilot not flying.

During the approach to Zurich airport the inertial reference unit 1 (IRU 1) failed. The crew did not subsequently carry out an adequate analysis of the situation, did not use the remaining systems appropriately and safe control of the aircraft was for at times no longer guaranteed.

According to the available rating sheets from the previous years and the statements made by superiors, the crew consisted of well qualified to very well qualified pilots. No weaknesses are listed in any rating sheet for either pilot. It is attested with reference to both pilots that they worked consistently according to "PPAA", undertook clear analyses in the event of faults and also worked in accordance with the rules of crew resource management (CRM). This is noteworthy in that on these two points the crew exhibited distinct weaknesses during the serious incident.

It is also worth mentioning in this context that just over two months before the serious incident the commander had to make an approach in the simulator during a refresher, using only the standby instruments, and in addition both pilots had in particular practised flying using raw data in the year 2010. As the serious incident shows, however, significant weaknesses were revealed in the crew with this type of control of the aircraft.

The difference in the work of the crew during simulator exercises and their performance in the serious incident is considerable. The reason for this discrepancy is that in simulator exercises crews are prepared in detail for the faults that occur, and these are expected. The effect of surprise, as was present in the serious incident, is largely lacking. In principle, this applies to all crews. The question therefore is how recurrent training can be better designed so that what is practised in the simulator can be effectively implemented in a real situation.

4.1.2.2 Safety recommendation No. 458

"Das Bundesamt für Zivilluftfahrt sollte zusammen mit den Flugbetriebsunternehmen sicherstellen, dass im Rahmen der periodischen Leistungsüberprüfungen und refresher im Simulator möglichst realitätsnahe Trainingsszenarien geübt werden."

[The Federal Office of Civil Aviation should strive, together with the operators, that during checks and refreshers in the simulator, most realistic scenarios can be exercised.]

4.2 Measures taken since the serious incident

Among other things, the operator has envisaged, in 2012, addressing the topic "Navigation" in the simulator refresher "SIM REFR RJ1H RT 2012". The operational focal points will include, among other things, the following two points: "crew resource management skills" and "RDI approach and G/A" .

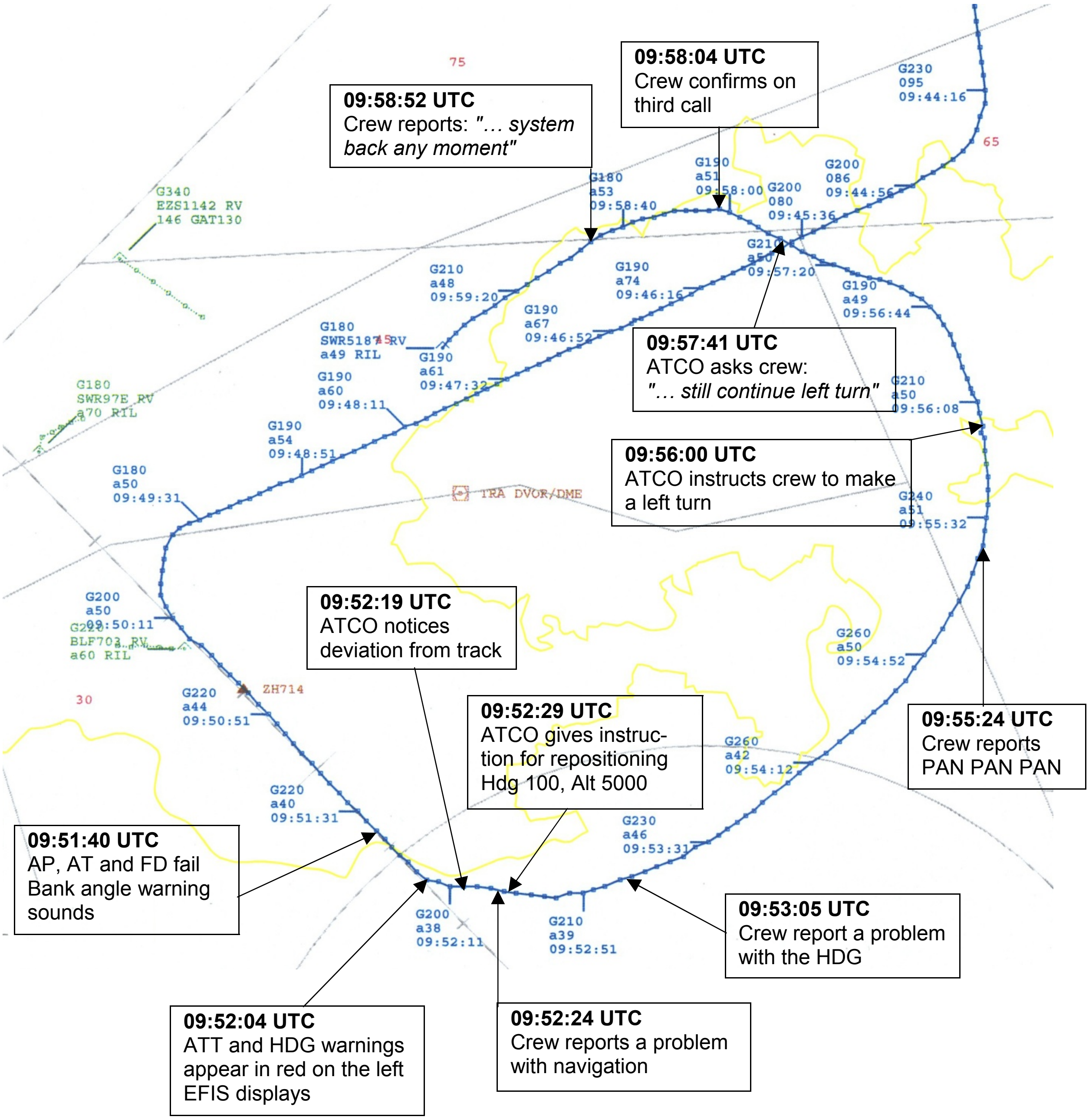
Payerne, 10 October 2012 Swiss Accident Investigation Board

