



Ministry of Transport and Civil Aviation of Federal Republic of Somalia

Aircraft Accident Investigation Branch

Final Report

Accident to the AIRBUS - A321
registered **SX-BHS**
operated by Daallo Airlines
on 2nd February 2016
On initial climb from AD Mogadishu
(Somalia)

Table of contents

SYNOPSIS.....	4
1. FACTUAL INFORMATION	6
1.1 HISTORY OF FLIGHT.....	6
1.2 INJURIES TO PERSONS.....	8
1.3 DAMAGE TO AIRCRAFT.....	8
1.4 OTHER DAMAGE.....	8
1.5 PERSONAL INFORMATION.....	8
1.6 AIRCRAFT INFORMATION.....	9
1.7 METEOROLOGICAL INFORMATION.....	19
1.8 AIDS TO NAVIGATION.....	19
1.9 COMMUNICATIONS.....	19
1.10 AERODROME INFORMATION.....	19
1.11 FLIGHT RECORDERS.....	19
1.12 WRECKAGE AND IMPACT INFORMATION.....	21
1.13 MEDICAL AND PATHOLOGICAL INFORMATION.....	24
1.14 FIRE.....	24
1.15 SURVIVAL ASPECTS.....	24
1.16 TESTS AND RESEARCH.....	24
1.17 ORGANIZATIONAL AND MANAGEMENT INFORMATION.....	24
1.18 ADDITIONAL INFORMATION.....	24
1.19 USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES.....	24
2. ANALYSIS	25
3. CONCLUSIONS.....	25
4. SAFETY RECOMMENDATIONS.....	26

GLOSSARY

ACRONYMS	
AD	Aerodrome
A/P	Autopilot
A/T	Autothrust
AMM	Aircraft Maintenance Manual
ATC	Air Traffic Control
ATPL	Airline Transport Pilot Licence
BEA	Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile
CRM	Cockpit Resource Management
CVR	Cockpit Voice Recorder
ECAM	Electronic Centralised Aircraft Monitor
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
F/O	First Officer
ILS	Instrument Landing System
MEL	Minimum Equipment List
PF	Pilot Flying
PFD	Primary Flight Display
PFR	Post Flight Report
PM	Pilot Monitoring

Synopsis

Location of the accident	AD Mogadishu (Somalia)
Date and time	February 2, 2016, 08 h 34 ¹
Type of aircraft	Airbus A 321
Operator	Daallo Airlines (Somalia)
Type of flight	International Public Transport of passengers
People on board	Crew : 7 Passengers : 74

Bomb explosion inside the cabin during initial climb, depressurization, emergency return, safe landing

Summary

On February 2nd 2016, flight DAO159, radio callsign Daallo 159, an Airbus 321 registered SX-BHS, was scheduled to perform a flight from Mogadishu (Somalia) to Djibouti (Republic of Djibouti).

At 08 h 34 min 19, flight DAO 159 was cleared for take-off runway 05, wind 090°/17kt, and right turn after departure. The first officer was Pilot Flying (PF), the captain was Pilot Monitoring (PM).

The flight ws cleared to climb to FL 300.

At 08 h 41 min 03, as the aircraft was passing 10 400 ft, an explosion occurred in the cabin. Immediately afterwards, the flight crew performed an emergency return to Mogadishu.

At 8 h 53 min, the aircraft landed safely at Mogadishu airport.

As a consequence of the explosion the passenger seated at 16F was ejected from the aircraft and was found dead on the ground in the vicinity of the airport. Three other passengers seated close to seat 16F were injured.

The origin of the explosion was a terrorist attack. The passenger seated at 16F triggered a blast device from a laptop that he carried with him.

Consequences

Injuries	Crew	Passengers	Other	Aircraft
Fatal	-	1	-	Severely damaged
Serious	-	3	-	
Minor	-	-	-	
None	7	70	-	

¹ All times in this report are UTC, except where otherwise specified. 3 hours should be added to obtain the local time (LT) applicable in Somalia on the day of the accident.

Organization of the investigation

After establishing that the Daallo airlines aircraft accident had occurred, the Somali Authorities launched a technical investigation. In accordance with article 26 of the Convention and ICAO Annex 13 "Aircraft Accident and Incident Investigation", an Investigation Committee was formed by the Minister of Transport and Civil Aviation in order to conduct the investigation. An Investigator-in-charge (IIC) was designated by the Minister to lead and initiate an investigation immediately.

As per the provisions of the ICAO Annex 13, an Accredited Representative from the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) was appointed.

1. Factual information

1.1 History of Flight

Note: the following information is based on the data recovered from the FDR and CVR. The ATC recordings were not saved.

On February 2nd 2016, flight DAO159, radio callsign Daallo 159, an Airbus A321 registered SX-BHS, is scheduled to perform a scheduled passenger flight from Mogadishu (Somalia) to Djibouti (Republic of Djibouti).

The aircraft has been wet leased by Daallo Airlines (national carrier of the Republic of Djibouti) from Hermes Airlines (Greece).

At 08 h 34 min 19, DAO 159 is cleared for take-off runway 05, wind 090°/17kt, and right turn after departure. The first officer is Pilot Flying (PF), the captain is Pilot Monitoring (PM).

At 08 h 39 min 39, the ATC requests the flight crew to provide the estimated times at SALUL, ALNAB and LUTAR².

The flight crew answers "SALUL 0904, ALNAB 0935 and LUTAR 0951". The flight is then cleared to climb initially to FL 300. The flight crew reads back the clearance and informs the ATC that they are passing through 9 000 ft. The aircraft crosses 10 000 ft at 08 h 40 min 47.

At 08 h 41 min 03, passing 10 400 ft, the sound of an explosion is heard on the CVR, followed by a cavalry charge warning related to the AP disconnection. At that moment, the recorded indicated airspeed is 261 kt and the recorded magnetic heading is 359.6°. The recorded latitude and longitude are 02°14'08.4" N and 45°17'06.3" E. Immediately after the sound of the explosion, the Captain says "I have control". The F/O replies "you have control". The Captain immediately applies nose down inputs and left turn orders. The aircraft starts to descend.

At 8 h 41 min 08 s, a Master Warning and a CAB PR EXCESS CAB ALT message³ are triggered on the ECAM.

At 08 h 41 min 14, the Captain instructs the F/O "read this". The F/O lists the following items "cabin pressure, mask use, descent initiate". At 08 h 41 min 37, the Captain instructs the F/O to ask the ATC clearance to perform an emergency return to Mogadishu. The F/O complies. The request is approved by the ATC. Following the ATC request, the F/O replies that they are 17 NM out and passing through FL 100 descending. The ATC asks the flight crew to report on final runway 05.

At 08 h 42 min 32, a flight attendant requests permission to enter the cockpit, tells the flight crew about a stroke and asks if it is not dangerous. The captain replies that they are going back now and says it is not dangerous. Upon the flight attendant's request about what to announce the passengers, the captain tells her to inform the passengers that they are flying back to Mogadishu. He tells her that it is not dangerous and that they are going to land in 15 minutes.

At 08 h 43 min 03, the F/O says that he goes ahead with the ECAM and says "cabin pressure, safety, valve ... open" then "keep differential pressure below zero... 0,4 so below zero checked". The crew then prepares for the arrival.

At 8 h 43 min 09 s, A/P2 is re-engaged in CLIMB/NAVIGATION modes.

² The environment is non-radar

³ Message related to a depressurization event

At 08 h 44 min 22, the Captain calls the ATC and says that they are inbound MOBUDU, estimating MOBUDU in two minutes, descending to FL 50, expecting a visual approach runway 05, and informs the ATC that they are having a decompression problem. The ATC copies the information and asks the flight crew to confirm that they are approaching the right hand base 05. The Captain replies that they are arriving overhead.

At 08 h 45 min 17, the First Officer tells the Captain that the aircraft is recovering the cabin pressure as they are crossing 10 000 ft in descent. Both flight crew members talk about a possible window shield broken in the cabin.

