Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Schweizerische Sicherheitsuntersuchungsstelle SUST
Service suisse d'enquête de sécurité SESE
Servizio svizzero d'inchiesta di sicurezza SISI
Swiss Transportation Safety Investigation Board STSB

Final Report No. 2269 by the Swiss Transportation Safety Investigation Board STSB

concerning the serious incident of the commercial aircraft Airbus A330-343, HB-JHB,

on 21 November 2014

110 NM west-northwest of Basel

CH-3003 Bern
Tel. +41 58 466 33 00, Fax +41 58 466 33 01
info@sust.admin.ch
www.sust.admin.ch

Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass als Folge eines blockierten *outflow valve* die automatische Regulierung des Kabinendruckes ausfiel und das Verfahren für dessen manuelle Steuerung nicht vollständig angewendet worden war.

Folgender Faktor wurde als ursächlich ermittelt:

- Die Flugbesatzung leitete intuitiv einen Notabstieg (*emergency descent*) ein, ohne zuvor eine strukturierte Situationsanalyse vorgenommen zu haben.

Folgender Faktor hatte zum schweren Vorfall beigetragen:

- Das systembedingte Ausblenden der Anzeigen für die Kabinendruckhöhe und den Differenzdruck bei einer Kabinendruckhöhe unterhalb -2060 ft.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances around and causes of the serious incident under investigation.

In accordance with Art. 3.1 of the 10th edition of Annexe 13, effective from 18 November 2010, to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Aviation Act, the sole purpose of an aircraft accident or serious incident investigation is to prevent further accidents or serious incidents from occurring. Legal assessment of the circumstances and causes of aircraft accidents and serious incidents is expressly excluded from the aircraft accident investigation. It is therefore not the purpose of this report to establish blame or to determine liability.

Should this report be used for purposes other than those of accident prevention, this statement should be given due consideration.

The German version of this report constitutes the original and is definitive.

All information, unless otherwise indicated, relates to the time of the serious incident.

All of the times mentioned in this report, unless otherwise indicated, are given in coordinated universal time (UTC). For the region of Switzerland, the Central European Time (CET) is used as local time (LT) at the time of the serious incident. The relationship between LT, CET and UTC is: LT = CET = UTC + 1 hour.

Contents

Summary

Overview

Owner	Swiss International Air Lines Ltd. Post Box, CH-4002 Basel
Operator	Swiss International Air Lines Ltd. Post Box, CH-4002 Basel
Manufacturer	Airbus S.A.S., Toulouse, France
Aircraft type	A330-343
Country of registration	Switzerland
Registration	HB-JHB
Location	*Flight Information Region* (FIR) France, Reims control 110 NM west-northwest of Basel
Date and time	21 November 2014, 12:03 UTC

Investigation

The serious incident occurred on 21 November 2014 at 12:03 UTC. The report came in on the same day. The former Swiss Accident Investigation Board informed France about the serious incident. The French authorities declared on 1 December 2017 that they did not provide for an investigation but were ready to assist. The Swiss Accident Investigation Board opened an investigation on 2 December 2014. France appointed an accredited representative to work with the investigation.

For the investigation the following sources of information were available:

- collect evidence on the spot
- radio communication recordings
- recordings of the cockpit voice recorder (CVR) and the quick access recorder (QAR)
- statements of the flight crew
- various expertise

The present final report is published by the Swiss Transportation Safety Investigation Board (STSB).

Synopsis

On 21 November 2014, the scheduled flight (flight number SWR 19R) from Newark (KEWR) to Zurich (LSZH) was carried out with the commercial aircraft Airbus A330-343, registered as HB-JHB. There were two pilots, 10 cabin crew members and 166 passengers on board.

After an uneventful flight, the amber warning message <u>CAB PR</u> SYS 1 FAULT was displayed in the cockpit at 12:03:12 UTC during the descent from flight level (FL) 370 to FL 310. A single chime sounded a minute later and the amber warning message <u>CAB PR</u> SYS 1+2 FAULT was displayed simultaneously.

Subsequently, the flight crew decided to request an immediate further descent from Reims control and sent an urgency message (Pan Pan). The flight crew don their oxygen masks, initiated an emergency descent and informed the cabin crew of this. A short time later, the flight crew reported Mayday to air traffic control and received clearance to descend to FL 150.

The flight crew were of the view that the oxygen masks in the cabin had been released. Shortly afterwards, the commander initiated the corresponding ECAM[1] procedure which, among other things, requests that the cabin altitude is to be controlled manually. The flight crew briefly discussed the displayed cabin altitude and found it to be okay. Approximately five minutes later, the commander mentioned that the cabin altitude was no longer being displayed.

The flight crew therefore decided to land as quickly as possible and to fully open the outflow valves manually during the approach at an altitude of approximately 4000 ft. This was to ensure that the cabin doors could be opened after landing. The commander subsequently informed the line maintenance department in Zurich that they no longer had the cabin altitude and differential pressure displays. At 12:11:47 UTC, the flight crew informed air traffic control that they would cancel Mayday.

After a frequency change to Zurich's approach control, the flight crew was given clearance for an instrument approach to runway 14 with the aid of radar vectoring. Shortly before landing, the copilot noticed that the cabin altitude was being displayed again. At 12:38:08 UTC, the aircraft HB-JHB touched down on runway 14.

The passengers and the crew disembarked the aircraft normally. There were no injuries.

Causes

The serious incident is attributed to the failure of the automatic cabin pressure regulation as a consequence of a jammed outflow valve and the fact that the procedure for its manual control was not applied fully.

The following factor was found to be causal:

- The flight crew intuitively initiated an emergency descent, without first having undertaken a structured analysis of the situation.

The following factor contributed to the serious incident:

- The system-related blanking out of the cabin altitude and the differential pressure displays when the cabin altitude reaches below -2060 ft.

Safety recommendations and safety advices

A safety recommendation and a safety advice were made with this final report.

[1] ECAM = electronic centralised aircraft monitor

1 Factual information

1.1 Pre-history and history of the flight

1.1.1 General

During the entire flight, the copilot acted as the pilot flying (PF) and the commander as the pilot monitoring (PM).

It was a scheduled flight operated according to instrument flight rules (IFR).

1.1.2 Pre-history

The aircraft A-330, registered as HB-JHB, designated for the scheduled flight from Newark (KEWR) to Zurich (LSZH), arrived in Newark approximately two hours late coming from Zurich. The designated flight number SWR 19 was therefore changed to SWR 19R.

The aircraft was prepared by the flight crew for the flight to Zurich. The preparations proceeded normally and no problems or restrictions were recorded in the aircraft's tech log.

1.1.3 History of the flight

On 21 November 2014 at 05:39 UTC, the commercial aircraft HB-JHB with flight number SWR 19R, taxied from the parking position in Newark (KEWR) to the runway, and at 05:53 UTC, the scheduled flight took off to Zurich (LSZH). There were two pilots, 10 cabin crew members and 166 passengers on board.

After an uneventful flight, the flight crew received clearance from Reims air traffic control at 11:55:28 UTC to descend from their cruising altitude of flight level (FL) 390 to FL 370. The flight crew confirmed this clearance and at 12:00:02 UTC, the copilot as PF began with the approach briefing for the upcoming landing in Zurich.

At 12:01:20 UTC, Reims control instructed the flight crew to descend to FL 310. The flight crew confirmed this clearance immediately. A little later at 12:03:12 UTC, the amber warning message <u>CAB PR</u> SYS 1 FAULT was displayed in the cockpit and the CAB PRESS page was simultaneously displayed on the system display (SD) (see annex 8). At the same time, the flight crew voiced a feeling of pressure in their ears. One minute later at 12:04:12 UTC, a single chime sounded in the cockpit and the warning message <u>CAB PR</u> SYS 1+2 FAULT was displayed simultaneously. At the time, the aircraft was descending at FL 344; on the CAB PRESS page, a cabin altitude of 5470 ft was displayed with a sink rate of 300 ft/min and a differential pressure of 8.44 PSI.

The commander spoke about this warning message to the copilot and added that they would possibly have to carry out an emergency descent. The copilot replied that they ought to descend immediately and inform air traffic control about it. The commander agreed and reported to air traffic control at 12:04:29 UTC: *„Swiss one niner Romeo, Pan Pan Pan, we have a problem with our cabin and we would like to descend down to level one four zero at least."* At the same time, both pilots put their oxygen masks on. The flight crew immediately received clearance to descend to FL 230 and notification that they would be called again shortly. The flight crew confirmed this clearance and initiated an emergency descent. The cabin crew was informed about this decision at 12:05:06 UTC with the words, *„Cabin crew emergency descent"* over the public address (PA) system (see annexe 3). In addition, air traffic control was informed as follows at 12:05:19 UTC: *„Swiss one niner Romeo, Mayday Mayday Mayday"*. Air traffic control immediately confirmed this distress message and gave the flight crew clearance for FL 150 which was confirmed at 12:05:33 UTC.

The copilot informed the commander at 12:05:40 UTC that he had set the transponder to emergency code 7700. At the same time, both pilots checked that they were able to communicate with each other with their oxygen masks on.

At FL 277, descending, the commander informed the copilot at 12:05:55 UTC that he would now begin with the ECAM procedure. By that, he was referring to the procedure that includes the requirement, in the corresponding checklist, to now operate the cabin pressure system manually (see chapter 1.17.1.3). The copilot took note of this and reported to the commander that he had the aircraft under control and would now descend to FL 150. According to the recordings, the cabin altitude was 3200 ft at that time with a cabin sink rate of 1300 ft/min. The differential pressure was 8.2 PSI.

To the copilot's subsequent question about whether the commander wanted to say something to the passengers, the latter answered in the negative and remarked that he did not have any time at the moment. He made a comment to the effect that he assumed that the passengers had don their oxygen masks.

At 12:06:58 UTC, the commander informed the copilot that the cabin altitude was 2000 ft. Remarking that they had a good cabin altitude, the copilot informed the commander at 12:08:08 UTC that he would reduce the sink rate somewhat. At this time, the aircraft was descending at FL 172. The recordings show a cabin altitude of 300 ft, a cabin sink rate of 1200 ft/min and a differential pressure of 7.0 PSI. In the meantime, the flight crew had received clearance at 12:07:11 UTC to descend to FL 100 which the flight crew immediately confirmed.

Subsequently, a short conversation ensued about the cabin altitude. The aircraft was descending at FL 149 when the copilot asked the commander at 12:08:47 UTC with surprise whether he had seen that the cabin altitude was now in the negative range and that the cabin was „pumping up". The recordings show a cabin altitude of -480 ft and a cabin sink rate of 1200 ft/min. The commander answered with *„Yes, yes"* and at the same time air traffic control called as follows: *„Swiss one niner Romeo, when able, say intentions and do you need assistance on landing?"* The commander responded immediately: *„Stand by, we have to level off now and we have to organise the cockpit, we will call you back."* To which air traffic control responded: *„Copied, call me back when able."*

At 12:09:07 UTC, the commander said that he would take his oxygen mask off and the copilot answered that he would keep his on for a brief moment. Approximately one minute later at 12:10:12 UTC, the cabin crew supervisor reported to the cockpit and announced that they would have to finish the work in the cabin and that this would take another 20 minutes.

At 12:10:51 UTC, the commander notified the copilot that he could no longer see the cabin altitude on the screen. At this time, the recordings show a cabin altitude of -2680 ft. As determined by the system, the cabin altitude was no longer displayed on the CAB PRESS page. The copilot responded that it had initially not been available, then it was displayed again and now it was gone again. At this time, the aircraft was at FL 100. After a short discussion, the flight crew decided to land as quickly as possible and the commander remarked that they did not know exactly where the problem was but that they had to be able to open the cabin doors after landing. To this the copilot replied that indeed they did not know the cabin altitude, but they could bring the cabin altitude to the altitude of the aircraft by opening the outflow valves. The commander responded that they would do that at an altitude of 4000 ft and the copilot said *„exactly, precisely."*

Subsequently, the flight crew reported the following to air traffic control at 12:11:47 UTC: *„OK, Swiss one niner Romeo, we cancel Mayday and we would like to proceed for a direct approach in Zurich."* Air traffic control confirmed this message and communicated the following to the flight crew at 12:12:03 UTC: *„Swiss one niner Romeo, maintain one zero zero. I'll call you back for the approach."*

Approximately 20 seconds later, the commander made radio contact with the line maintenance department in Zurich and the copilot confirmed that he would now take over communication with air traffic control. At 12:14:05 UTC, he was instructed to change to Zurich's arrival frequency and report the heading to them. This instruction was repeated at 12:14:21 UTC and the copilot reported the following to the Zurich arrival air traffic control officer (ATCO) at 12:15:01 UTC: *„Zurich arrival, good afternoon, Swiss one niner Romeo heavy, we have Juliette heading is one zero zero and speed two two zero, I call you when ready for the approach."* The ATCO confirmed this call.

In the meantime, the pilot conducted a lengthy conversation with the line maintenance department. He told them, among other things, that they did not have any indication of the cabin altitude or the differential pressure. He also confirmed that the forward outflow valve was closed and the aft outflow valve was slightly opened. At 12:17:25 UTC, he informed the line maintenance department that they had no idea what the cabin altitude was. Then he was informed by the copilot that the safety valve had opened. The recordings show a cabin altitude of -7250 ft at this time, with a cabin sink rate of 0 ft/min and a differential pressure of 8.81 PSI (see annexe 5).

In the meantime, the ATCO had given the SWR 19R flight crew their requested heading instructions in the direction of the holding area above the GIPOL waypoint.

At 12:17:56 UTC, the copilot made a comment to the commander to the effect that he had the feeling that the cabin had „pumped up" again and that therefore the safety valve had opened, they could however not have foreseen this deve-lopment. The commander communicated this information to the line maintenance department and subsequently ended the conversation. A brief conversation ensued in the cockpit, indicating that the cabin altitude on the CAB PRESS page was still not visible to the flight crew.