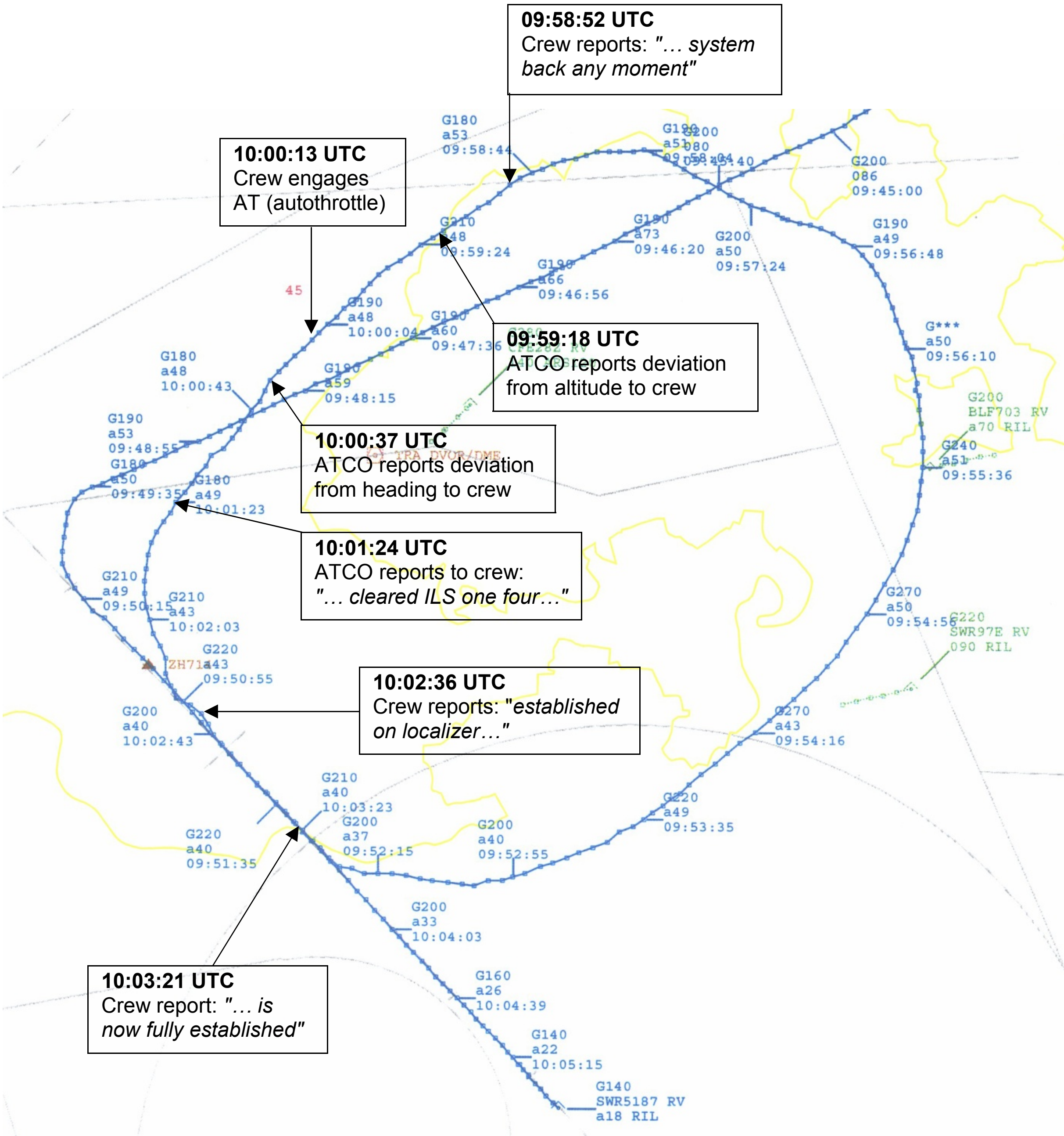
This final report was approved by the management of the Swiss Accident Investigation Board SAIB (Art. 3 para. 4g of the Ordinance on the Organisation of the Swiss Accident Investigation Board of 23 March 2011).