At 8 h 45 min 35 s, Cabin Pressure Warning is recorded off. The aircraft altitude is 8100 ft;

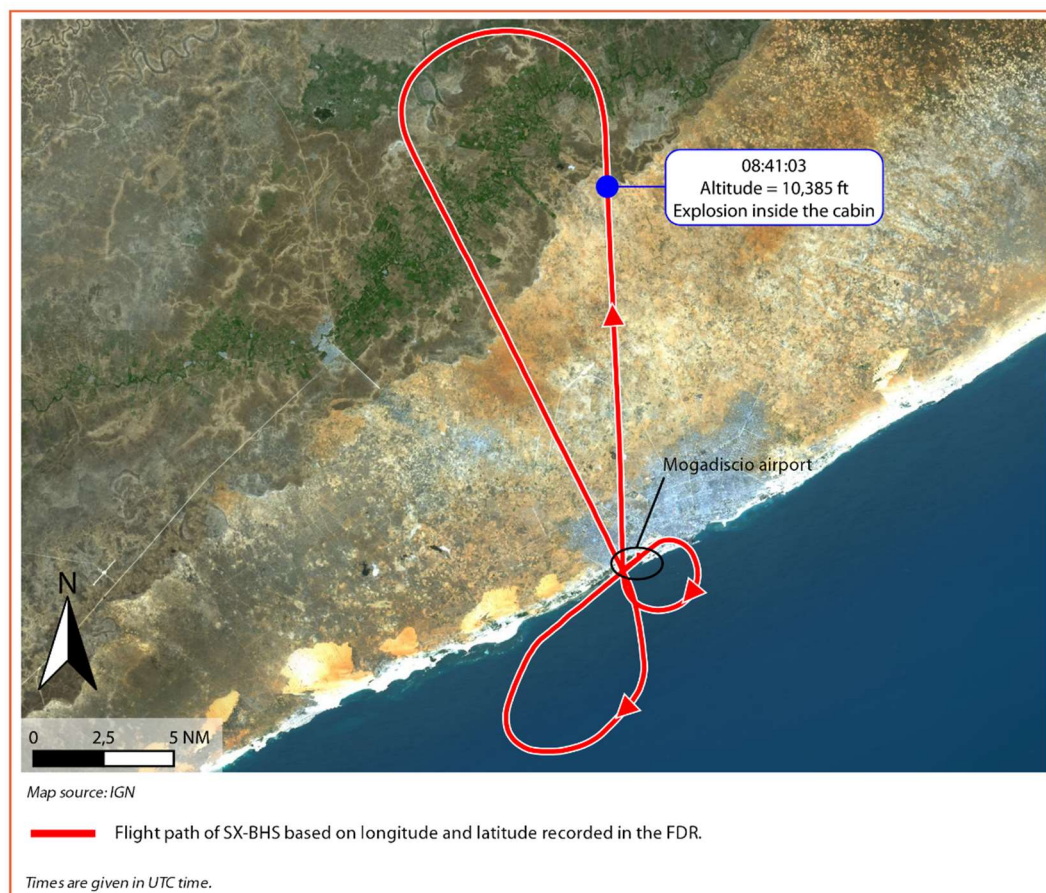
In the cabin, the flight attendant repeatedly asks the passengers to seat down.

At 08 h 47 min 04, the flight attendant again requests to enter the cabin. She tells the flight crew that one window is broken and asks if it is dangerous. The captain replies that they will be on ground in 5-6 minutes.

At 8 h 53 min, the aircraft safely lands at Mogadishu airport in full configuration with a landing weight of about 69.4 t. The vertical acceleration at touchdown is about 1.5 g.

As a consequence of the explosion the passenger seated at 16F was ejected from the aircraft and was found dead on the ground in the vicinity of the airport. Three other passengers seated close to seat 16F were injured.

The origin of the explosion was a terror attack. The passenger seated at 16F triggered a blast device from a laptop that he carried on him.



SX-BHS Flight path

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	-	1	
Serious	-	3	-
Minor	-		-
None	7	70	-

1.3 Damage to Aircraft

Fuselage was perforated on its right hand side on approximately 1 square meter at the level of row 16 around frame (FR) 35.8, between the wing and the emergency door 2.

The damage analysis is further detailed in paragraph 1.12



Aircraft picture taken after landing

1.4 Other Damage

None

1.5 Personal Information

The Captain and the First Officer had valid license and medical certificates.

1.6 Aircraft Information

The Airbus A321, registered SX-BHS, serial number 0642, was manufactured in 1996 and leased by Daallo Airlines from Hermes in May 2014. It is a low-wing aircraft, certified in medium category and it carries 185 to 236 passengers.

1.6.1 Airframe:

Type	A321-100
Manufacturer Serial Number	0642
Total Airframe Hours (At time of Accident)	35 682
Total Airframe Cycles (At time of Accident)	21 409

There was no relevant MEL item.

1.6.2 Engines

Engines were CFM56-5B engines

1.6.3 AIRCRAFT SYSTEMS AND PROCEDURES

1.6.3.1 ECAM messages

Post Flight Report (PFR) was recovered for the 3 preceding flights as well as the PFR of the event flight.

None of them presented any relevant message prior to the event.

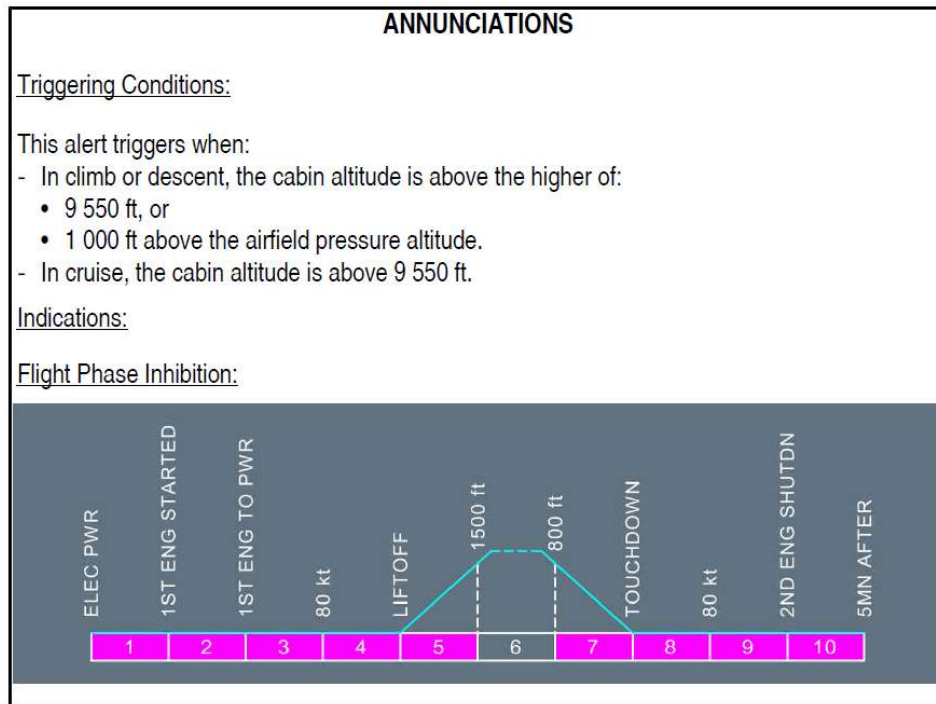
The event was characterized on the PFR by the following messages :

MAINTENANCE			DS/N	
POST FLIGHT REPORT			GVAD	
A/C ID	DATE	GHT	FLTN	CITY PAIR
SX-BHS	02FEB	0826/0854	DA0159	HCM HCM
ECAM WARNING MESSAGES				
GHT PH ATA				
0841 06 21-31 CAB PR EXCESS CAB ALT				
0842 06 21-31 CAB PR SAFETY VALVE OPEN				
0842 06 21-31 CAB PR LO DIFF PR				
FAILURE MESSAGES				
GHT PH ATA				
0827 02 22-82-12 AFS:MCDU1				
0827 02 23-73-19 CLOS1:NO CAN DATA				
0827 02 22-83-34 FMGC2(1CA2)/RMP2(1RG2)/MNR2(1BRT2)				
0833 02 22-82-12 AFS:MCDU1(FW DISC)/FMGC2				
0833 02 22-82-12 AFS:MCDU1(FW DISC)/FMGC1				
			SOURCE	IDENT.
			AFS	
			CLOS 1	
			MNR 2	MNR 1
			AFS	
			AFS	

GMT 0841 flight phase 6 (above 1500ft) ATA 21-31 CAB PR EXCESS CAB ALT
GMT 0842 flight phase 6 (above 1500ft) ATA 21-31 CAB PR SAFETY VALVE OPEN
GMT 0842 flight phase 6 (above 1500ft) ATA 21-31 CAB PR LO DIFF PR


1.6.3.1.1 “CAB PR EXCESS CAB ALT”


This ECAM message is triggered when the cabin altitude reaches 9550ft.



The fuselage perforation occurred at an altitude of 10390ft. This ECAM message is consistent with a cabin altitude above 9550ft.