At 12:19:41 UTC, the copilot confirmed to the commander that he was now taking over the radio communication again so that the latter could inform the passengers. At 12:20:16 UTC, the ATCO asked the flight crew if they had time to answer a question. The flight crew answered in the affirmative and the ATCO thereupon asked: *„Confirm your problem is about pressurisation of the cabin?"* to which the copilot responded: *„Yes exactly, we lost both cabin pressure controllers."* A little later at 12:22:32 UTC, the copilot informed the commander that the safety valve had opened again.

At 12:24:07 UTC, the ATCO asked the flight crew whether they would require support once they had landed. Because the commander had discussed the situation with the cabin crew supervisor in the meantime and the latter had told him that everything was fine with the passengers, the enquiry from the ATCO was answered in the negative. Despite this, the flight crew decided to contact the airline's dispatch centre and communicate to them that someone should be on the ground after landing to answer any possible questions from the passengers.

Subsequently, the ATCO guided the flight crew to the approach of runway 14 using radar vectoring. At 12:29:49 UTC, the flight crew received clearance to descend to 4000 ft. The flight crew again had a brief conversation and noticed that according to ECAM everything had been dealt with and the only thing left to do when reaching 4000 ft was to open the outflow valves with the MAN V/S CTL toggle switch (see chapter 1.17.1.3). The copilot confirmed that the approach briefing was finished and they could land.

At 12:32:00 UTC, the ATCO gave the flight crew heading instructions and clearance for an instrument approach to runway 14. The commander confirmed this clearance and simultaneously communicated to the ATCO: *„We have cancelled Mayday, so you can give us another squawk."* Thereafter the flight crew was allocated squawk 2014. Moments later the commander informed the copilot that he would now open the outflow valves. The aircraft was at an altitude of 4850 ft QNH. According to the recordings, the cabin altitude was -10 600 ft at this time, with a cabin sink rate of 500 ft/min and a differential pressure of 8.79 PSI.

At 12:33:58 UTC, the flight crew reported: *„Swiss one niner Romeo we are established, one question, in case of go around can we stay at four thousand?"* The ATCO answered: *„Of course Swiss one niner Romeo, no problem."*

The flight crew was now prompted to change to the Zurich tower frequency, which it immediately did. At 12:34:46 UTC, the commander appeared astonished that the cabin altitude's climb rate was now 2050 ft/min. The recordings show a cabin altitude of -5170 ft and a cabin climb rate of 2250 ft/min.

Approximately 50 seconds later, the copilot noticed they now suddenly had the cabin altitude display again. The recordings show a cabin altitude of 200 ft, a cabin climb rate of 6350 ft/min and a differential pressure of 1.5 PSI. In addition, the copilot communicated at 12:36:14 UTC that the cabin altitude was now 2800 ft. The recordings confirm this statement. The cabin altitude now corresponded to the aircraft altitude and there was no differential pressure present.

Subsequently, the cabin altitude subsided in line with the aircraft altitude and the aircraft landed on runway 14 at 12:38:08 UTC.

No damage was sustained; passengers and crew were able to disembark the aircraft normally.

1.1.4 Time and location of the serious incident

Location	FIR France, Reims control 110 NM west-northwest of Basel
Date and time	21 November 2014, 12:03 UTC
Coordinates	N 48° 08' 48'' E 004° 56' 49''
Light conditions	Daytime
Altitude	Descending from FL 370 to FL 310

1.2 Injuries to persons

Injuries	Crew members	Passengers	Total no. of occupants	Third parties
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	12	166	178	n/a
Total	12	166	178	0

1.3 Damage to aircraft

Not applicable

1.4 Other damage

None

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Commander

1.5.1.1.1 General

Person	Swiss national, born 1957	
Licence	Airline transport pilot licence aeroplane (ATPL)(A), according to the European Aviation Safety Agency (EASA), issued by the Federal Office of Civil Aviation (FOCA)	
Medical certificate	Class 1 Restrictions: VNL (shall have available corrective lenses for near vision)	
Flying experience	Total	17 985:23 hours
	Of which as commander	12 260:00 hours
	On type involved in the serious incident	4 191:00 hours
	During the last 90 days	90:15 hours
	Of which on type involved in the serious incident	39:04 hours

1.5.1.1.2 Duty times

Time on duty before day of serious incident	19 November 2014: 15:05 UTC to 20 November 2014: 01:32 UTC
Start of duty on day of serious incident	21 November 2014: 04:15 UTC
Length of duty time at the time of the serious incident	7:48 hours

1.5.1.2 Copilot

1.5.1.2.1 General

Person	Swiss national, born 1972	
Licence	ATPL(A) in accordance with EASA, issued by FOCA	
Medical certificate	Class 1; no restrictions	
Flying experience	Total	6 399:01 hours
	On type involved in the serious incident	739:28 hours
	During the last 90 days	106:20 hours
	Of which on type involved in the serious incident	75:53 hours

1.5.1.2.2 Duty times

Time on duty before day of serious incident	19 November 2014: 15:05 UTC to 20 November 2014: 01:32 UTC
Start of duty on day of serious incident	21 November 2014: 04:15 UTC
Length of duty at the time of the serious incident	7:48 hours

1.6 Aircraft information

1.6.1 General information

Registration	HB-JHB
Aircraft type	A330-343
Specification	Twin engine medium- and long-range aircraft with turbofan engine
Manufacturer	Airbus S.A.S., Toulouse, France
Owner	Swiss International Air Lines Ltd. Post Box, CH-4002 Basel
Operator	Swiss International Air Lines Ltd. Post Box, CH-4002 Basel
Engine	RB211 Trent 772B-60
Max. permissible mass	Take-off 233 000 kg Landing 187 000 kg
Mass and centre of gravity	Both mass and centre of gravity were within the permissible limits of the aircraft flight manual (AFM).

1.6.2 Cabin pressurization system

1.6.2.1 General

The cabin pressurization system has, among other things, the function of regulating the atmospheric pressure in the passenger cabin and cockpit. Because the atmospheric pressure is very low at cruising level, excess pressure must be built up in the aircraft. To enable this, a relatively constant volume of air is led into the inside of the aircraft. By opening and closing the outflow valves, the pressure is regulated.

The cabin pressurization system consists of the following components[2]:

- two cabin pressure controllers (CPC)
- the forward outflow valve
- the aft outflow valve
- the cabin pressure control panel
- two safety valves

In automatic mode, one of the two CPCs controls the outflow valves. In the event of failure, it is automatically switched to the second CPC. To ensure system redundancy, it is automatically switched to the other CPC after every flight.

Each outflow valve can be moved by three electric motors; one each for CPC 1 and CPC 2 in automatic mode, and one for manual mode. Controlling the electronic motors in automatic mode is facilitated by one electronic module each. This allows for the correct implementation of the positioning commands issued by the CPC and reports back the position taken. The electric motor for manual mode is directly controlled via the MAN V/S CTL switch on the cabin pressure control panel (see figure 1).

The cabin pressure control panel serves the operation of the cabin pressurization system. The individual controls are described in annex 7.

The safety valves open independently and purely mechanically when the differential pressure (ΔP) reaches a value between 8.75 PSI and 8.95 PSI. In the interest of safety, two safety valves are mounted on the pressure dome at the rear of the aircraft fuselage. When a safety valve opens, a master caution warning is activated.

The cabin pressurization system can be operated in two operating modes. These are described in the following subchapters. The simplified block diagram of the cabin pressurization system is shown in annex 6.

1.6.2.2 Automatic mode

As standard, the cabin pressure system is operated in automatic mode. If the corresponding data[3] from the flight management guidance computer (FMGC) is available, it is used by the CPC to calculate an optimal climb or sink profile of the cabin altitude. In this process, the current ambient pressure, the maximum differential pressure (ΔP) and the maximum permissible climb or sink rates are taken into consideration.

If this data is not present, the landing field elevation has to be entered manually so that the CPC can internally calculate a sink profile. After landing, the outflow valves

[2] The list was consciously reduced to the components that had played a role in the serious incident.

[3] Top of climb time, top of descent time, time of arrival, landing field elevation, cruise flight level, final cruise flight level, QNH at destination

are opened in order to equalise the pressure. The relevant parameters are shown on the ECAM (see annex 8).

In case of a malfunction of both CPCs, the ECAM procedure stipulates a switch over to manual mode. According to the recording, in the present case CPC 1 turned itself off with the amber warning message SYS 1 FAULT at 12:03:12 UTC and approximately one minute later, CPC 2 also turned itself off with the amber warning message SYS 1+2 FAULT. The reason for that was that the aft outflow valve jammed in the closing phase at approximately 7°.

1.6.2.3 Manual mode

In the case of a double failure of CPC 1 and 2, the FAULT annunciator light illuminates on the cabin pressure control panel. By pressing the MODE SEL pushbutton, the system is switched into manual mode which is confirmed by the MAN annunciator light (see figure 1).

By pressing the MODE SEL pushbutton, switching into manual mode can be done at any time and independent of a malfunction.

In manual mode, the position of the outflow valves and with this the cabin altitude can be controlled by the spring-loaded MAN V/S CTL switch. With the VALVE SEL selector, an individual outflow valve can be manually operated if necessary.

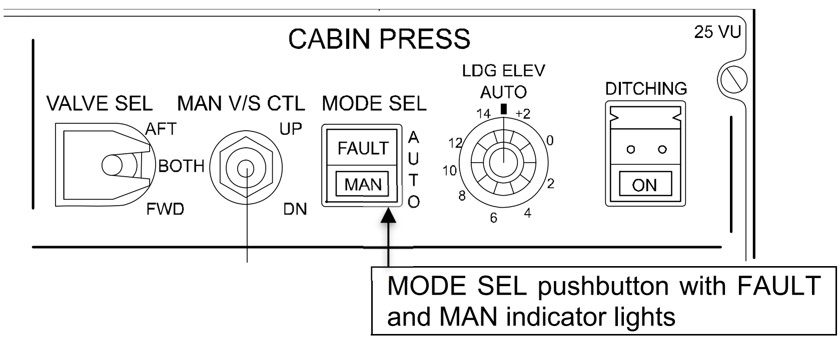


Figure 1: Cabin pressure control panel

The cabin altitude, cabin altitude rate, differential pressure, forward outflow valve position, aft outflow valve position parameters are displayed as in automatic mode on the ECAM. Because the electronics of the manual backup part in CPC 1 were purposely kept simple, the processing of these signals is carried out in the SDAC. The manual backup part in CPC 2 is not used. The manual backup part in CPC 1 is powered by a separate electrical power source (DC BAT BUS).

The cabin pressure parameter is transferred to the SDAC as direct current (analogue) signal. There it is converted into a digital parameter from which the cabin altitude is calculated. The direct current has a lower and upper limit as a result of which this parameter is no longer displayed from a cabin altitude of -2060 feet.

The cabin altitude rate parameter is derived from the cabin altitude. The differential pressure parameter is calculated from the formula $\Delta P = P_{cabin} - P_{ambient}$. The ambient pressure is supplied by the ADIRS. The data flow is shown in figure 2.

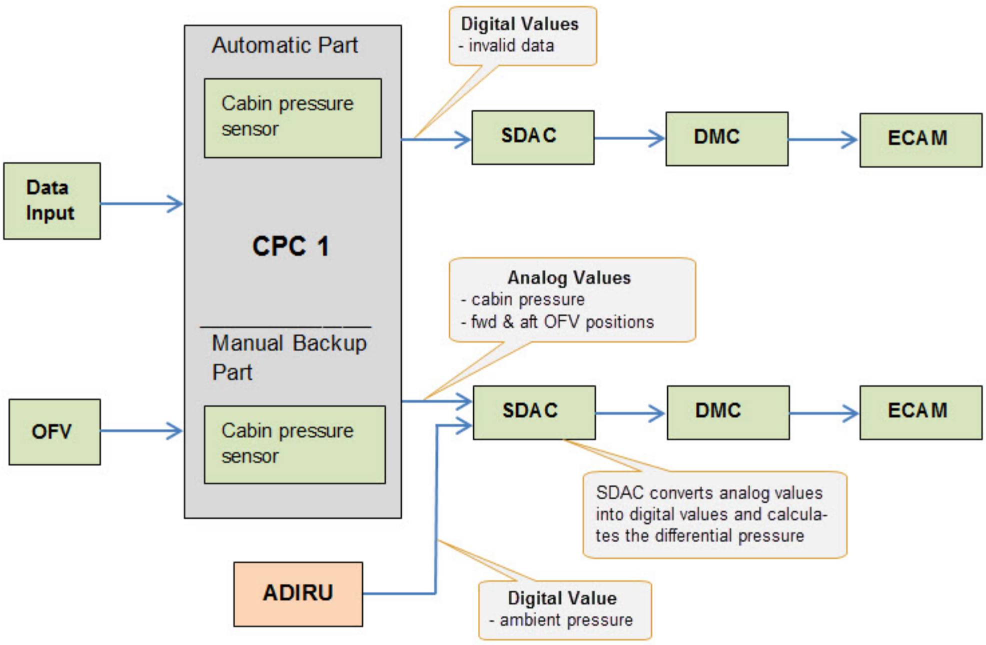


Figure 2: Data flow diagram for ECAM displays in manual mode (SYS 1 FAULT)

1.6.3 Electronic instrument system

1.6.3.1 General

The general cockpit layout looks as follows:

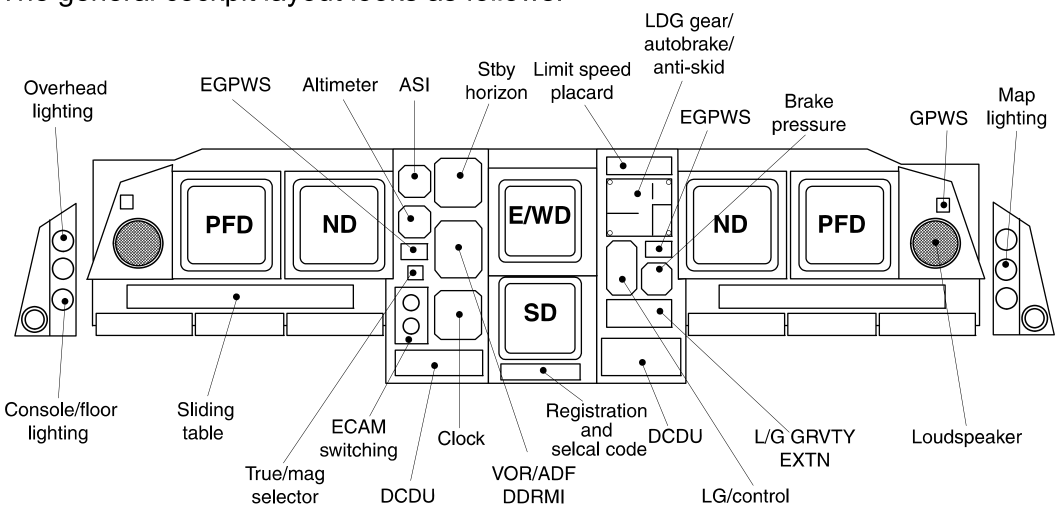


Figure 3: HB-JHB cockpit layout

The six screens (2 PFDs, 2 NDs, E/WD, SD) serve primarily as the following displays:

PFD — Both of these screens, primary flight displays (PFD), are the primary flight data displays for the commander and copilot. The PFDs serve primarily as the display of flight attitude, flight altitude, airspeed and heading.