Berne, 20 November 2012

Annexes

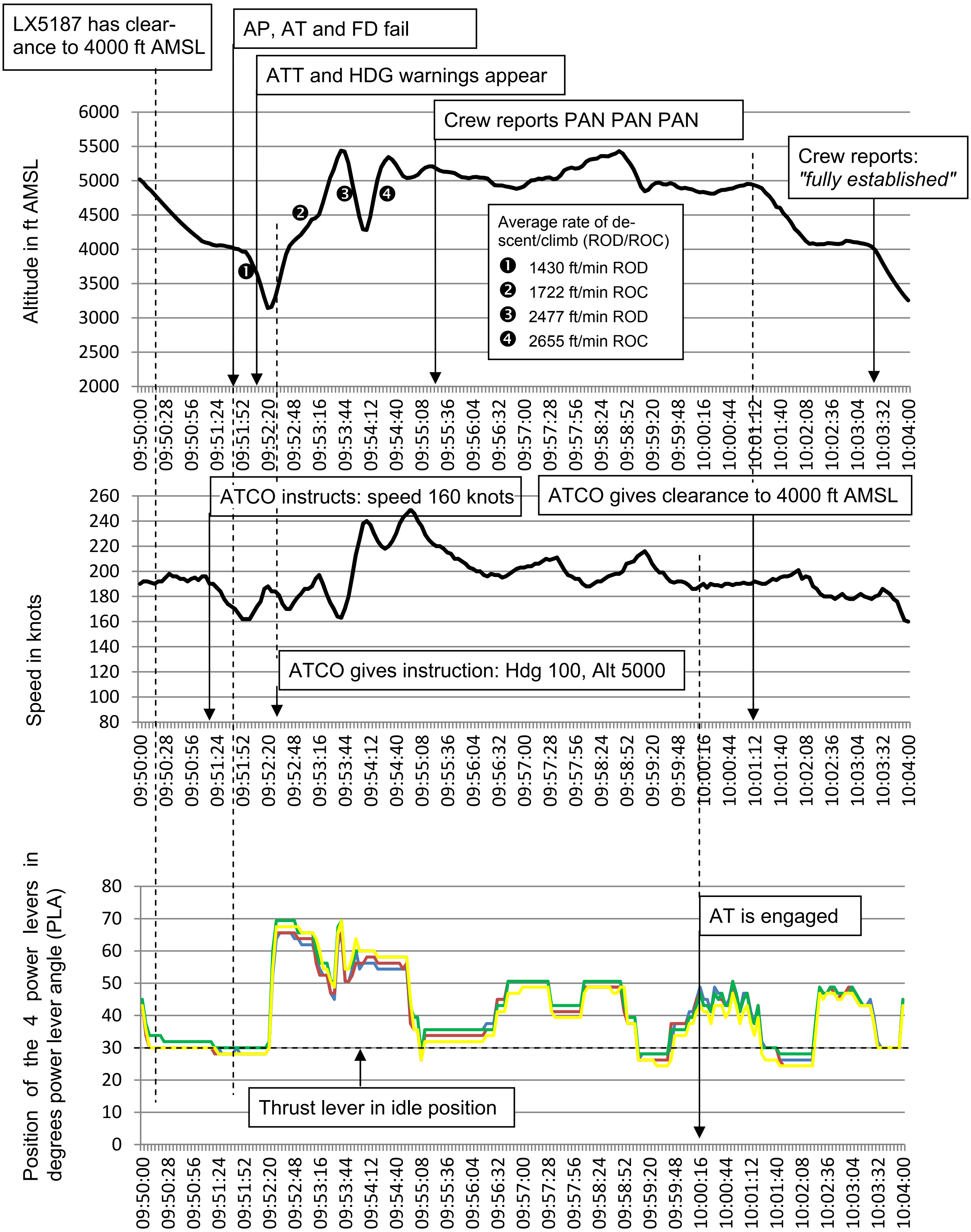
Annex 1: Flight path on approach




09:58:52 UTC
Crew reports: *"… system back any moment"*
10:00:13 UTC
Crew engages AT (autothrottle)
09:59:18 UTC
ATCO reports deviation from altitude to crew
10:00:37 UTC
ATCO reports deviation from heading to crew
10:01:24 UTC
ATCO reports to crew:
"… cleared ILS one four…"
10:02:36 UTC
Crew reports: *"established on localizer…"*
10:03:21 UTC
Crew report: *"… is now fully established"*
G140
SWR5187 RV
a18 RIL

Annex 2: Altitude, speed and thrust lever position

The FDR (flight data recorder) only records flight attitude reference data of the IRU 1. Since these parameters were no longer available from 09:52:04 UTC, a representation of pitch and bank angle was omitted.



Annex 3: Commander’s instrument panel

Switch for EFIS displays
In "BOTH 2" position, for example, the data from PFD2 / ND2 are copied to PFD1 / ND1.

Annex 4: Technical information for AVRO RJ crews

EORT Info

swiss + Swiss European

Technical Pilot AVRO RJ

December 22, 2009

Flight Guidance System Malpractice

Background

Lately we have experienced several irregularities with the DFGS System where, amongst others, the following flight deck effects were observed: A/P disconnect, F/D out of view, TRP off, and sometimes the ELEC TRIM and FTC annunciator illuminating.

Our investigations resulted in our assumption that the reason is (partly confirmed) in the Total Air Temperature (TAT) probes or generally caused by the Air Data System.

Description

Two Flight Guidance Computer are installed which perform mainly autopilot, flight guidance functions and provide commands to control the engines using several aircraft sensors.

In certain cases and circumstances a malfunction, like a TAT probe failure or temperature miscompare, will lead to a disconnection of the Flight Guidance System.