Associated FCOM procedure

 A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	<p align="center">PROCEDURES</p> <p align="center">ABNORMAL AND EMERGENCY PROCEDURES</p> <p align="center">AIR CONDITIONING / PRESSURIZATION / VENTILATION</p>
<p align="center">CAB PR EXCESS CAB ALT</p>	
<p>Applicable to: MSN 0517-0642, 0879</p>	
<p>Ident.: PRO-ABN-21-T-00010754.0006001 / 02 SEP 14</p>	
<p>Rely on the <u>CAB PR EXCESS CAB ALT</u> warning even if not confirmed on the <u>CAB PRESS SD</u> page. The warning can be triggered by a cabin pressure sensor different from the one used to control the pressure and display the cabin altitude on the SD.</p>	
<p>CREW OXY MASK (IF ABOVE FL100)..... USE</p> <p>■ If above FL 100, and under FL 160:</p> <p>DESCENT.....INITIATE</p> <p>MAX FL..... 100/MEA</p>	
<p>■ If above FL 160:</p> <p>SIGNS..... ON</p> <p>EMER DESCENT INITIATE</p> <p>DESCENT.....INITIATE</p> <p>THR LEVERS (IF A/THR NOT ENGAGED)..... IDLE</p> <p>SPD BRK..... FULL</p> <p>Ⓛ Extension of speedbrakes will significantly increase VLS. In order to avoid autopilot disconnection and automatic retraction of speedbrakes due to possible activation of angle of attack protection, allow the speed to increase before starting to use speedbrakes.</p> <p>Ⓛ SPD..... MAX/APPROPRIATE</p> <p>Ⓛ Descend at maximum appropriate speed. However, if structural damage is suspected use the flight controls with care and reduce speed as appropriate. Landing gear may be extended below 25 000 ft. In this case, speed must be reduced to VLO/VLE.</p> <p>Ⓛ ENG MODE SEL..... IGN</p> <p>ATC..... NOTIFY</p> <p>Ⓛ 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. Squawk 7700 unless otherwise specified by ATC. To save oxygen, set the oxygen diluter selector to N position. With the oxygen diluter left to 100 %, oxygen quantity may not be sufficient for the entire descent profile. Ensure that the flight crew can communicate wearing oxygen masks. Avoid the continuous use of the interphone position to minimize the interference from the noise of the oxygen mask.</p>	
<p align="right"><i>Continued on the following page</i></p>	

 A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	<p style="text-align: center;">PROCEDURES</p> <p style="text-align: center;">ABNORMAL AND EMERGENCY PROCEDURES</p> <p style="text-align: center;">AIR CONDITIONING / PRESSURIZATION / VENTILATION</p>
CAB PR EXCESS CAB ALT (Cont'd)	
L1 MAX FL..... 100/MEA	
<p>● IF CAB ALT > 14 000 FT: PAX OXY MASKS.....MAN ON</p>	
<p>L2 This action confirms that the passenger oxygen masks are released.</p>	
<p><u>Note:</u> - When descent is established and if time permits, check that the OUTFLOW VALVE is closed on the CAB PRESS SD page. If it is not closed and ΔP is positive, select the other CPC. If the OUTFLOW VALVE is still not closing set the cabin pressure MODE SEL pb to MAN and the V/S CTL sw to full down.</p> <p>- Notify the cabin crew when the aircraft reaches a safe flight level, and when cabin oxygen is no more necessary.</p>	
<small>Ident.: PRO-ABN-21-T-00010755.0001001 / 05 AUG 10</small>	
<p style="text-align: center;">STATUS</p> <p>MAX FL..... 100/MEA </p>	

1.6.3.1.2 “CAB PR SAFETY VALVE OPEN”

This message is triggered when

- Either safety valve is not fully closed on ground or
- Not fully closed for more than 1min in flight.

ANNUNCIATIONS

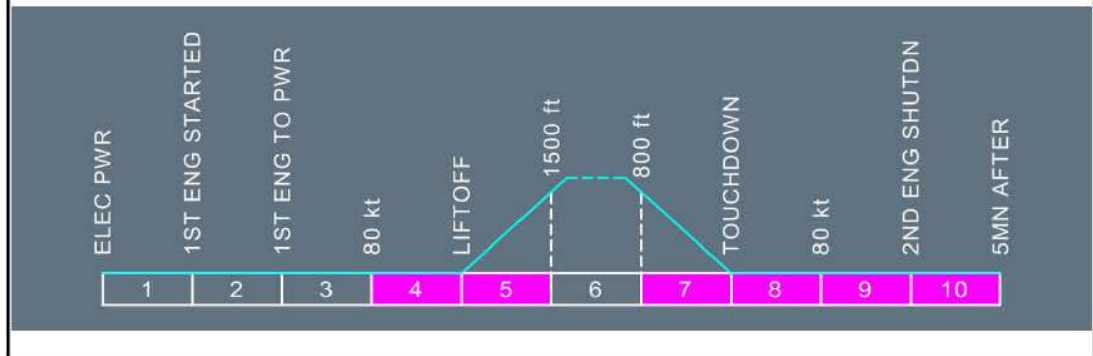
Triggering Conditions:

This alert triggers:

- On ground, if the safety valve is not fully closed, or
- In flight, if the safety valve is not fully closed for more than 1 min.

Indications:

Flight Phase Inhibition:



Safety valves can open in flight due to excessive (+ or -) differential pressure ($>+8.6$ psi or <-0.175 psi).

Safety valves

Two independent pneumatic safety valves prevent cabin pressure from going too high (8.6 PSI above ambient) or too low (1 PSI below ambient). They are located on the rear pressure bulkhead, above the flotation line.

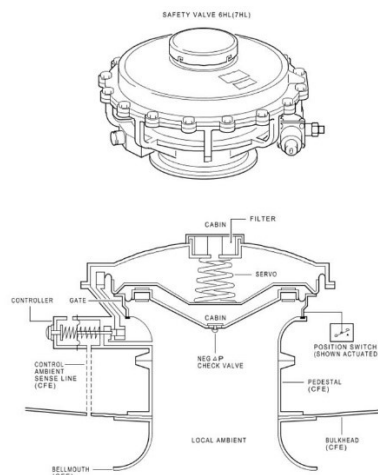
The AMM describes the safety valves as follows:

The safety valves 6HL (7HL) are poppet-type pneumatic valves. They have a valve part and a control part in a housing. The valve part has a cap with a filter, a diaphragm, a pedestal and a bellmouth. The control part has a position switch, a negative delta-P check-valve and a controller. The position switch is connected electrically to the System Data Acquisition Concentrators (SDACs).

The negative delta-P check-valve opens if the external pressure is higher than the internal pressure. The controller has a diaphragm, a poppet and springs to preload the poppet. The poppet gives accurate limit control.


If the internal pressure is more than the design goal of 8.6 psi (0.59bar) above the external pressure, the poppet moves and air flows out of the fuselage.





For negative delta-P condition it is ensured by a minimum of one safety valve operating, that the internal pressure is not more than 0.07 bar (1.02 psi) below the external pressure.



The triggering of **“CAB PR SAFETY VALVE OPEN”** ECAM alert was consistent with the activation of the Safety Valve for more than one minute after the dynamic internal overpressure event. Its activation resulted either from the blast inherent to the dynamic internal overpressure, or indicated sustained differential pressure resulting from the airflow through the fuselage hole.

Associated FCOM procedure

 A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES AIR CONDITIONING / PRESSURIZATION / VENTILATION
--	--

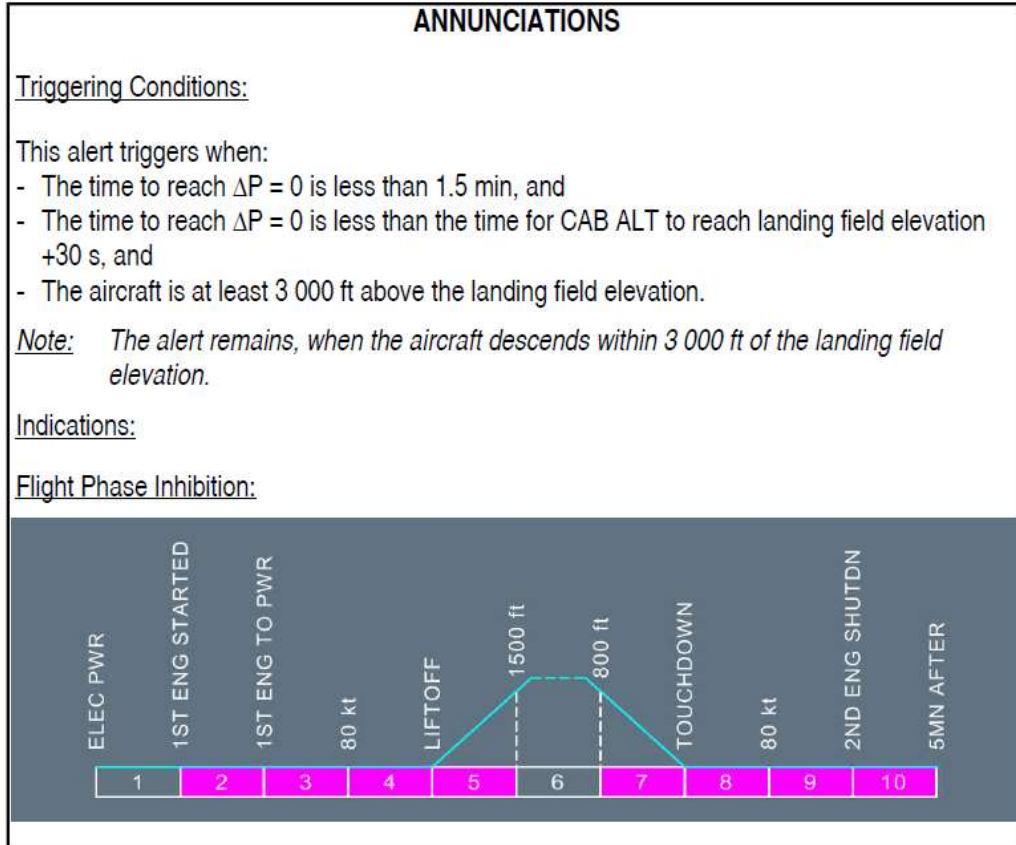
CAB PR SAFETY VALVE OPEN
Applicable to: MSN 0517-0642, 0879-1422 Ident.: PRO-ABN-21-W-00010766.0002001 / 05 AUG 10
<p> The safety valve has opened due to cabin overpressure, or negative differential pressure.</p> <p> ■ IF DIFF PR ABV 8 PSI: MODE SEL.....MAN MAN V/S CTL.....AS RQRD</p> <p> If overpressure is confirmed, reduce cabin ΔP. It may take 10 s in manual mode before the crew notices a change of the outflow valve position.</p> <p> ● IF UNSUCCESSFUL: A/C FL..... REDUCE</p> <div style="border: 2px solid red; padding: 5px;"> <p>■ IF DIFF PR BELOW 0 PSI: EXPECT HI CAB RATE A/C V/S..... REDUCE</p> </div> <p>Ident.: PRO-ABN-21-W-00010767.0003001 / 17 MAR 11</p>