ND — Both of these screens serve, among other things, as the navigation display (ND). They show map displays and flight plan information. In addition, a wide range of other information can be displayed, for example, air traffic displays, weather, terrain, approach charts and waypoint information.

E/WD This engine/warning display (E/WD) screen displays mainly engine primary indication, flap/slat position and warning & caution messages.

This screen is part of the electronic centralised aircraft monitor (ECAM) (see chapter 1.6.3.3).

SD This screen serves as the system display (SD); the systems are shown simplified in system synoptic diagrams. The various system displays can be selected on the ECAM control panel (ECP). In addition, various systems' status is listed.

The electronic instrument system (EIS) is divided into two subsystems:

- the electronic flight instrument system (EFIS)
- the electronic centralised aircraft monitor (ECAM)

1.6.3.2 Electronic flight instrument system

The EFIS includes both PFD and ND screens.

1.6.3.3 Electronic centralised aircraft monitor

The ECAM consists of two screens arranged on top of each other. Engine data and warning messages are displayed on the upper engine/warning display (E/WD). System pages, which provide the pilot with an overview of the various systems and their switching statuses, are displayed on the lower system display (SD).

The system to be displayed can be selected on the ECAM control panel. In the event of failure, the corresponding system page is automatically displayed depending on the cause of failure. So, for example, CAB PR SYS 1 FAULT is displayed on the E/WD screen in case of a CPC 1 malfunction, and the CAB PRESS page is shown automatically (see annex 8). This malfunction is normally displayed in cruise. In other flight phases, e.g. landing, it is suppressed.

The three display management computers (DMC) process the data for the EFIS and the ECAM (see figure 5). The data for the EFIS is primarily provided by the flight guidance and navigation systems. Normally, DMC 1 supplies the data for the commander's EFIS, and DMC 2 the data for the copilot's EFIS. In the event of failure, it can be switched to the opposing DMC or to DMC 3.

For the ECAM, the three DMCs process the data received from the system data acquisition concentrator (SDAC) and the flight warning computer (FWC). ECAM data is displayed on the E/WD (DU1) and SD (DU2). With the ECAM selector switch on the ECAM switching panel in AUTO position, DMC 3 supplies the data. In the event of failure, it can be switched to DMC 1 or DMC 2 (see figure 4).

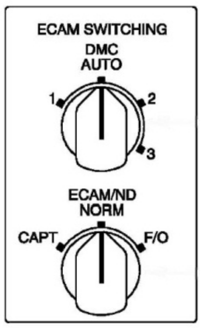


Figure 4: ECAM switching panel

The two identical FWCs generate alert messages, aural alerts and synthetic voice messages. Signals for the red warning displays reach the three DMCs via the

FWC. Signals for the amber warning messages are transmitted from the SDAC to the DMC via the FWC. Along with the warning messages, the FWC provides the radio altitude callouts and data for the system pages.

During the serious incident, the amber warning message <u>CAB PR</u> SYS 1 FAULT was displayed on the E/WD at 12:03:12 UTC and one minute later the amber warning message <u>CAB PR</u> SYS 1+2 FAULT. The latter warning message was accompanied by a single chime and the master caution lights illuminated.

As safety valve 1 opened, the master caution annunciator lights lit up each time and a single chime sounded. The amber warning message SAFETY VALVE OPEN was displayed on the E/WD.

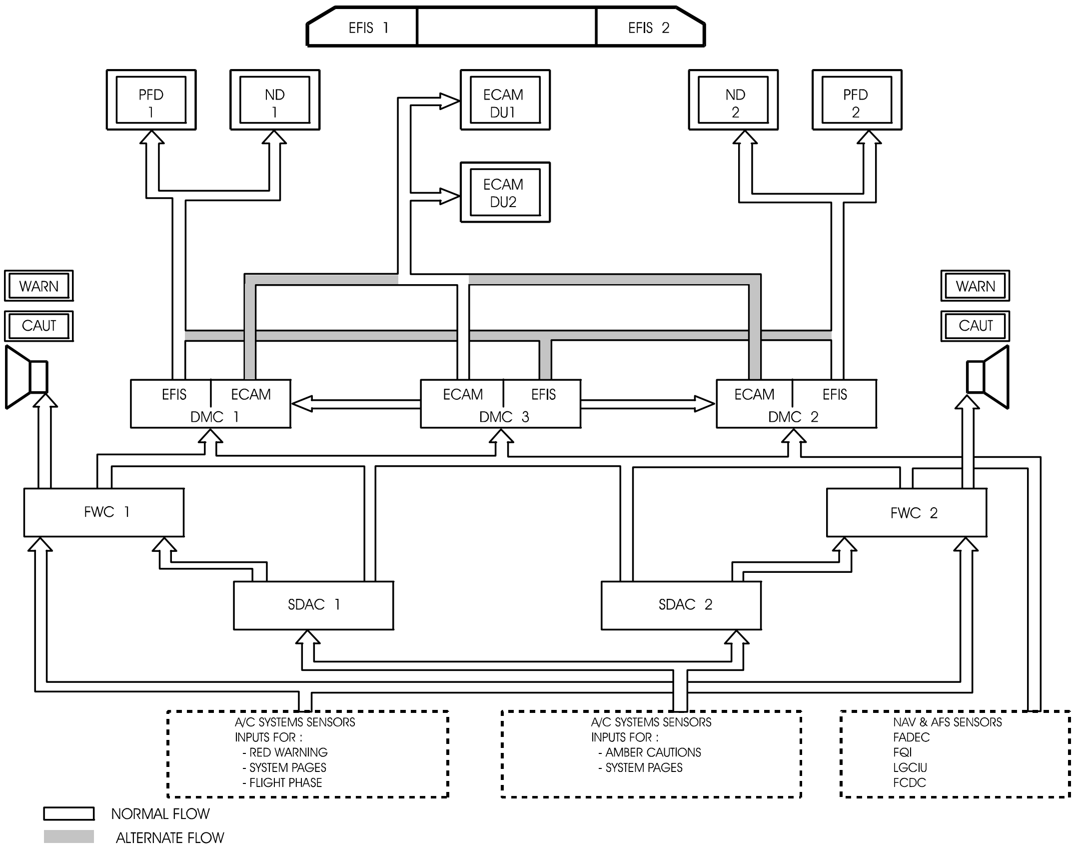


Figure 5: Block diagram of the electronic instrument system (EIS)

1.6.4 Centralised fault display system

The centralised fault display system (CFDS) permits the line maintenance personnel to analyse system failures that occurred during the flight and to initiate specific repair measures. A so-called post flight report (PFR) can be printed out in the cockpit after the flight. Additionally, individual systems can be tested on the ground via CFDS.

The CFDS comprises largely of the centralised fault display interface unit (CFDIU), the multipurpose control display units (MCDUs) and a printer. The

MCDUs serve as human interface for various systems, including for the flight management and guidance system (FMGS). The CFDS receives BITE data[4] from various electronic aircraft systems as well as ECAM fault reports from the flight warning system (FWS) (see figure 6).

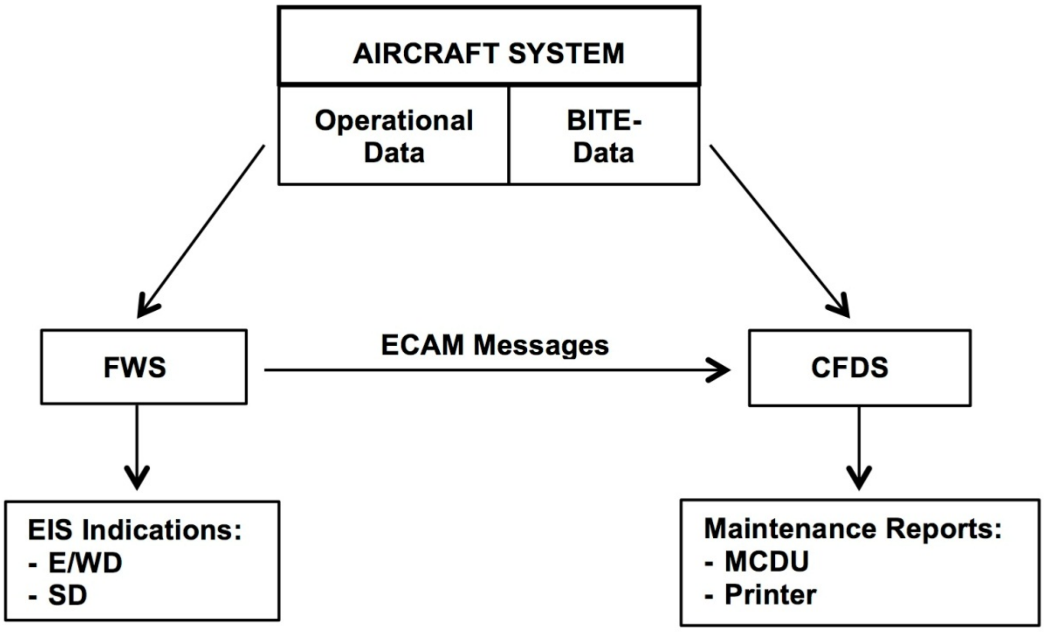


Figure 6: Data flow diagram of the centralised fault display system (CFDS)

The fault reports are divided into classes.

- Class 1 faults are visible to the crew (ECAM warning, flag, etc.) and have an impact on the operation of the aircraft. They trigger a post flight report (PFR) at the end of the flight. If the fault cannot be corrected before the next flight, the minimum equipment list (MEL) shall apply.
- Class 2 faults do not have any operational consequences. They trigger a post flight report (PFR) at the end of the flight. In addition, the problem is listed on the ECAM status page, so that it can be entered in the tech log by the crew.

The CFDS can store data from several flights. This data can be retrieved and printed out via MCDU as required. For PFR, the memory capacity for the warning messages displayed on the ECAM is limited to the last 40 entries, i.e. all older entries are continually overwritten.

The CFDS issues a current flight report (CFR) during the flight. This can be viewed on the MCDU when required. Certain fault reports are also transmitted to ground stations via ACARS[5].

[4] BITE stands for built-in test equipment. Most electronic devices are continuously self-testing (continuous BITE) and send fault reports to the CFDS.

[5] ACARS stands for airborne communications addressing and reporting system. ACARS is a digital data transmission system which transmits simple information between the aircraft and ground stations and vice versa. The system transmits, among other things, fault reports automatically and without the crew's intervention to the corresponding ground services.

1.7 Meteorological information

1.7.1 General weather conditions

At ground level, there was an area of low pressure from the North Atlantic to the Canary Islands. France was between this area of low pressure and higher pressure over North East Europe. At altitude, a ridge extended from Algeria to Scotland. Mild air pushed forward over France northwards which led to extensive high and medium-high cloud fields over North East France.

1.7.2 Weather at the time and location of the serious incident

At FL 390 the wind blew at approximately 45 kt from 240 to 270 degrees. The air temperature was minus 55 degrees Celsius. The HB-JHB was located south-west of and outside the polar-front jet stream's catchment area whose axis ranged from the North Sea across the middle of Germany to the North Aegean. Along the flight path when descending, the wind blew primarily from the west with a speed in the range of 25 to 35 kt. In the area surrounding Zurich Airport there was a westerly wind; a south-westerly wind at ground level. Along HB-JHB's final approach, the wind blew on average at 10 ±5 kt.

1.7.3 Astronomical information

Position of the sun in Reims	Azimuth: 188 °	Elevation: 20 °
Light conditions	Day	

1.7.4 Airport weather report

At the time of the serious incident, the following meteorological aviation routine weather report (METAR) was valid:

METAR LSZH 211250Z VRB02KT 6000 SCT072 BKN110 10/06 Q1021 NOSIG=

This means in long form:

On 21 November 2014, the following weather conditions were observed shortly before the 12:50 UTC Zurich Airport weather report was dispatched:

Wind	2 kt, variable
Meteorological visibility	6 km
Precipitation	None
Cloud	3/8-4/8 at 7200 ft AAE[6] 5/8-7/8 at 11 000 ft AAE
Temperature	10 °C
Dew point	6 °C
Atmospheric pressure (QNH)	1021 hPa, pressure reduced to sea level, calculated with the values of the ICAO[7] standard atmosphere.
Landing weather forecast	In the two hours following the weather observation, no significant changes are expected.

[6] AAE: above aerodrome elevation

[7] ICAO International Civil Aviation Organisation

1.8 Aids to navigation

At the time of the serious incident, no relevant restrictions for flight SWR 19R were published for Zurich Airport.

1.9 Communication

Radio communication between the pilots and air traffic control was duly undertaken, in English and without difficulties.