In some cases, e.g. for transient faults, a successful re-engagement of the system was observed.

Recommendation

Apart from handling the case according to the existing procedures acc. OM-B and the ACL / ECL, further attempts to re-engage the system could be made periodically.

Outlook

Our Engineering and Technical Department works in close collaboration with the manufacturer to investigate and solve this issue.

In case of any questions do not hesitate to contact me.

Best Regards

[redacted]

Technical Pilot AVRO RJ

Annex 5: Checklist in the event of failure of an IRS

Loss of IRS

If the AP is engaged, it will disengage and cannot be re-engaged.

The YD fails and cannot be recovered. The amber YD flight annunciator will illuminate. Observe the YD failed limitations - refer to **Limitations with Yaw Damper Inoperative** on Page 14.11.

Windshear detection and recovery guidance unavailable. WINDSHR INOP caption illuminates.

Category 2 approaches are not allowed.

Autoland not available; NO CAT 3 LAND advisory annunciator illuminates.

?

One IRS lost

Attitude and heading can be regained on the EFIS by using the EFIS transfer switch or the ATT/HDG transfer switch.

If the ATT/HDG switch is used:

- The FD and A/T will be lost.
- Monitor the standby compass and standby attitude indicator.

If the EFIS switch is used:

- The FD and A/T will be retained.
- Monitor attitude, heading, airspeed and ILS against standby instruments.

Both IRSs lost

Use the standby compass and standby attitude indicator.

L and R EFIS heading and attitude lost.

AP, FD and A/T lost.

Terrain awareness display lost.

EGPWS enhanced modes degraded.

TCAS lost.

Attempt to regain the IRSs using the **IRS Attitude Mode** procedure in the box on page 14.11.