STATUS												
MAN CAB PR CTL TGT V/S: CLIMB..... 500 FT/MIN TGT V/S: DESC..... 300 FT/MIN												
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: center;">A/C FL</th> <th style="width: 50%; text-align: center;">CAB ALT TGT</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">390</td><td style="text-align: center;">8 000</td></tr> <tr><td style="text-align: center;">350</td><td style="text-align: center;">7 000</td></tr> <tr><td style="text-align: center;">300</td><td style="text-align: center;">5 500</td></tr> <tr><td style="text-align: center;">250</td><td style="text-align: center;">3 000</td></tr> <tr><td style="text-align: center;">< 200</td><td style="text-align: center;">0</td></tr> </tbody> </table> <p>● DURING FINAL APPR: MAN V/S CTL..... FULL UP</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>CAUTION Check that ΔP is zero before opening the doors.</p> </div>	A/C FL	CAB ALT TGT	390	8 000	350	7 000	300	5 500	250	3 000	< 200	0
A/C FL	CAB ALT TGT											
390	8 000											
350	7 000											
300	5 500											
250	3 000											
< 200	0											

1.6.3.1.3 “CAB PR LO DIFF PR”

This message is triggered when

- the aircraft is at least 3 000ft above landing field elevation (LFE) and
- the time to reach $\Delta P = 0$ is less than 90 seconds and
- the time to reach $\Delta P = 0$ is less or equal to the time for cabin altitude to reach landing elevation +30seconds.



The ECAM message “CAB PR LO PRES DIFF PR” is generated when the Cabin Pressure Controller (CPC) predicts that the cabin differential pressure will be zero in 1.5 min time assuming that the aircraft continues the descent to landing at the existing rate of descent.

Given the fuselage damage created by dynamic internal overpressure, the triggering of this message was consistent with sudden delta P drop in cruise.

Associated FCOM procedure:

CAB PR LO DIFF PR	
Ident: PRO-ABN-21-00010762.0002001 / 05 AUG 10	
Applicable to: ALL	
EXPECT HI CAB RATE	
A/C VIS.....	REDUCE
<input type="checkbox"/> This line is not displayed in case of Emergency Descent due to Excessive Cabin Altitude.	

1.6.3.2 Cabin oxygen masks

During cabin inspection, a number of oxygen masks were observed to be deployed.



Cabin interior forward looking aft


Pilots reported that the masks were not deployed automatically nor manually (MASKS MAN ON cockpit action).

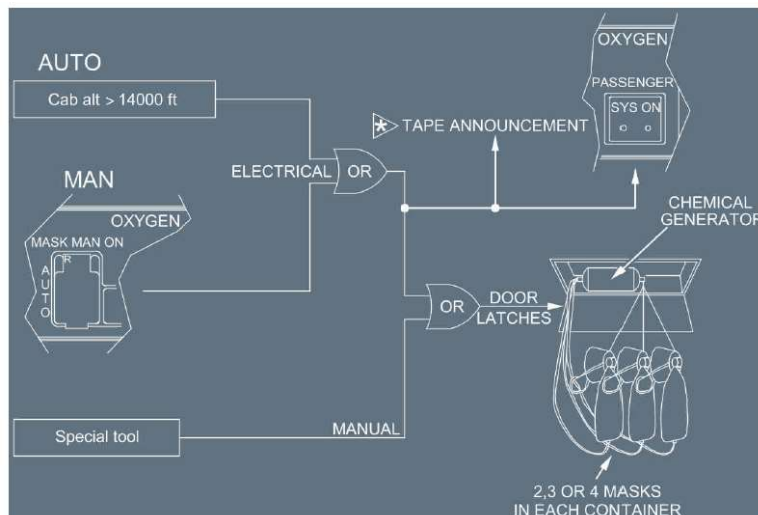
Masks are designed to automatically deploy at 14000ft cabin altitude, therefore there were no reasons why the masks would deploy automatically.

OPERATION

² Ident.: DSC-35-30-10-00016920.0001001 / 21 MAR 16

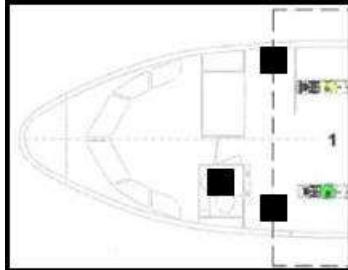
Applicable to: ALL

Each container has an electrical latching mechanism that opens automatically to allow the masks to drop, if the cabin pressure altitude exceeds 14 000 ft (+250, -750 ft), or 16 000 ft (+250, -750 ft) for the operation on high altitude airfields .

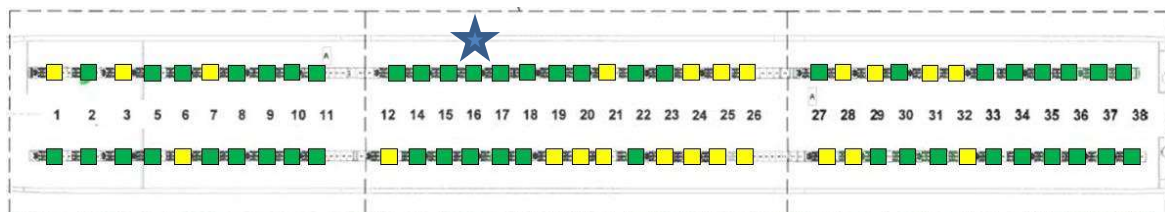


Here follows a mapping of the cabin representing masks deployed (green), masks not deployed (yellow) or no information (grey).

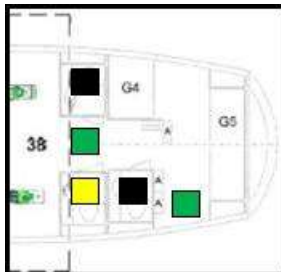
Front of the aircraft:



Cabin interior:



Aft of the aircraft:



From the observations made and the pilot report, the masks have probably dropped following the dynamic overpressure (blast) inside the cabin.

1.6.3.3 Systems summary

Following the rapid decompression event, several ECAM messages were triggered. Those messages were consistent with structural observations of a dynamic internal overpressure event and the pilots reporting *"a rapid decompression –confirmed by ECAM- together with a sound like an explosion, followed by a draft of air and smoke which was felt in the cockpit"*.

The majority (68%) of cabin masks were found deployed. Based on the aircraft altitude and pilot report, the oxygen masks were not deployed automatically.

Cabin crew actions during flight or maintenance actions after the flight are unknown to the investigators at the date of this report. This deployment could also be the consequence of the dynamic overpressure event.

1.7 Meteorological information

At the time of the accident the surface wind was 090°/17kt, temperature 31°C, QNH 1011 hPa.

1.8 Aids to navigation

The airplane was fitted with GPS and FMS.

1.9 Communications

The flight crew was in communication with the Departure controller.
There was no ATC radiocommunications recorded at Mogadishu.
The CVR allowed to perform a chronology of the communications between the flight crew and the ATC and the communications among the crew members.

1.10 Aerodrome information

The Mogadishu Aden Adde aerodrome is open to both military and civilian traffic (IFR and VFR). It is located 1 NM West of the city. The reference altitude is 28 ft.
It has a runway in asphalt which is 3184 meters long and 45 meters wide.
The runway orientation is 050°/230° Magnetic.



1.11 Flight recorders

The aircraft was equipped with two flight recorders: a CVR (L-3 COM A200S) and a FDR (Honeywell 4700).

The flight recorders were sent by the Investigator In Charge (IIC) to the BEA that received them on May 17th 2016.

The readout of both flight recorders took place at the BEA on June 1st 2016 with the IIC's authorization.