1.10 Aerodrome information

1.10.1 General

Zurich Airport is in the north-east of Switzerland. In 2013, the airport served 24.86 million passengers and approximately 262 000 aircraft movements.

The airport reference elevation is 1416 ft AMSL[8], the reference temperature is defined as 24.0 °C.

1.10.2 Runway system

Zurich Airport features a system of three runways. Runways 16 and 14 are equipped with a category III instrument landing system (ILS) and runway 34 with a category I ILS. Runway 28 is equipped with an uncategorised ILS which features increased weather minima compared to category I.

The runways at Zurich Airport have the following dimensions:

Runway designation	Dimensions	Runway threshold elevation
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, all three runways in their entire lengths were available for landings.

1.10.3 Emergency and fire services

At the time of the serious incident, Zurich Airport was equipped with category 10 fire-fighting agents. The airport's fire service carried out permanent on-call service during air traffic hours.

1.11 Flight recorders

1.11.1 Flight data recorder

Model	SSFDR
Manufacturer	Honeywell
Serial number	Serial number 16993; part number 980-7400-042
Number of parameters	64
Recording medium	Solid state memory
Length of recording	100 hours

[8] AMSL: above mean sea level

The data from the flight data recorder were recorded uninterrupted and could be read out. The cabin altitude and the cabin differential pressure are not recorded. This data is recorded in the quick access recorder (QAR) and has been available for the investigation.

1.11.2 Cockpit voice recorder

Model	SSCVR
Manufacturer	Honeywell
Serial number	Serial number 09656; part number 980-6022-001
Number of channels	4
Recording medium	Solid state memory
Length of recording	2 hours

It was possible to examine all four channels of the cockpit voice recorder (CVR) and they have been available for the investigation.

1.12 Wreckage and impact information

Not applicable

1.13 Medical and pathological information

There is no evidence of health problems or fatigue in relation to the pilots.

1.14 Fire

Not applicable

1.15 Survival aspects

Up to a flying altitude of approximately 4000 ft, the position of the forward and aft outflow valves was not changed by the crew whilst descending. Consequently, the cabin pressure steadily increased. One of the cabin pressure safety valves opened upon reaching the maximum cabin differential pressure. As a result, excessive pressure in the cabin was avoided and there was no significant risk of injury.

1.16 Tests and research

1.16.1 Measures taken after landing

The faults that occurred on the aircraft were automatically transmitted to the operator's line maintenance department via the ACARS. Consequently, the line maintenance department was prepared.

The PFR on the aircraft's own CFDS confirmed the relevant fault reports for the serious incident which were transmitted by the ACARS as follows:

12:03 UTC: AFT OUTFLOWVALVE
12:03 UTC: CAB PR SYS 1 FAULT
12:04 UTC: AFT OUTFLOWVALVE
12:04 UTC: CAB PR SYS 1 + 2 FAULT
12:10 UTC: CPC 1
12:17 UTC: CAB PR SAFETY VALVE OPEN

A subsequent functional test carried out resulted in 'no failure found'.

Subsequently, CPC 1 and the aft outflow valve were removed for a more in-depth investigation. CPC 2 was also removed a few days later. The results of the equipment manufacturer's inspection can be found in the following chapters.

1.16.2 Inspection by the equipment manufacturer

The equipment manufacturer thoroughly inspected both CPCs and the aft outflow valve. This consisted of, among other things, a visual inspection for exterior damage of the received parts.

1.16.2.1 Inspections of the CPCs

The internal memory of both CPCs was read out. The data confirmed the findings from the QAR that at the time of the serious incident, the outflow valve had jammed during the closing process in a position of approximately 7 degrees. This almost corresponded to the closed position.

Subsequently, both CPCs were tested on the automatic test station in accordance with the component maintenance manual (CMM). Both devices passed the test without an error message.

1.16.2.2 Inspections of the aft outflow valve

A thorough visual inspection was carried out on the aft outflow valve. No mechanical damage whatsoever (scratch marks, deformations) was found in the process.

Both electronic boxes passed the functional check in accordance with the CMM without any problems.

The actuator, consisting of the gear box, two electronic boxes and three electric motors, was tested as a single unit in accordance with the CMM. The test ran without any problems.

The aft outflow valve was cooled to minus 40 degrees in the cooling chamber and then tested several times as it warmed up. This test also ran without any problems.

1.16.2.3 Extended functional checks

Both CPCs were connected to the so-called base tester (see figure 7). In this test system, the aircraft's inputs (ADIRS, FMGC, etc.) are simulated and the outputs are displayed on a screen. The test outflow valve was used as aft outflow valve. The forward outflow valve was simulated. Both CPCs were connected to special equipment with which the cabin pressure (P_{cabin}) could be simulated. The external pressure ($P_{ambient}$) was simulated by the base tester. The pressure conditions were set to those of the serious incident.

The aft outflow valve got jammed in a position close to closed, in order to force a loop closure failure. Both CPCs entered standby fault (failure state) status successively, which was consistent with expectations. This chronological course corresponded almost exactly to the QAR recordings.

On the base tester display, the Arinc 429 digital output signals of both CPCs were observed. All showed the status 'invalid status' (ssm = 00).

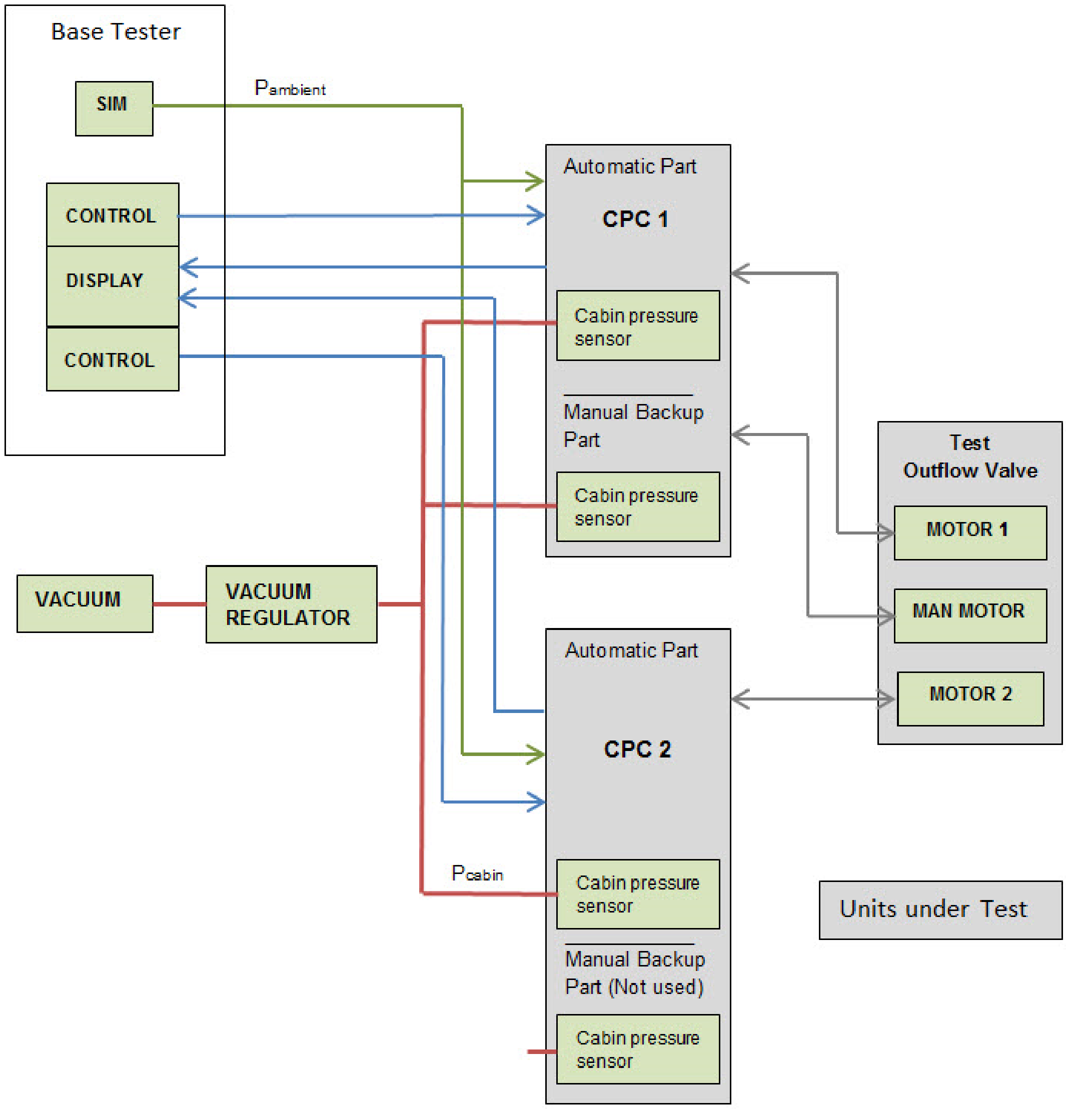


Figure 7: Simplified presentation of the Nord Micro base tester

1.16.2.4 Functional check of CPC 1's manual backup part

According to the crew's statements, the cabin altitude and the differential pressure were intermittently not displayed in manual mode. The base tester provided the opportunity to clarify this.

For this purpose, a breakout box and a multimeter were fitted in the analogue signal's circuit for the transmission of the cabin pressure (see figure 2). Furthermore, the vacuum generator was connected only to the cabin pressure sensor in the manual backup part of CPC 1.

The measurement indicated that the cabin pressure sensor output showed a total range of 0-11.68 V, corresponding to 0-1400 hPa. The operational range was limited to 4.6-9.2 V, corresponding to 546-1091 hPa (1091 hPa corresponds to an altitude of -2060 ft). The measurement results were consistent with the CPC's specification.

The cabin altitude and cabin differential pressure parameters are calculated in the SDAC when CPC 1 is in manual mode (see figure 2). The SDAC receives the cabin pressure in analogue form from CPC 1. The analogue value is converted into a digital parameter and the cabin altitude and the cabin altitude rate are derived from it. The SDAC receives the ambient pressure digitally from the ADIRS. The cabin differential pressure is calculated using the formula $\Delta P = P_{cabin} - P_{ambient}$. Because the operational range of the cabin pressure is limited to 9.2 V, the cabin altitude is not displayed below -2060 ft. The digital display is replaced by amber crosses and the analogue display is blanked out. This also applies to the cabin differential pressure. The aircraft manufacturer's reason for this is as follows: *"The rational for that is because the analogue pressure sensor is designed to have a sufficient range to cover lowest and highest worldwide airport altitudes."*

1.17 Organizational and management information

1.17.1 Airline Operator

1.17.1.1 General

The various procedures are detailed in the respective operations manuals of the airline operator. The general procedures are laid down in the operations manual (OM) A and the aircraft-specific procedures in OM B.

1.17.1.2 General procedural requirements

With regards to terminology and communication in abnormal or emergency situations, the operator's OM A states, among other things:

„8.3.20.1 Terminology

8.3.20.1.1 Abnormal conditions

Abnormal conditions require increased attention to safety by the crew. They can be caused by technical, operational or other reasons such as passenger illness.

8.3.20.1.2 Emergency conditions

In emergency conditions safety is compromised or will be compromised within a critical time. The crew devotes all its attention to the safety of the aeroplane, its passengers and crew.

(...)

An emergency condition is classified in accordance with the degree of danger or hazard being experienced, as follows:

- ***Urgency:** A condition concerning the safety of an aeroplane or other vehicle, or some person on board or within sight, which does not require immediate assistance. The appropriate phraseology is the word „Pan Pan" repeated three times.*
- ***Distress:** A condition of being threatened by serious and/or imminent danger and requiring immediate assistance. The appropriate phraseology is the word „Maday" repeated three times."*

Furthermore, when dealing with faults, following procedure is detailed in chapter 8.3.20.3 Procedures:

„8.3.20.3.1 Decision finding process

8.3.20.3.1.1 General

***PPAA** (power, performance, analysis, action) principle helps the crew, in any critical or abnormal situation, to immediately find mental access to a structured process.*

PPAA shall make sure, that all appropriate measures are taken regarding aeroplane performance, obstacle free vector and technical redundancy. As soon as the execution of PPAA results in a consolidated situation allowing, e.g. to evaluate operational considerations, the below defined well-structured decision finding process shall be applied.

8.3.20.3.1.2 Decision finding

***SPORDEC** stands for a step-by-step procedure for a decision finding under involvement of all resources inside and outside of the crew.*

***S** ituation catch*	*Situation shall be analysed, carefully taking into account all available information.*
***P** reliminary actions*	*Time-critical actions shall be executed such as calling for external assistance, ordering emergency preparations or calling for additional information.*
***O** ptions*	*Search for options.*
***R** ating*	*Evaluate options for risk and benefit.*
***D** ecision*	*The CMD makes up a decision. He conducts the planning for execution.*
***E** xecution*	*Co-ordinated actions and mutual monitoring take place.*
***C** ontrolling*	*Results and ongoing development are carefully monitored. If the situation warrants, a new decision finding shall be started.*

8.3.20.3.2 Use of checklists

The use of checklists and approved flight deck documents is mandatory in case of abnormal conditions. In an emergency they shall be used as guidelines at the CMD's discretion."

1.17.1.3 Aircraft-specific procedural requirements

The OM B is available to the flight crew electronically. It consists of the following individual manuals:

- Flight crew operating manual (FCOM) also containing, among other things, the aircraft manufacturer's operating engineering bulletins (OEB);
- Minimum equipment list (MEL) including MEL operational procedures;
- Quick reference handbook (QRH);
- Configuration deviation list (CDL).

Along with the system descriptions, all procedures for standard operation, abnormal operation and emergency situations are also published in the FCOM.

In the FCOM, the procedure in case of failure of both pressurization systems (pressure fault) can be found in the chapter „abnormal and emergency procedures, air conditioning / pressurization / ventilation" and is shown as follows:

CAB PR SYS (1+2) FAULT
(BOTH SYSTEMS AFFECTED)

Applicable to: ALL

- **If one door not locked closed on ground:**
  CAB PR INHIB BY DOORS
- **In all other cases:**

L2 Due to the slow closure of the outflow valve in manual pressurization mode and depending on the failure, the following procedure may not avoid a depressurization.