Equipments examined:

FDR Honeywell 4700 P/N : 980-4700-042 S/N : 09294	CVR Fairchild A200 P/N : S200-0012-00 S/N : 00277
	

1.11.1 FDR readout

A visual examination was performed. The FDR was in good condition. The technical seals were still in place and intact. A direct readout was performed using the manufacturer equipment (RPGSE readout station).

The download was successful. A raw file (.dlu format) was generated. The synchronization level was good and around 50 hours of flight data were recorded.

The raw data were decoded using the 128 words per second aircraft manufacturer's decoding dataframe.

The UTC time reference was created using UTC parameters recorded in the FDR. The CVR and FDR were synchronized using VHF keying, the auto-pilot disengagement with the associated audio alarm, and the sound assumed to be the explosion.

The flight of the event was recorded in the FDR.

The following observations were made from the FDR data of the accident flight (UTC time is used):

- At 8 h 35 min, the aircraft takes off from Mogadishu airport with the Copilot acting as Pilot Flying and the Captain as Pilot Monitoring;
- At 8 h 36 min 16 s, aircraft climbing passing 1700 ft QNH, A/THR is engaged in Thrust mode;
- At 8 h 38 min 04 s, aircraft climbing passing 4200 ft QNH, A/P2 is engaged in CLIMB/NAVIGATION modes. Selected Altitude is FL 300;
- At 8 h 41 min 03 s, normal, longitudinal and lateral accelerations show a spike at respectively -0.8g, -0.04g and 0.05g. The recorded standard altitude is 10392 ft, the recorded indicated airspeed is 261 kt and the recorded magnetic heading is 359.6°. The recorded latitude and longitude are 02°14'08.4" N and 45°17'06.3" E. At that time in the CVR a sound assumed to be related to the explosion is heard;
- At 8 h 41 min 07 s, A/P2 is disengaged and Cavalry Charge is recorded 1 s later in the CVR. The Captain takes over as Pilot Flying and first applies mainly nose down and left orders. The aircraft starts descending ;
- At 8 h 41 min 08 s, Master Warning and Cabin Pressure Warning are triggered;
- At 8 h 41 min 15 s, Master Warning is recorded off. Following Captain nose down inputs, Pitch Attitude is decreasing from 3.2° up to 0.7° up before stabilizing around 2° up at 8 h 41 min 29 s;
- At 8 h 41 min 16 s, following Captain left inputs, Roll Attitude parameter becomes negatives indicating a left turn that ends at 8 h 44 min 07 s. The aircraft magnetic heading at the end of the left turn is about 148°;
- At 8 h 41 min 17 s, Thrust Lever Angle Eng1&Eng2 decrease from 23° (CLIMB detent) to 11°. This movement triggers the ECAM message "A/THR LIMITED" associated with a single chime activated every 5 s;
- At 8 h 41 min 31 s, Thrust Lever Angle Eng1&Eng2 decrease from 11° to 6°;
- At 8 h 41 min 36 s, consequently to Thrust Lever Angle reduction both HP bleed valves are recorded opened;
- At 8 h 41 min 50 s, Thrust Lever Angle Eng1&Eng2 decrease from 6° to 0° (IDLE detent). A/THR is disengaged;
- At 8 h 43 min 09 s, A/P2 is engaged in CLIMB/NAVIGATION modes. Selected Altitude is still FL 300. Pitch starts increasing. The recorded altitude is 9192 ft and the recorded indicated airspeed is 221 kt;
- At 8 h 43 min 19 s, both Thrust Lever Angle increase and both HP bleed valves are recorded closed 9 s later;
- At 8 h 43 min 44 s, A/THR is engaged and both Thrust Lever Angle increase up to CLIMB detent 4 s later;
- At 8 h 43 min 56 s, Selected Altitude changes to 5000 ft. 2 s later, AP/FD modes change to OPEN DESCENT/NAVIGATION modes.

- At 8 h 45 min 35 s, Cabin Pressure Warning is recorded off. The recorded altitude is 8100 ft;
- At 8 h 53 min, the aircraft lands at Mogadishu airport in FULL configuration with a landing weight of about 69.4 t. The normal acceleration at touchdown is about 1.5 g.

A set of plots of validated parameters is available in appendix 1.

1.11.2 CVR readout

A visual inspection was performed. No physical damage was found. The technical seals were still in place and intact. A direct readout was performed.

The readout happened in two steps, as described in the manufacturer procedure.

A first readout of the audio signal recorded on the four HQ channels was performed with the portable official manufacturer mean, the DAPU, used as an analogic player. The four HQ channels were digitized while replayed in real time. Four wave files with duration of 30 min 37 s were generated.

Another similar readout was performed with the DAPU to retrieve the audio data from two SQ channels. Two wave files with duration of 2 h 02min 54s were generated.

The six audio files contain the audio relative to the flight of the event.

The CVR audio recording was of good quality. The audio data was synchronized with FDR parameters and a transcript of the recording was done. The event of interest (loud thud followed by AP Off and Master Warning) was recorded.

1.12 Wreckage and impact information

1.12.1 Structure overview

This section concentrates in the main aircraft structure and covers the main right hand (RH) fuselage structure at FR 35.8 area and the RH pylon.

1.12.2 Fuselage

Main fuselage damage area was observed on the right hand (RH) side of the fuselage between frames FR 35.8 and FR 35.6, and stringers (STGR) STGR 14 and STGR 22.

The fuselage showed a separation of the skin from stringers and frames associated with outwards deformation.



General view of the fuselage perforated area

All passenger doors, forward and aft cargo doors and bulk cargo doors were in expected position (closed).



Right hand fuselage doors views

Left hand side of the aircraft did not present any visible damage:



Left hand fuselage front view



Left hand fuselage rear view

See appendix 2 for the detailed structure analysis

1.12.3 Summary of the structure analysis

Overall fuselage damage showed a separation of the skin from stringers and frames associated with deformation from the inside to the outside of the aircraft.

The fuselage structure showed evidence of skin failure mode in dynamic shear consistent with a dynamic internal overpressure located between frames 35.7 to 35.8, stringers 18 to 20RH, above the passenger floor.

Skin was multi-fragmented with overall bent deformation and no sign of shear bent phenomenon. Stringers and frames showed tension rupture mode.

Observations made on aircraft structural parts (deformations and ruptures) were not consistent with any excessive in-flight loadings (resulting from an aircraft operational behaviour), nor with structure fatigue failure mode.

Soot, overheat, and melting traces were consistent with high temperature blow generated by the dynamic internal overpressure.

This is also consistent with the report of *“a rapid decompression”* and *“a sound like an explosion”* by the flight crew.

1.13 Medical and pathological information

The body of the man found near the town of Balad (Somalia) was taken to hospital for post-mortem examination. It was found that he was the passenger seated on the 16F seat. On the plane, he was carrying a laptop with explosive.

1.14 Fire

No fire occurred after the explosion.

1.15 Survival aspects

Two passengers were injured.

1.16 Tests and research

Not applicable

1.17 Organizational and management information

Not applicable

1.18 Additional information

1.18.1 Pilot report

“Departure has taken place with a delay of 20 minutes. During climb when we were passing 10,800ft we experienced a rapid decompression –confirmed by ECAM- together with a sound like an explosion, followed by a draft of air and smoke which was felt in the cockpit. We have requested an emergency return to the departure airport. We have followed the company’s SOP and landed normally and safely.”

1.18.2 Origin of the event

High level of expertise in planning, recruiting, coordination and execution were performed by a terrorist group. The actors had good knowledge of the airport environment.

1.19 Useful or effective investigation techniques

Not applicable

2. ANALYSIS

2.1 Crew handling of the situation

Immediately after the explosion, the Captain took control of the aircraft. The flight crew followed the ECAM messages and applied the adequate actions provided by the airline SOPs. The CVR content shows that the flight crew remained professional, that they reassured the cabin crew and adopted an adequate flight path to perform a safe landing.

2.2 CRM

The task sharing between the Captain and the First Officer were in accordance with the expected actions. The communications between the Captain and the first officer were professional. This contributed to a safe conduct of the flight and a safe landing.

2.3 Origin of the event

The actors of the terror attack were familiar with the airport and had a good planning and execution of the attack.

3. CONCLUSIONS

3.1 Findings

- The aircraft took-off from Mogadishu with 81 people on board.
- The aircraft had a valid certificate of airworthiness.
- The weather conditions were not a factor.
- The first officer was Pilot Flying (PF), the captain was Pilot Monitoring (PM).
- Passing 10 400 ft, the sound of an explosion was heard on the CVR.
- A Master Warning and a Cabin Pressure Warning were triggered.
- At that moment, the recorded indicated airspeed was 261 kt and the recorded magnetic heading was 359.6°.
- The Captain took control of the aircraft and applied nose down inputs and left turn orders.
- The flight crew applied the depressurization procedure as per the airline SOPs.
- The flight crew performed an emergency return to Mogadishu.

- A very efficient CRM allowed to avoid stress and ensured the safe conduct of the flight until landing.
- The aircraft landed safely at Mogadishu 12 minutes after the explosion.
- As a consequence of the explosion the passenger seated at 16F was ejected from the aircraft and was found dead on the ground in the vicinity of the airport. Two other passengers seated nearby were injured.
- The origin of the explosion was proved to be a terrorist attack. The passenger seated at 16F triggered a blast device that he carried with him.

3.2 Causes

The accident was caused by the explosion of a laptop bomb device carried by a passenger on board.

4. SAFETY RECOMMENDATIONS

The investigation showed that the accident was caused by a bombing on board. This act was caused by a passenger with a laptop trapped by explosive. The passenger went through a series of controls without being detected.

Consequently, the Somalian Aircraft Accident Investigation Authority recommends the Somali Airport Authority and the Somali Civil Aviation Authority to :

- **Search all passenger baggage and employees at Mogadishu airport.**
- **Have all laptops switched on before checking in.**
- **Perform random questioning of passengers based on profiles.**
- **Implement Somalian Police Force (SPF) watchers in uniform at each access point.**
- **Minimize entrance of unnecessary personnel.**
- **Install random swabs with disposable explosive detection kits.**
- **Reinforce the separation between the passengers terminals and cargo areas.**
- **Prepare thorough assessment of the airport by a competent external and independent authority appointed by the Somalian Government.**