L1 MODE SEL....................MAN
MAN VALVE SEL....................BOTH
MAN V/S CTL....................AS RQRD

L2 *Monitor cabin V/S and cabin altitude frequently and adjust as necessary.*
Maintain aircraft altitude at or above cabin altitude. It may take 10 s in manual mode before the crew notices a change of the outflow valve position.
The two safety valves limit ΔP to 8.85 PSI.

Continued on the following page

CAB PR SYS (1+2) FAULT (Cont'd)
(BOTH SYSTEMS AFFECTED)

L12

STATUS

MAN CAB PR CTL:
TGT V/S: CLIMB 500 FT/MIN
TGT V/S: DES 300 FT/MIN

A/C FL	*CAB ALT TGT*
410	*8 000*
350	*6 500*
300	*5 000*
250	*2 500*
<200	*0*

- **DURING FINAL APPR:**
  MAN V/S CTL....................FULL UP
  When on intermediate approach (below 2 500 ft),adjust ΔP = 0.
  When ΔP is zero, select FULL UP to fully open both outflow valves.

CAUTION	*Check that ΔP is zero before opening doors.*

INOP SYS

CAB PR 1 + 2

Figure 8: Copy from the FCOM (PRO-ABN-21 P 13/30 and 14/30)

The same procedure appears as ECAM procedure on the E/WD and SD as follows:

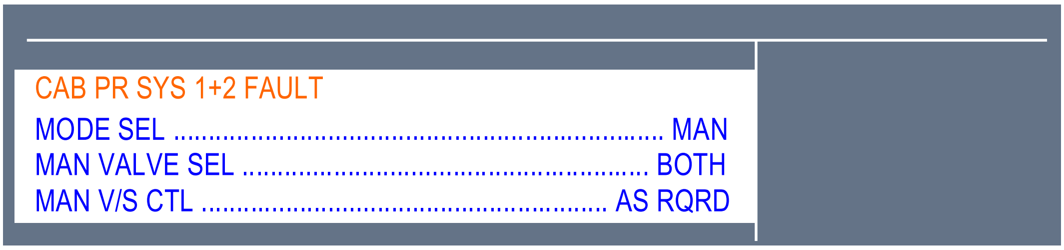


Figure 9: Display on the E/WD

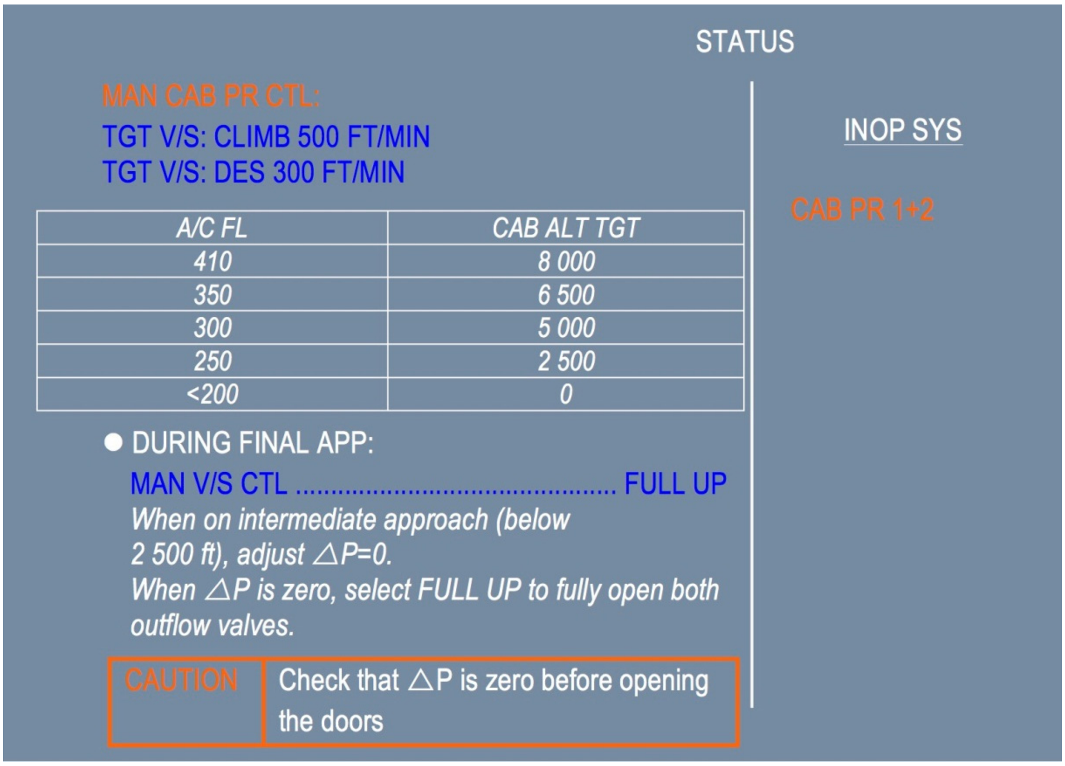


Figure 10: Display on the SD

In the FCOM, the procedure in case of an emergency descent can be found in the chapter “abnormal and emergency procedures, miscellaneous” (see annex 3).

1.18 Additional information

None

1.19 Useful or effective investigation techniques

Not applicable

2 Analysis

2.1 Technical aspects

2.1.1 General

The breakdown of both cabin pressure controllers (CPC 1+2) is consistent with a double failure. Controlling the cabin pressure was, consequently, only possible in manual mode. To accomplish this, the flight crew requires the cabin altitude and differential pressure displays. Because the flight crew stated that the displays for cabin altitude and differential pressure were not available to them, this situation was classified as a dangerous incident and was subsequently investigated.

Only over the course of the investigation did it become apparent that the displays were only partially, system-related not available in a certain range.

There is thus no evidence of pre-existing technical faults that could have caused or affected the serious incident.

2.1.2 Cabin pressure system

At 12:02:46 UTC, the aft outflow valve jammed during the closing phase at approximately 7°. As a result of this at 12:03:12 UTC, the amber warning message <u>CAB PR</u> SYS 1 FAULT was displayed on the E/WD display and the CAB PRESS page was automatically presented. One minute later at 12:04:12 UTC, the warning message <u>CAB PR</u> SYS 1+2 FAULT was displayed, accompanied by a single chime and the illumination of the master caution warning lights.

By 12:03:12 UTC, the requested position of 3.59° and the actual position of 7.61° of the aft outflow valve created a discrepancy which led to the deactivation of CPC 1 and the activation of CPC 2. Because the corresponding monitoring function in CPC 2 also found a discrepancy (set point = 1.41°, actual value = 7.18°), this also turned itself off at 12:04:12 UTC. Subsequently, the aft outflow valve remained at approximately 7° and the forward outflow valve at approximately 1.5°. This discrepancy is difficult to see on the analogue display on the CAB PRESS page (see annex 8).

In the absence of manual operation of the outflow valves by the crew, the cabin pressure was subsequently able to build up steadily. During the descent, the cabin differential pressure initially dropped. After reaching a flying altitude of 10 000 feet, the cabin differential pressure increased rapidly during level flight and reached values of 8.6 PSI and higher (see annexes 1 and 5).

To avoid overloading the airframe, the A330 in question is equipped with two safety valves. These are located on the pressure dome at the rear of the aircraft (see annexe 6). These valves operate autonomously. The safety valves open at a cabin differential pressure between 8.75 PSI and 8.95 PSI. In the period between 12:16:43 UTC and 12:24:47 UTC, safety valve 1 opened three times. This was displayed to the crew as warning message SAFETY VALVE OPEN on the E/WD, accompanied by a single chime and the illumination of the master caution warning lights. The switching status of the safety valve was schematically evident on the CAB PRESS page. After the crew had opened both outflow valves manually at 12:32:28 UTC, the cabin differential pressure fell rapidly, and at 12:36:02 UTC reached a value of zero at a flying altitude of 3000 feet.

As mentioned in chapter 1.16.2, both CPCs and the aft outflow valve were removed after the flight and tested by the equipment manufacturer. No malfunctioning of the equipment could be determined. It cannot be ruled out that a foreign object was located between the aft outflow valve’s frame and a valve flap and so led to the jamming. By manually opening the aft outflow valve, this foreign object could eventually have been dislodged and removed itself. However, during a test on the ground, the cabin pressure system functioned properly again.

2.1.3 Displays in the cockpit

The crew mentioned in their report that after switching the cabin pressurization system to manual mode, the cabin altitude and cabin differential pressure displays had failed.

In order to verify this, the equipment manufacturer carried out measurements on the cabin pressurization system (see chapter 1.16.2.4). These revealed that the stated parameters are no longer displayed at a cabin altitude below -2060 feet due to technical reasons. In the present case, a cabin altitude of -10 000 feet was reached. According to the CVR recordings, the crew first mentioned the loss of said displays as the cabin altitude reached a value of -2680 feet.

The fact that the commander informed the copilot at 12:06:58 UTC that the cabin altitude was 2000 ft, and that the copilot asked the commander with surprise at 12:08:47 UTC whether he had seen that the cabin altitude was now in the minus range and that the cabin was "pumping up", dispels any doubts that the cabin altitude as well as the differential pressure were displayed up to that time.

By the time the cabin altitude had again increased to above -2000 feet (see annexe 1), it was mentioned that the displays were available again.

Hence, it was not a technical malfunction. With appropriate operation of the cabin pressurization system in manual mode, such low cabin altitude levels should not be reached.

2.2 Human and operational aspects

2.2.1 Flight crew

When the warning <u>CAB PR</u> SYS 1 FAULT was displayed in the cockpit and one minute later the warning <u>CAB PR</u> SYS 1 + 2 FAULT, the commander immediately reacted to both of these warnings. This corresponded to the monitoring function of the PM according to the closed loop principle and thereby created a good foundation for further handling of the problem. That the commander mentioned at the same time they possibly had to plan for an emergency descent was not fitting for the situation in so far as this created a mental prejudice. It stands to reason that the copilot's decision to immediately descend further in this case was influenced as a result.

There is no evidence that the „PPAA" (power, performance, analysis, action) course of action set out by the operator for the appearance of a fault was carried out systematically in the present case (see chapter 1.17.1.2). This applies in particular to the first point of the „SPORDEC" procedure. The emergency descent was evidently initiated without a fault analysis being done. After the warning message <u>CAB PR</u> SYS 1+2 FAULT had been triggered, the displays on the CAB PRESS page showed a cabin altitude of 5470 ft with a cabin sink rate of 300 ft/min and a differential pressure of 8.44 PSI. A conscious analysis of the displays would have made it clear that it was not correct to expect a decompression scenario. It is possible that the necessary attention was not paid to this latest situation because the flight crew repeatedly stressed that they had a feeling of unease. Another factor may be that in training, flight crews generally prepare for decompression scenarios with subsequent initiation of an emergency descent when cabin pressure problems arise. This is practised time and time again. In addition, in this case the aircraft was already descending to its destination airport.

The flight crew decided to lend weight to their request to descend with an urgency message. That was appropriate for the situation and heightened the air traffic control's attention. After initiating the emergency descent, the flight crew sent out a distress message. This corresponded to the procedural requirements for an emergency descent. It has to be mentioned though that from a technical viewpoint, the flight crew was not in a situation that fits the definition for a distress message (see chapter 1.17.1.2).

Almost two minutes after the amber warning message CAB PR SYS 1+2 FAULT had been triggered, the commander said that he was beginning the respective ECAM procedure. In accordance with this procedure, he had to switch[9] the MODE SEL pushbutton to MAN (manual). At the time of switching, the CAB PRESS page showed a cabin altitude of 2000 ft with a cabin sink rate of 1250 ft/min and differential pressure of 7.64 PSI. The aircraft was now at FL 227, descending. The ECAM procedure sets a cabin altitude of approximately 2500 ft and a cabin sink rate of 300 ft/min as a benchmark for this flying altitude (see chapter 1.17.1.3). It is possible that the displayed cabin altitude, which corresponded more or less to the tabular value in the ECAM procedure, led the flight crew into not paying any attention to the cabin sink rate (see annex 4). This was approximately 1000 ft/min higher than the one in the ECAM procedure and the differential pressure had also not decreased.

The discussion in the cockpit indicates that in this phase the commander still thought that the oxygen masks had been released in the cabin. Thus, he did not reduce the cabin sink rate because he would have had to open the outflow valves manually which ran contrary to the perceived decompression. The decision not to adjust the outflow valves was possibly supported by the fact that when descending at FL 220 at 12:06:58 UTC, a cabin altitude reading of approximately 2000 ft had been taken. This altitude did correspond to the tabular value, the cabin sink rate of 1250 ft/min, however, was still almost 1000 ft/min above the recommended value.

Shortly afterwards, the copilot asked the commander whether he had noticed that the cabin altitude was now in the negative range and the cabin pressure was increasing further. It is doubtful whether the commander consciously processed this question as he was distracted by the communication from air traffic control only seconds later. The displayed cabin altitude of -480 ft and the cabin sink rate of 1200 ft/min, together with the copilot's remark, would have been a further indication that the differential pressure was high and could have been reduced by opening the outflow valves.

At 12:10:51 UTC when the commander ascertained that the cabin altitude was no longer displayed, it was already at an attitude of -2680 ft according to the recordings. Due to the system design, the analogue cabin altitude is blanked out on the CAB PRESS page below -2060 ft, and the digital display is replaced by amber crosses (see chapter 1.16.2.4 and annex 1 and 4). Consequently, the flight crew no longer had any information about the cabin altitude and differential pressure. It is understandable that the flight crew were anxious under these conditions and did not change the position of the outflow valves. The flight crew's decision, to land as quickly as possible and to manually open the outflow valves at 4000 ft QNH, was therefore appropriate for the situation.

A little later, the commander contacted the line maintenance department in Zurich and described the problem. A solution could not be found. Towards the end of this approximately five-minute-long conversation, the copilot notified the commander

[9] The time of switching could only be determined by the non-volatile memory (NVM). This parameter is neither recorded by the DFDR, nor the QAR.

that the safety valve had opened. The copilot thereby showed a good overview: he had assumed the control of the aircraft along with handling of the communication with air traffic control and this contact was intensive in this phase of the flight. No more than half a minute later, the copilot added to his comment that the cabin had „pumped up” and that therefore the safety valve had opened. This would have been a further indication towards the problem with the differential pressure and the cabin altitude. There was no response to the copilot’s observation.

In summary: after a cabin pressurization problem had arisen, the flight crew decided on an emergency descent without prior, structured analysis. Thus, the failure of the automatic cabin pressurization control system led to a challenging task for all parties. Control of the cabin altitude in manual mode would, on the other hand, only have led to a slight increase in the flight crew’s workload.

2.2.2 Air traffic control

The assistance given to the flight crew by all participating air traffic control centres was suitable and appropriate for the situation.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was approved for VFR and IFR operation.
- Both mass and centre of gravity of the aircraft were found to be within the AFM-permitted limits at the time of the serious incident.
- The investigation did not find any indication of pre-existing technical defects which could have influenced the serious incident.
- Both CPCs and the aft outflow valve were changed after the flight. No malfunction was found on any of these units.

3.1.2 Crew

- The pilots held the required licences for the flight.
- There is no indication of impairment to the pilots' health during the serious incident.

3.1.3 History of the flight

- After an uneventful flight, the flight crew received clearance from Reims control at 11:55:28 UTC to descend to flight level (FL) 370, and at 12:01:20 UTC to descend to FL 310.
- During descent, the amber warning message CAB PR SYS 1 FAULT was displayed at 12:03:12 UTC.
- One minute later, a single chime sounded and the warning message CAB PR SYS 1+2 FAULT was displayed.
- The flight crew contemplated a possible decompression and requested a further descent at 12:04:29 UTC as follows: *„Swiss one niner Romeo, Pan Pan Pan, we have a problem with our cabin and we would like to descend down to level one four zero at least."*
- At the same time, both pilots don their oxygen masks and an emergency descent was initiated.
- The cabin crew was informed about this decision over the public address (PA) system at 12:05:06 UTC with the words *„Cabin crew emergency descent".*
- At 12:05:19 UTC, the flight crew informed air traffic control as follows: *„Swiss one niner Romeo, Mayday Mayday Mayday."*
- At 12:05:55 UTC, the commander informed the copilot that he would now begin with the ECAM procedure. According to recordings, the cabin altitude was 3200 ft at that time with a sink rate of 1300 ft/min. The differential pressure was 8.2 PSI.
- At 12:06:47 UTC, the commander made a comment to the copilot to the effect that the passengers had don their oxygen masks.
- At 12:06:58 UTC, the commander informed the copilot that the cabin altitude was now 2000 ft.
- Both pilots found this altitude to be okay and the copilot reduced the aircraft's sink rate.

- At 12:08:47 UTC, the copilot was surprised and asked the commander whether he had seen that the cabin altitude was now in the negative range and the cabin was „pumping up".
- The commander answered with *„Yes, yes" and* was then interrupted by air traffic control who inquired about the flight crew's intention.
- The commander responded with: *„Stand by, we have to level off now and we have to organise the cockpit, we will call you back."*
- At 12:10:51 UTC, the commander said to the copilot that he had no longer a display of the cabin altitude. At this time, the recordings show a cabin altitude of -2680 ft. This was no longer displayed to the flight crew due to the system design. The aircraft was at FL 100.
- After a brief conversation, the flight crew concluded that they did not know exactly where the problem was, but that they could bring the cabin altitude in line with the aircraft altitude by opening the outflow valves after reaching 4000 ft.
- At 12:11:47 UTC, the flight crew sent the following message: *„OK, Swiss one niner Romeo, we cancel Mayday and we would like to proceed for a direct approach in Zurich."*
- Subsequently, the commander made radio contact with the line maintenance department in Zurich and spent approximately five minutes describing what had been happening.
- At 12:17:25 UTC, the copilot informed the commander that the safety valve had opened. The recordings show a cabin altitude of -7250 ft at this time, with a cabin sink rate of 0 ft/min and a differential pressure of 8.81 PSI.
- At 12:17:56 UTC, the copilot said to the commander that he had the feeling, the cabin had „pumped up" again and that the safety valve had therefore opened.
- The ATCO guided the flight crew to the approach of runway 14 using radar vectoring and at 12:29:49 UTC gave the flight crew clearance to descend to 4000 ft QNH.
- At 12:32:30 UTC, at a flying altitude of 4800 ft QNH, the commander opened the outflow valves. According to the recordings, the cabin altitude was -10 600 ft at this time, with a cabin sink rate of 500 ft/min.
- At 12:33:58 UTC, the flight crew reported to the ATCO that they were established on ILS.
- Shortly after that, the flight crew noticed that the cabin altitude was displayed again and that the value of approximately 2800 ft corresponded with the aircraft altitude, and that there was no differential pressure present.
- Subsequently, the cabin altitude subsided in line with the aircraft altitude and the aircraft landed on runway 14 at 12:38:08 UTC.

3.1.4 General conditions

- When the cabin altitude reaches a value below -2060 ft, the digital display on the CAB PRESS page is replaced by amber crosses and the analogue display is blanked out. This also applies to the display of the cabin differential pressure.
- The weather had no influence on the serious incident.

3.2 Causes

The serious incident is attributed to the failure of the automatic cabin pressure regulation as a consequence of a jammed outflow valve and the fact that the procedure for its manual control was not applied fully.

The following factor was found to be causal:

- The flight crew intuitively initiated an emergency descent, without first having undertaken a structured analysis of the situation.

The following factor contributed to the serious incident:

- The system-related blanking out of the cabin altitude and the differential pressure displays when the cabin altitude reaches below -2060 ft.

4 Safety recommendations, safety advices and measures taken since the serious incident

Safety recommendations

According to the provisions of Annexe 13 of the International Civil Aviation Organisation (ICAO) and Article 17 of Regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which must decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Safety Investigation of Transport Incidents (OSITI):

"Art. 48 Safety recommendations

[1] The STSB shall submit the safety recommendations to the competent federal office and notify the competent department of the recommendations. In the case of urgent safety issues, it shall notify the competent department immediately. It may send comments to the competent department on the implementation reports issued by the federal office.

[2] The federal offices shall report to the STSB and the competent department periodically on the implementation of the recommendations or on the reasons why they have decided not to take measures.

[3] The competent department may apply to the competent federal office to implement recommendations."

The STSB shall publish the answers of the relevant Federal Office or foreign supervisory authorities at www.stsb.admin.ch in order to provide an overview of the current implementation status of the relevant safety recommendation.

Safety advices

The STSB may publish safety advice in response to any safety deficit identified during the investigation. Safety advice shall be formulated if a safety recommendation in accordance with Regulation (EU) No. 996/2010 does not appear to be appropriate, is not formally possible, or if the less prescriptive form of a safety advice is likely to have a greater effect. The legal basis for STSB safety advice can be found in Article 56 of the OSITI:

"Art. 56 Information on accident prevention

The STSB may prepare and publish general information on accident prevention."

4.1 Short description

On 21 November 2014, the scheduled flight (flight number SWR 19R) from Newark (KEWR) to Zurich (LSZH) was carried out with the commercial aircraft Airbus A330-343, registered as HB-JHB. There were two pilots, 10 crew members and 166 passengers on board.

After an uneventful flight, the amber warning message CAB PR SYS 1 FAULT was displayed in the cockpit at 12:03:12 UTC during the descent from flight level (FL) 370 to FL 310. A single chime sounded a minute later and the amber warning message CAB PR SYS 1+2 FAULT was displayed simultaneously.

Subsequently, the flight crew decided to request an immediate further descent from Reims control and sent an urgency message (Pan Pan). The flight crew don their oxygen masks, initiated an emergency descent and informed the cabin crew regarding this. A short time later, they reported Mayday to air traffic control and received clearance to descend to FL 150.

The flight crew were of the view that the oxygen masks in the cabin had been released. At 12:05:55 UTC, the commander initiated the corresponding ECAM procedure which, among other things, requests that the cabin altitude is to be operated manually. The flight crew briefly discussed the displayed cabin altitude and found it to be okay. At 12:10:51 UTC, the commander mentioned that the cabin altitude was no longer displayed. Consequently, manual control of it, as stipulated in the ECAM procedure, would no longer be possible. The recordings show a cabin altitude of -2680 ft at this time. It was no longer displayed to the flight crew due to system design.

The flight crew decided to land as quickly as possible and to manually open the outflow valves fully during the approach at an altitude of approximately 4000 ft. This was to ensure that the cabin doors could be opened after landing.

Subsequently, after the outflow valves had been opened manually, the cabin altitude was displayed again during the instrument approach to runway 14 in Zurich.

4.2 Safety recommendations and safety advices

4.2.1 Digital cabin altitude indication

4.2.1.1 Safety deficit

The investigation has shown that by design, the cabin altitude digital display on the CAB PRESS page is replaced by amber crosses below -2060 ft and the analogue display is blanked out. This also applies to the display of the cabin differential pressure.

This fact is not known to the aircraft operators, contributes however to the fact that a flight crew can hardly perform manual cabin altitude regulation in such a case.

4.2.1.2 Safety recommendation no. 504

The European Aviation Safety Agency Safety (EASA), together with the aircraft manufacturer, shall ensure that cabin altitude below -2060 ft will be displayed to flight crews in an appropriate form.

4.2.2 Flight crew training in the simulator

4.2.2.1 Safety deficit

The investigation has shown that the flight crew immediately thought of a possible decompression when both cabin pressure controllers failed and consequently, considered an emergency descent which was initiated shortly after.

Carrying out the emergency descent and processing the corresponding checklist used up precious time. During this time, the cabin altitude fell below -2060 ft. By not opening the outflow valves manually, the cabin pressure was allowed to build up to the maximum value, hence triggering the safety valve.

4.2.3 Safety advice no. 3

Topic:	Simulator training
Target groups:	flight crews, airline training instructors and manufacturer of training devices

The aviation operators shall take steps to include pressurization problems more broadly in flight simulator exercises. Flight crews shall, thereby, not remain focused solely on decompression and emergency descent during pressurization problems.

4.3 Measures taken since the serious incident

In a letter, dated 23 September 2015, the operator states the following [translated from German]:

“Based on the incident findings and the basis of evidence based training, Swiss has supplemented their recurrent training 2016 as well as the training of their cruise relief pilots by the following focal areas:

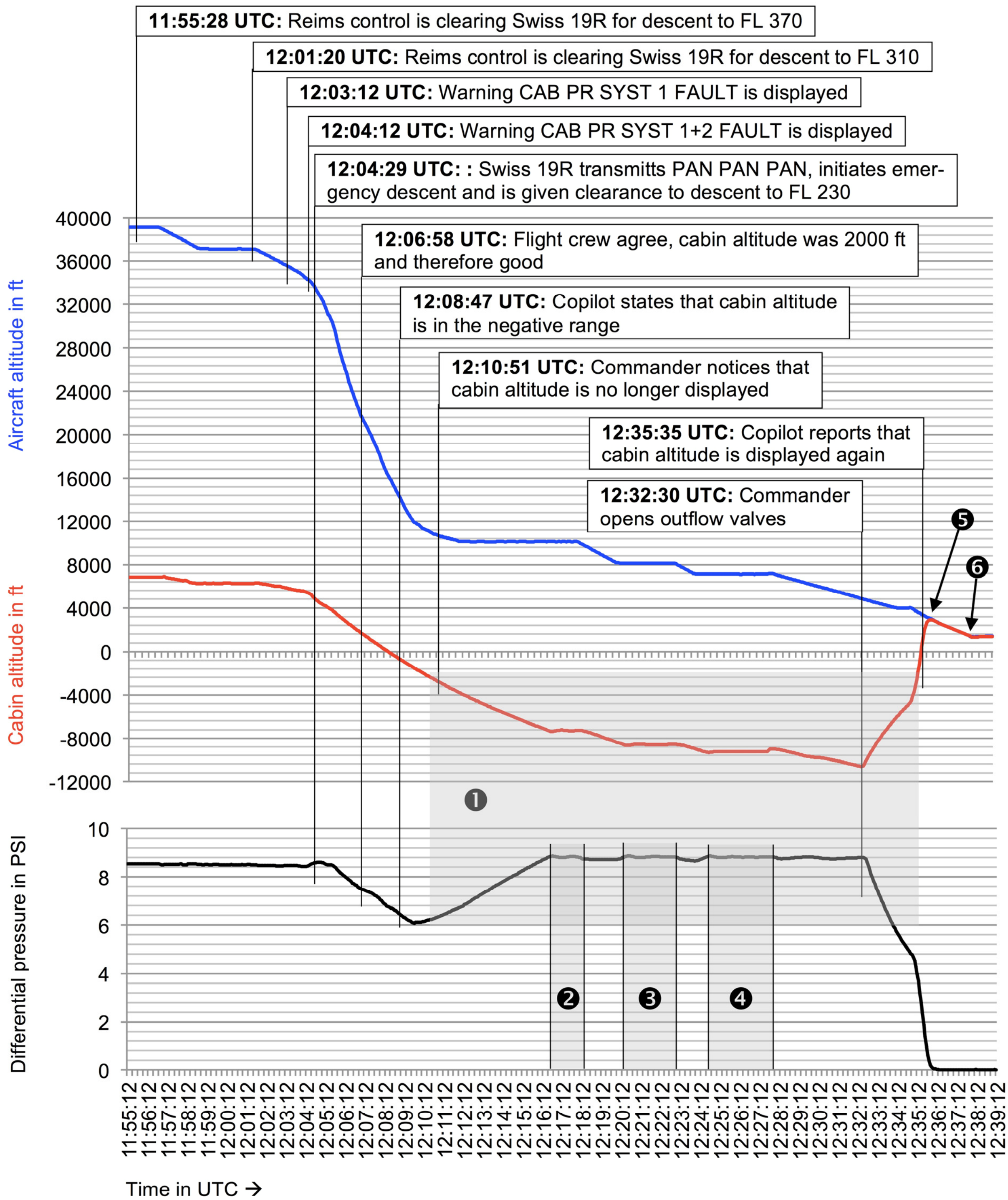
Training area which include a major share of line oriented flight training elements, respectively a technical or operational diffuse situation whereby the elements „Recognition and Handling of non-normal Situations” in conjunction with „Decision Making” are key elements.”