LIST OF APPENDICES

Appendix 1 FDR plots

Appendix 2 Detailed structure analysis

Appendix 1

FDR plots

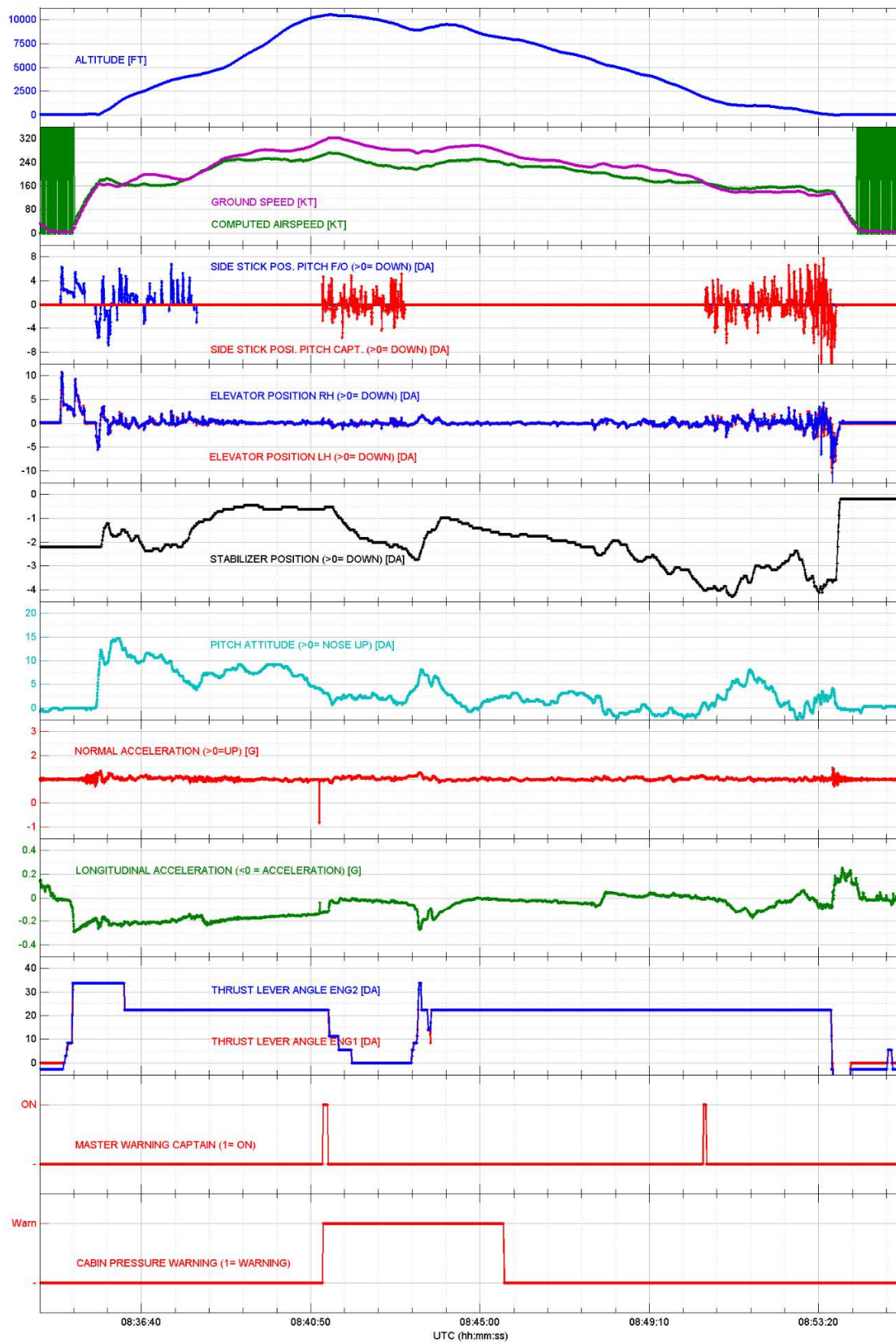


Figure 15: Longitudinal

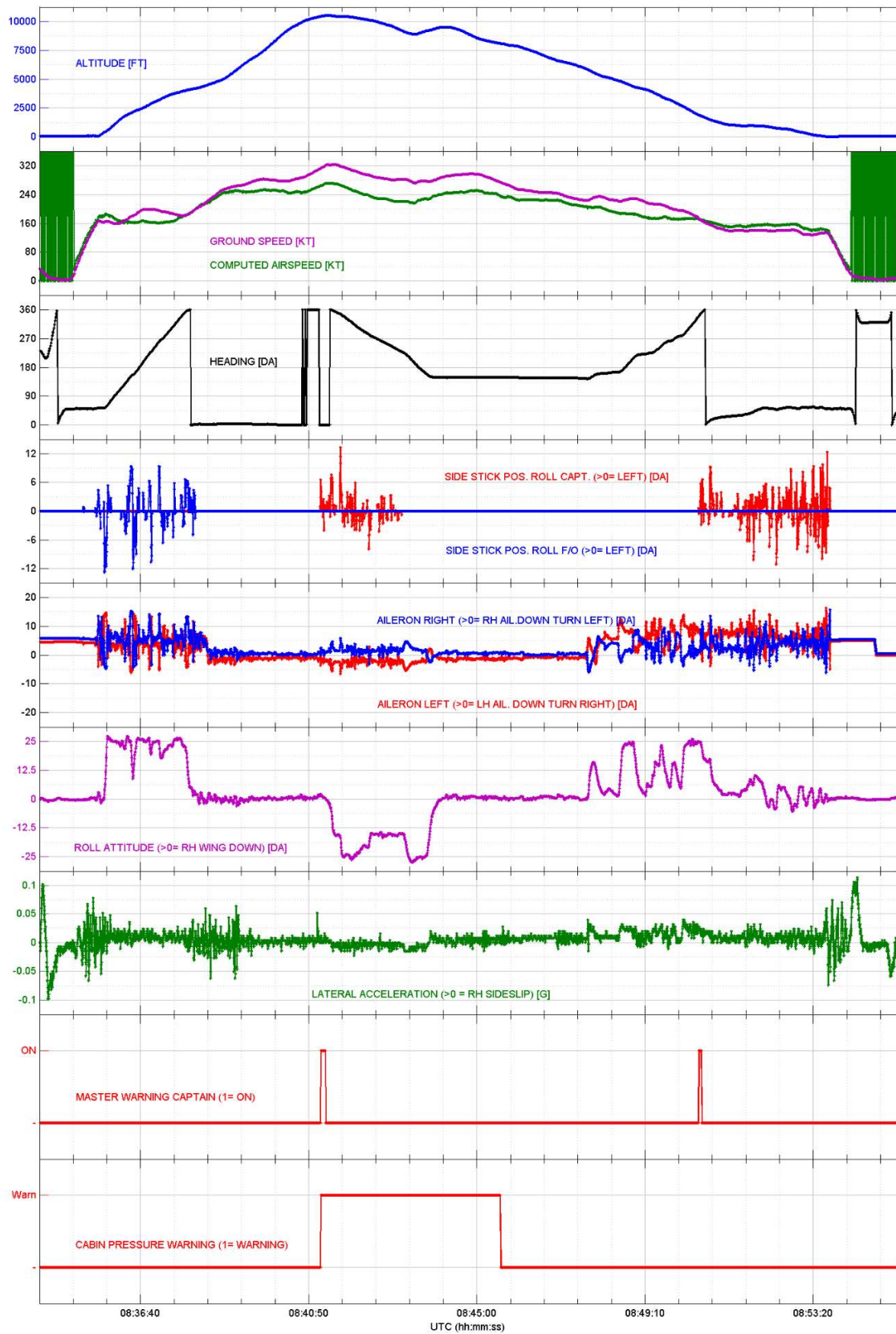


Figure 26: Lateral

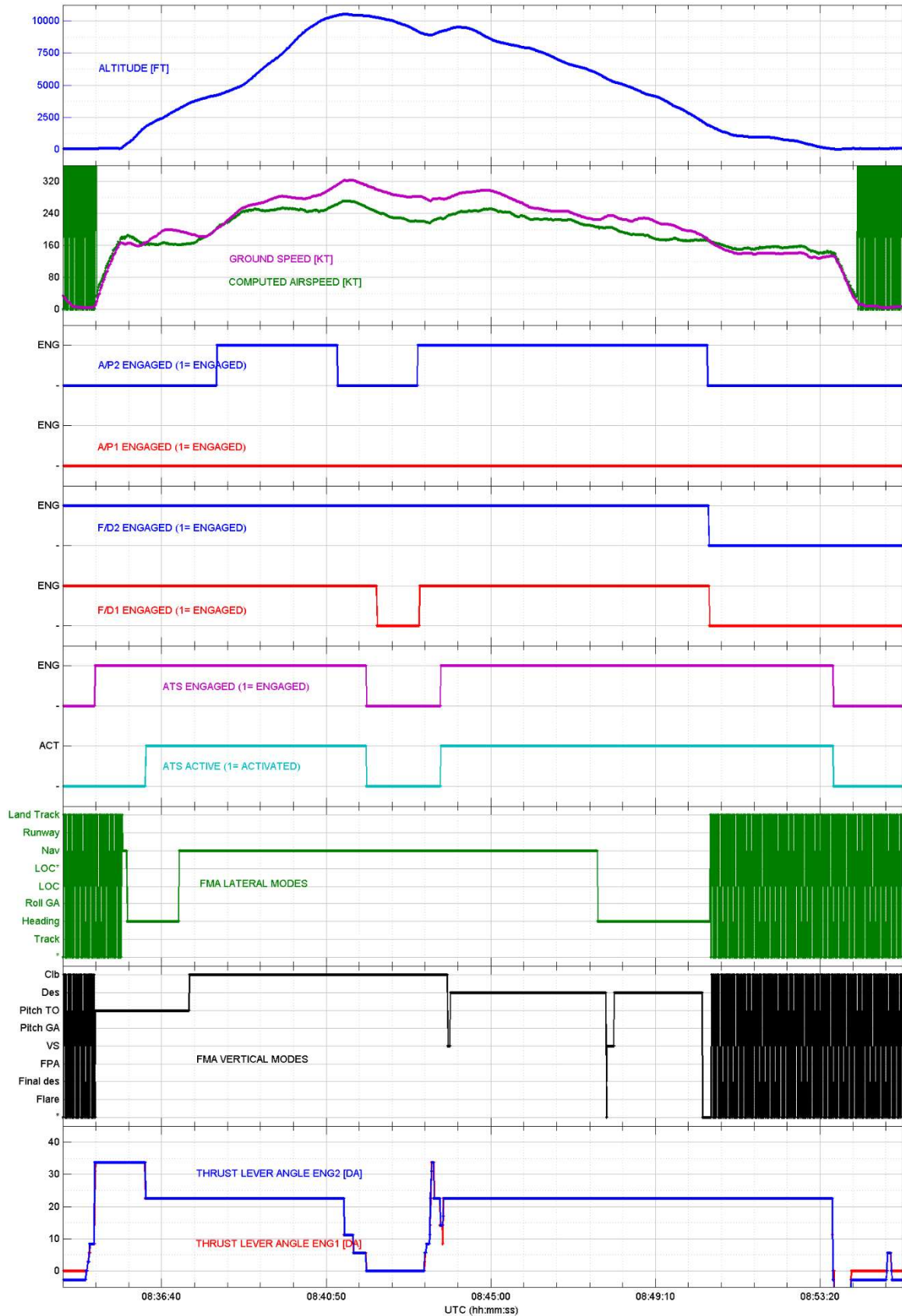


Figure 37: Auto Flight System

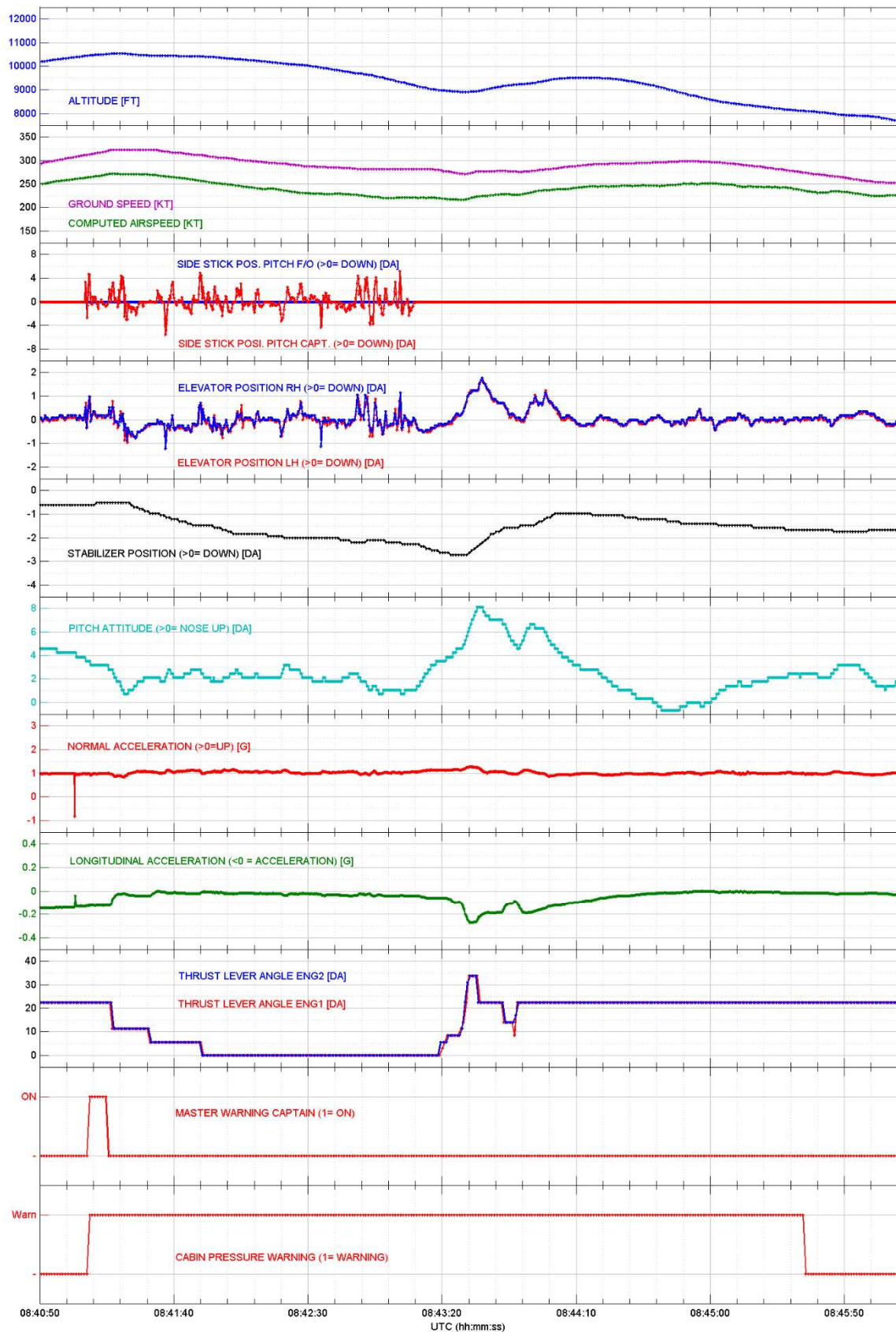


Figure 48: Longitudinal - Zoom in

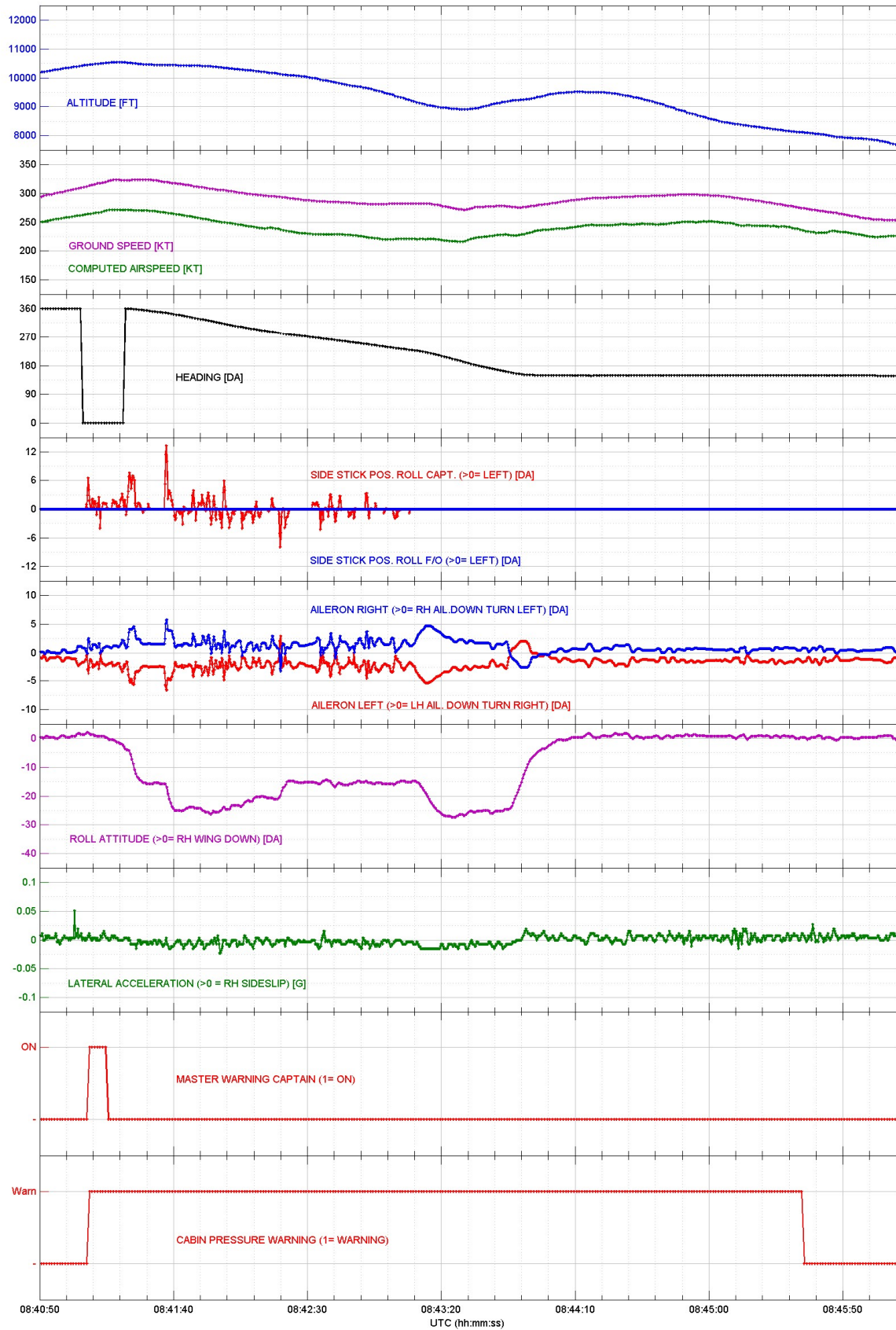


Figure 59: Lateral - Zoom in

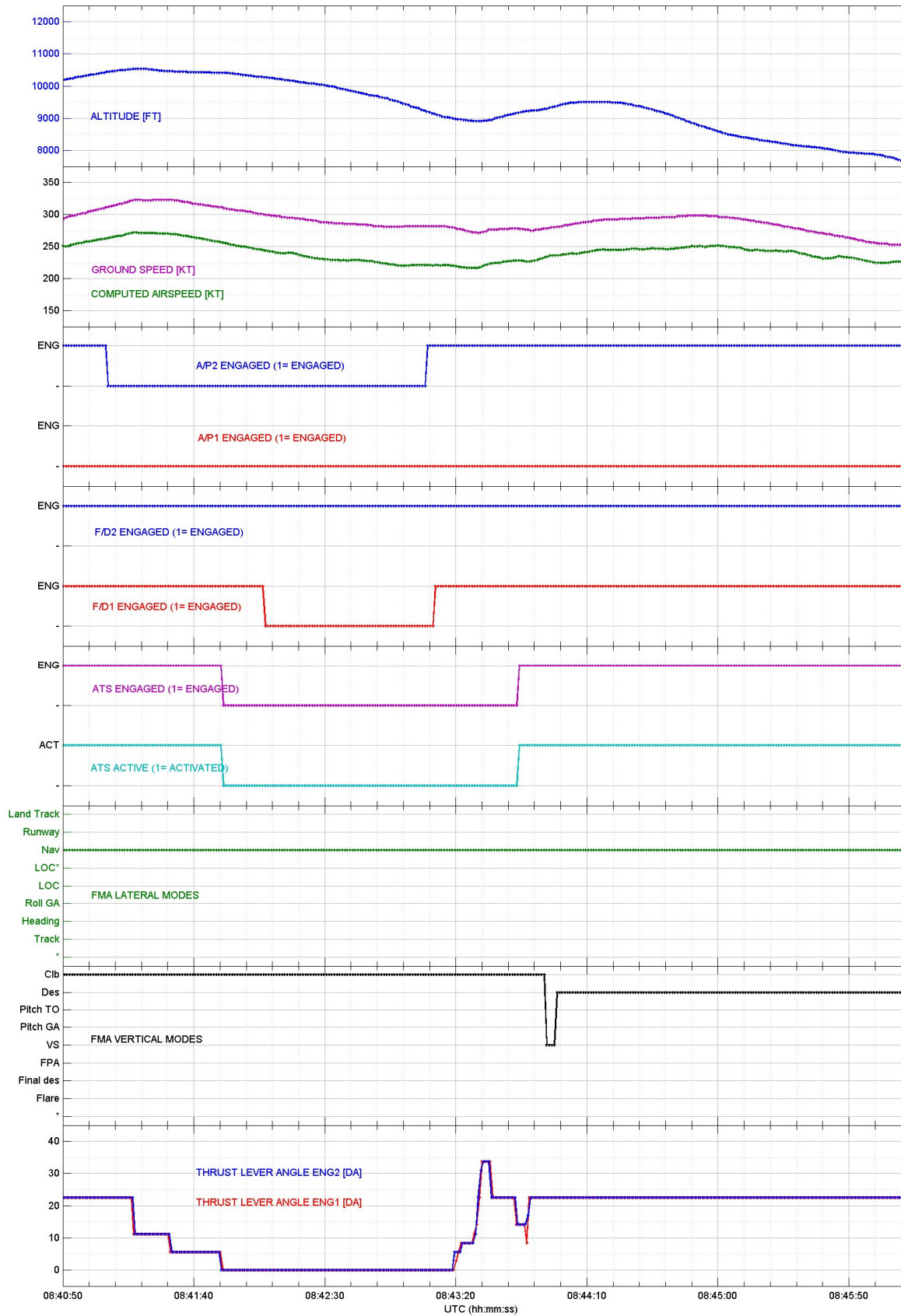


Figure 610: Auto Flight System - Zoom in

Appendix 2

Detailed structure analysis

1. External skin right hand side

The perforated skin panel is detailed in SRM 53-21-11.