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014).

Bern, 5th Decemer 2017 Swiss Transportation Safety Investigation Board

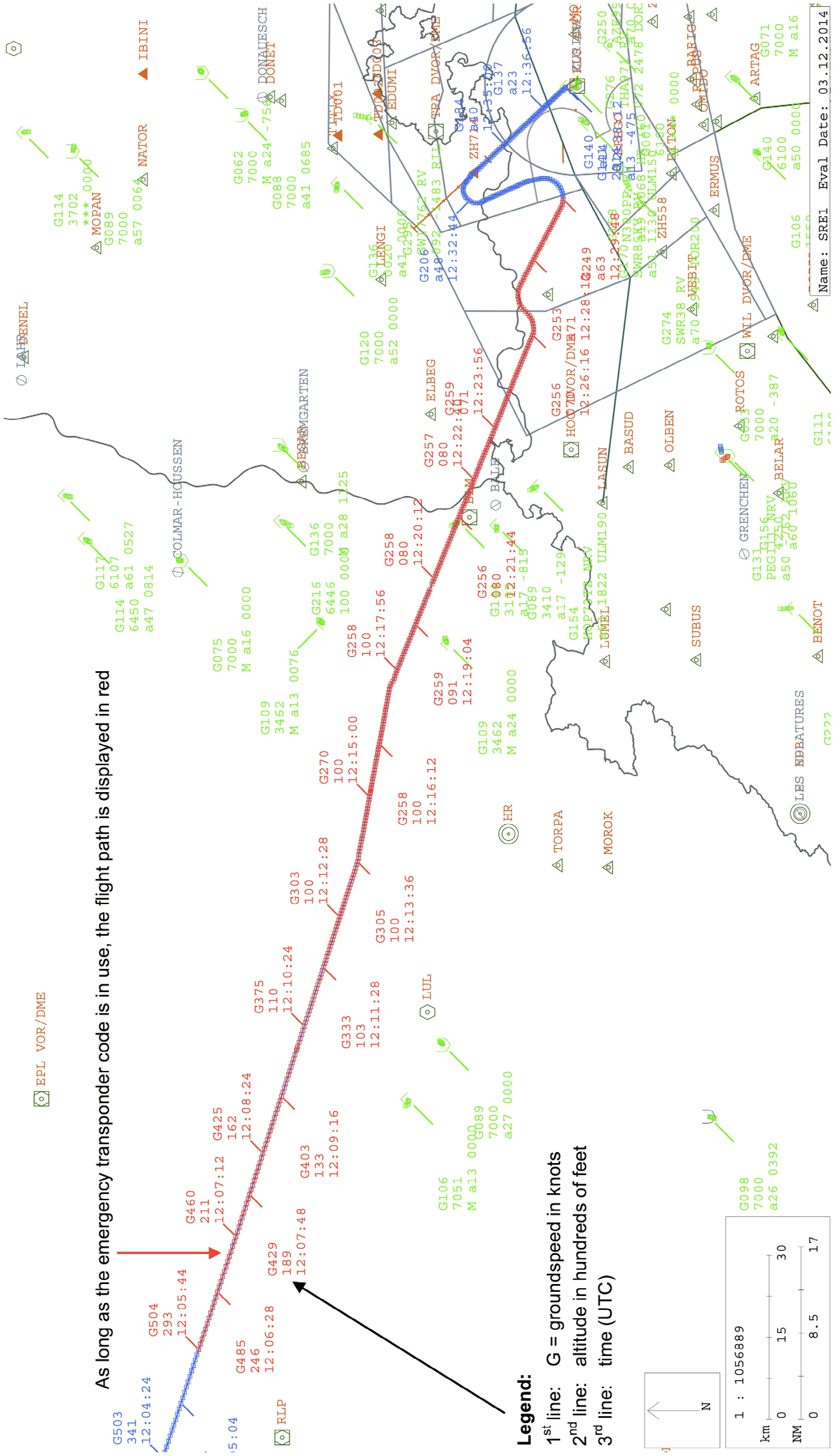
Annexes

Annex 1: Sink profile during the serious incident



❶ Cabin altitude and differential pressure displays are replaced by amber crosses
❷ **12:16:43 – 12:18:18 UTC:** *safety valve* 1 is open
❸ **12:20:38 – 12:23:12 UTC:** *safety valve* 1 is open
❹ **12:24:47 – 12:28:09 UTC:** *safety valve* 1 is open
❺ Cabin altitude and aircraft altitude are identical and subsequently decrease simultaneously
❻ **12:38:08 UTC:** Landing, aircraft touches down on runway 14

Annex 2: Flight path under Zurich control



Annex 3: Procedure for emergency descent

EMER DESCENT

Ident.: PRO-ABN-80-00012261.0001001 / 23 JAN 14
Applicable to: ALL

IMMEDIATE ACTIONS

CREW OXYGEN MASKS.......... ON
"EMERGENCY DESCENT".......... ANNOUNCE (PA)

The flight crew must inform the cabin of emergency descent on the PA system.

SIGNS.......... ON
EMER DESCENT.......... INITIATE

Descend with the autopilot engaged:
- *Turn the ALT selector knob and pull*
- *Turn the HDG selector knob and pull*
- *Adjust the target SPD/MACH.*

THR LEVER (if A/THR not engaged).......... IDLE

- *If autothrust is engaged, check that THR IDLE appears on the FMA.*
- *If not engaged, retard the thrust levers.*

SPD BRK.......... FULL

WHEN DESCENT ESTABLISHED

EMER DESCENT FL 100 or minimum allowable altitude.

SPEED.......... MAX/APPROPRIATE

CAUTION	Descend at the maximum appropriate speed. If structural damage is suspected, use the flight controls with care and reduce speed as appropriate.

Landing gear may be extended below 21 000 ft. Speed must be reduced to VLO/VLE.

ENG START SEL.......... IGN
ATC.......... NOTIFY

Notify ATC of the nature of the emergency, and state intention. If not in contact with ATC, transmit a distress message on one of the following frequencies: (VHF) 121.5 MHz , or (HF) 2 182 kHz , or 8 364 kHz.

ATC XPDR 7700.......... CONSIDER

Squawk 7700 unless otherwise specified by ATC.

- *To save oxygen, set the oxygen diluter selector to the N position.*

Continued on the following page

EMER DESCENT (Cont'd)

- *With the oxygen diluter selector left at 100 % oxygen quantity may not be sufficient for the entire emergency descent profile.*
- *Ensure that the flight crew can communicate wearing oxygen masks. Avoid the continuous use of the interphone to minimize the interference from the noise of the oxygen mask.*

MAX FL.......... 100/MEA

● **IF CAB ALT > 14 000 ft:**

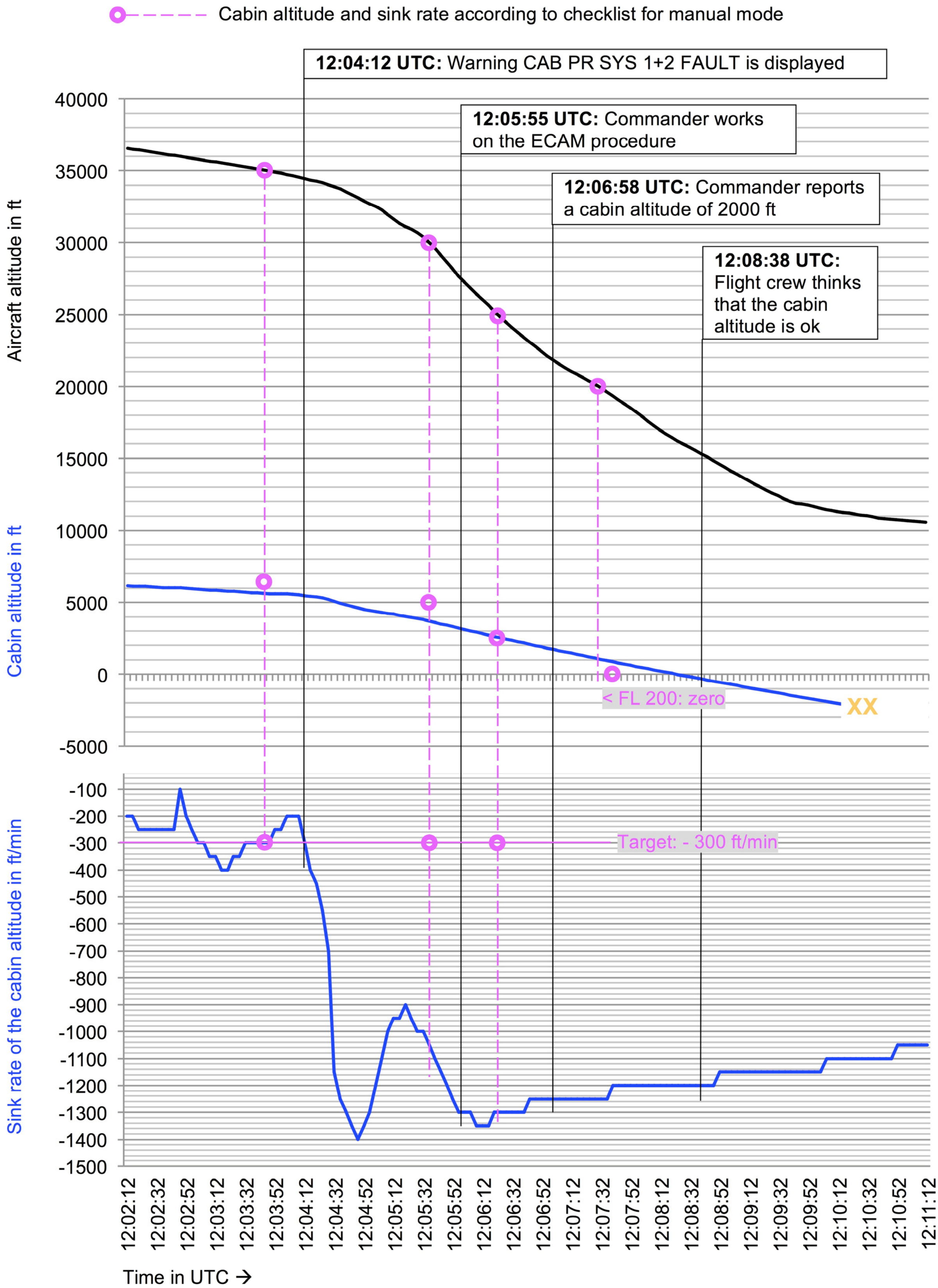
PAX OXY MASKS.......... MAN ON

This action confirms that the passenger oxygen masks are released.

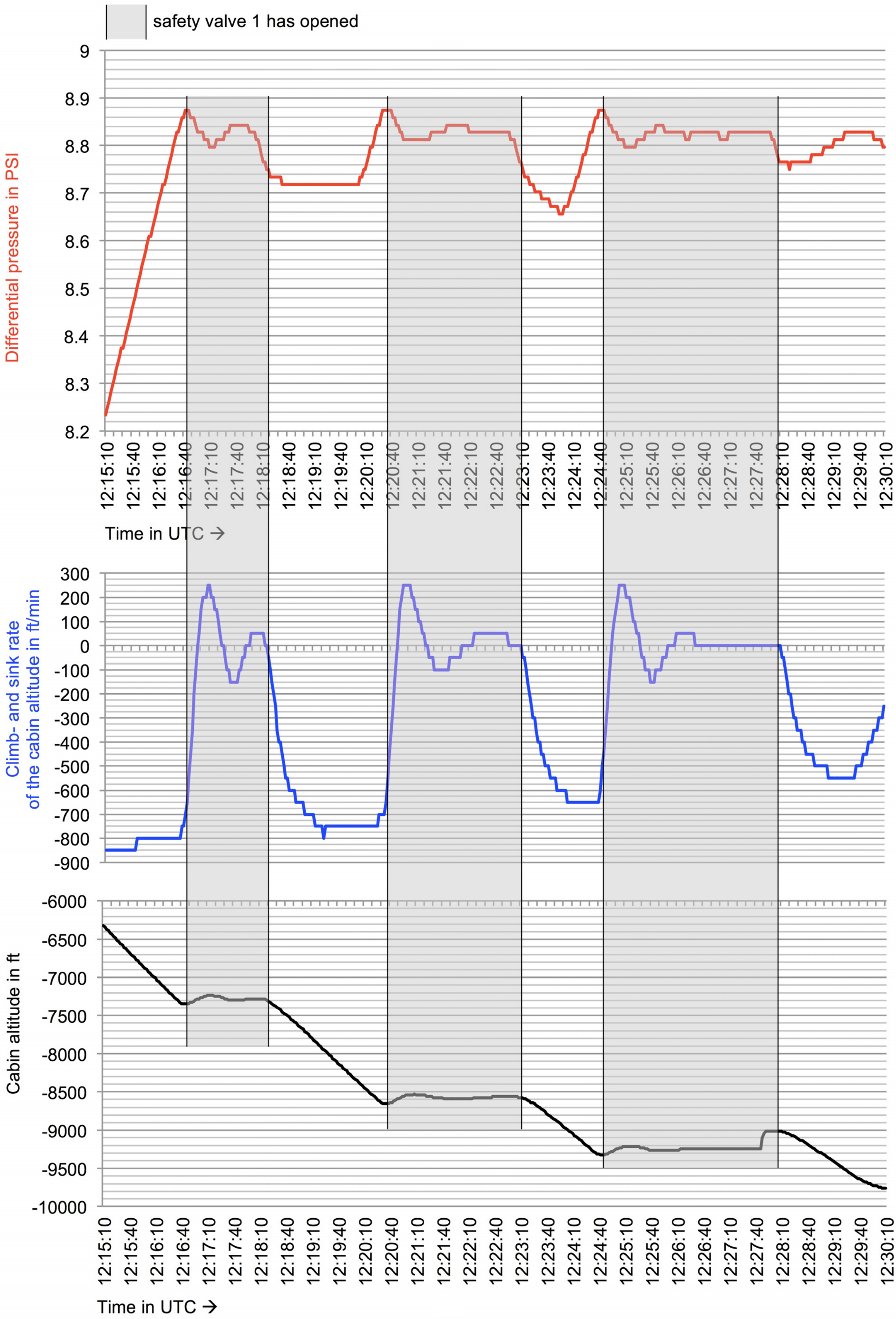
Note: *Notify the cabin crew, when the aircraft reaches a safe flight level, and when cabin oxygen is no more necessary.*

Figure 11: Copy from the FCOM (PRO-NON-80 P 8/9/28)

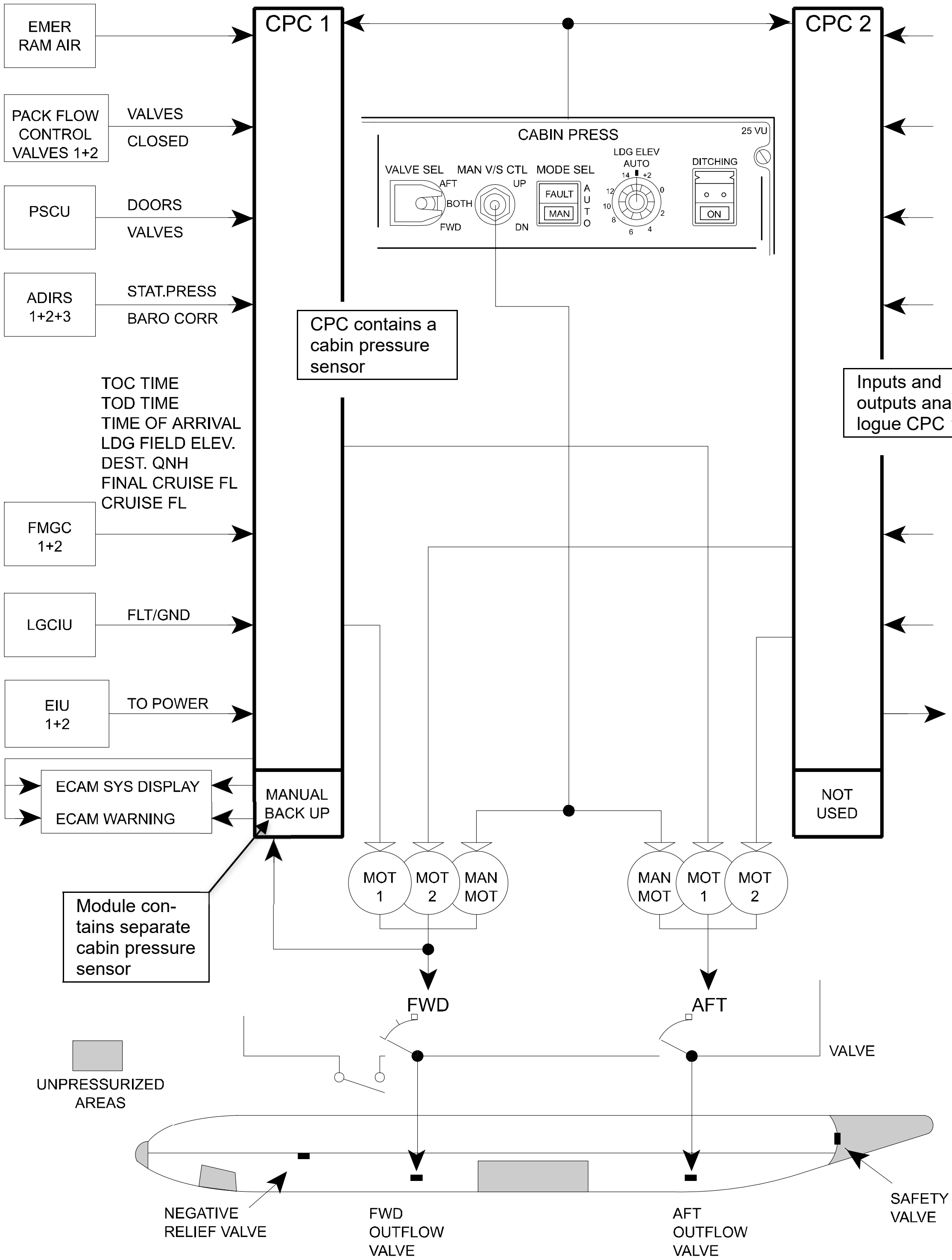
Annex 4: Course of flying altitude, cabin altitude and cabin sink rate



Annex 5: Operation of the safety valve during the serious incident



Annex 6: Block diagram of the cabin pressurization system



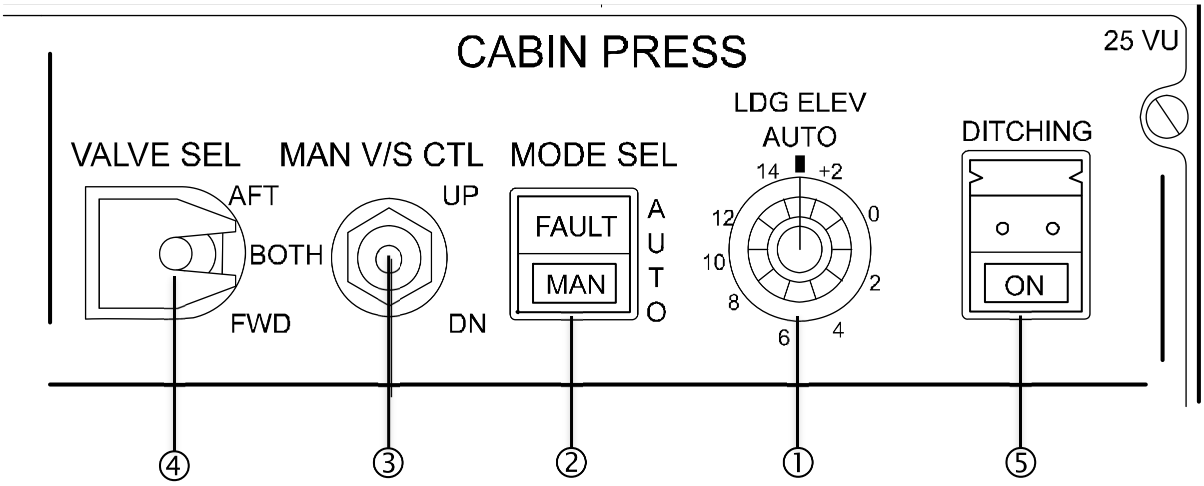
ECAM displays in AUTO mode:

Pressure in the cabin (P_{cabin}) is measured in the CPC with the aid of a pressure sensor. The cabin altitude (CAB ALT FT) is determined computationally. The cabin vertical speed (V/S FT/MIN) parameter is derived from the cabin altitude. The difference between external pressure and pressure in the cabin (ΔP PSI) is calculated using the formula $\Delta P = P_{cabin} - P_{ambient}$ ($P_{ambient}$ = STAT.PRESS from ADIRS).

ECAM displays in MAN mode:

The pressure in the cabin (P_{cabin}) is measured with the aid of a separate pressure sensor in the manual backup part. This parameter is transmitted as an analogue signal to the SDAC. In the SDAC, the cabin altitude (CAB ALT FT) and cabin vertical speed (V/S FT/MIN) parameters are calculated from it. As the $P_{ambient}$ parameter from the ADIRS is available, the differential pressure (ΔP) can be calculated (see figure 2).

Annex 7: Cabin pressure system control



① LDG ELEV selector

The selector is normally in the AUTO position. In this position, data from the flight management guidance and envelope computer (FMGEC) is used in order to guarantee an optimal course of cabin pressure build-up for the descent.

By pulling and turning the selector, the landing elevation can be adjusted manually and read from the ECAM.

② MODE SEL pushbutton

In the AUTO position, the active cabin pressure controller (CPC) controls both of the outflow valves.

By pressing the MODE SEL pushbutton, the system can be switched into manual (MAN) mode. The FAULT display appears when both CPCs show a malfunction.

③ MAN V/S CTL switch

The MAN V/S CTL switch is spring-loaded and controls the outflow valves chosen by the VALVE SEL selector. The MAN V/S CTL switch is only effective in manual (MAN) mode.

UP: opens the outflow valve(s)
DN: closes the outflow valve(s)

④ VALVE SEL selector

In AFT position, the aft outflow valve can be operated manually. The forward outflow valve remains under automatic control.

In FWD position, the forward outflow valve can be operated manually. The aft outflow valve remains under automatic control.

In BOTH position, both outflow valves are under manual control. The VALVE SEL selector is secured in this position.

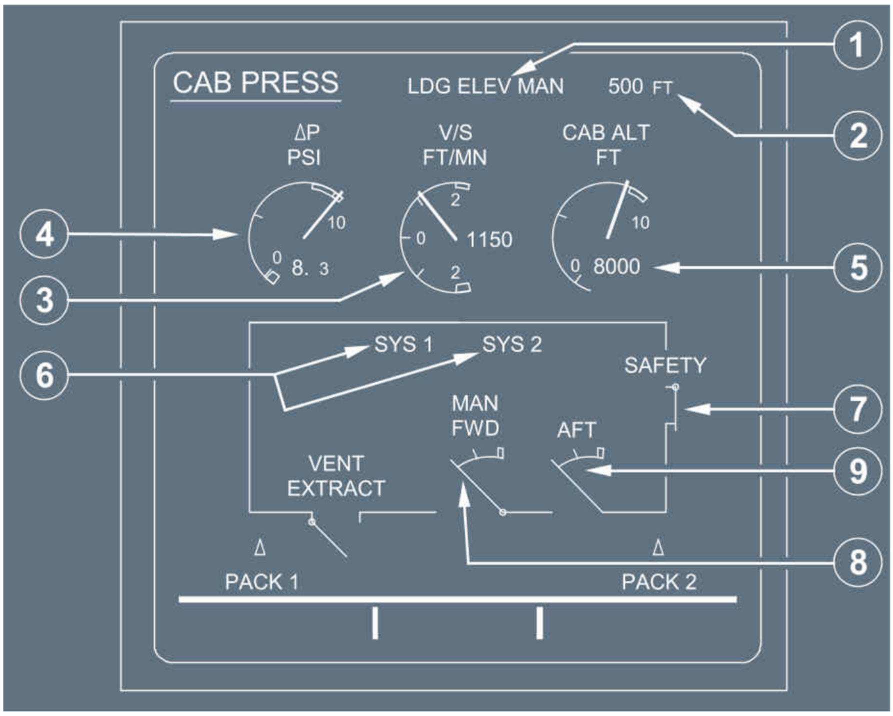
⑤ DITCHING pushbutton

When pressing the DITCHING pushbutton before an emergency water landing, various openings in the aircraft (the outflow valves among others) close in order to prevent water from entering. In order to prevent unintended operation of the pushbutton, it is secured.

Note:

The outflow valves do not close automatically in manual (MAN) mode.

Annex 8: ECAM system display



① LDG ELEV AUTO / MAN

LDG ELEV AUTO is displayed when the LDG ELEV selector is in the AUTO position and the FMGS transmits the landing elevation to the CPC.

LDG ELEV MAN is displayed when the LDG ELEV selector is not in the AUTO position.

② Landing elevation

Landing elevation display

③ V/S FT/MIN (cabin vertical speed)

The cabin vertical speed is displayed in green in analogue and digital formats when it is in the normal range. The display flashes if the cabin vertical speed is greater than ±1,800 ft/min.

④ ΔP PSI (cabin differential pressure)

The cabin differential pressure is displayed in green in analogue and digital formats when it is in the normal range. With ΔP ≤ -0.2 PSI or ≥ 8.85 PSI, the colour changes to amber.

⑤ CAB ALT FT (cabin altitude)

The cabin altitude is displayed in green in analogue and digital formats when it is in the normal range. The displays change to red if the cabin altitude climbs above 9,550 ft. The digital display flashes between 8800 ft and 9,550 ft.

⑥ Active system indication (SYS 1 or SYS 2 or MAN)

Display for the active system.

⑦ Safety valve position

SAFETY is displayed in white when both safety valves are closed. The colour changes to amber if one of the safety valves opens (is also shown schematically). The safety valves open at a cabin differential pressure between 8.75 and 8.95 PSI.

⑧ ⑨ Outflow valve position

Display of the forward outflow valve and aft outflow valve position.

Note: The displays (1) - (5) are also available on the CRUISE page (only in digital format)

Annex 9: Glossary

Abbreviation	Term
ADIRU	Air data inertial reference unit
ADIRS	Air data inertial reference system
ACARS	Airborne communications addressing and reporting system
ATCO	Air traffic control officer
CAB PR	Cabin pressure
CFDS	Centralised fault display system
CFDIU	Centralised fault data interface unit
CFR	Current flight report
CPC	Cabin pressure controller
CVR	Cockpit voice recorder
DU	Display unit
DMC	Display management computer
ECAM	Electronic centralised aircraft monitoring
E/WD	Engine/warning display
EFIS	Electronic flight instruments system
EIS	electronic instruments system
EIU	engine interface unit
FMGS	Flight management and guidance computer
FWC	Flight warning computer
FWS	Flight warning system
LGCIU	Landing gear control interface unit
MCDU	Multipurpose control and display unit
ND	Navigation display
OVF	Outflow valve
PFR	Post flight report
PFD	Primary flight display
PSI	Pounds per square inch
PSCU	Proximity switch control unit
QAR	Quick access recorder
SDAC	System data acquisition concentrator
SD	System display
SYS	System
V/S	Vertical speed