There was an overall outward deformation of the skin and the stiffening structure. Part of the fuselage skin was pull-out from fastening lines of stringers, frames and windows.



Figure 1 - Skin missing

The skin was damaged in multi fragments without any sign of shear:

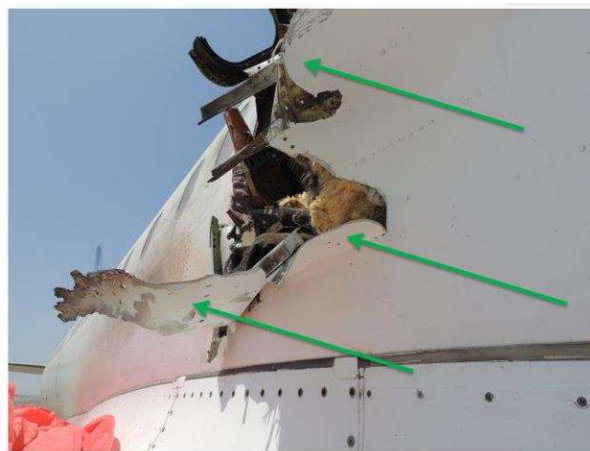


Figure 2 - Skin damaged in multi fragments

Ruptures along the rivet lines of skin attachment to stringers and frames are observed to be tension ruptures.

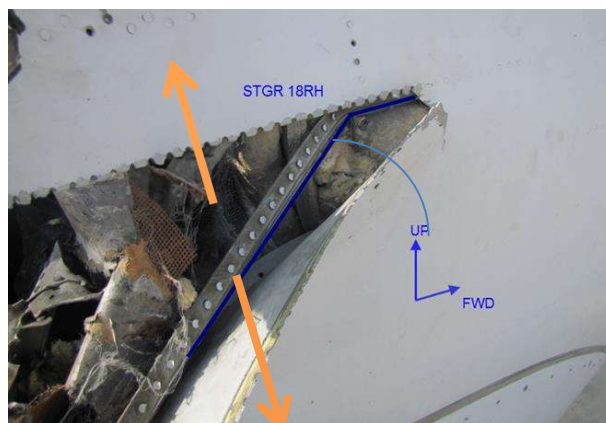


Figure 3 - Tension rupture at STGR 18 RH riveting line

The damaged skin, in its inner face, showed overheated and melted areas at fragmental impact locations (indicated by blue arrows).

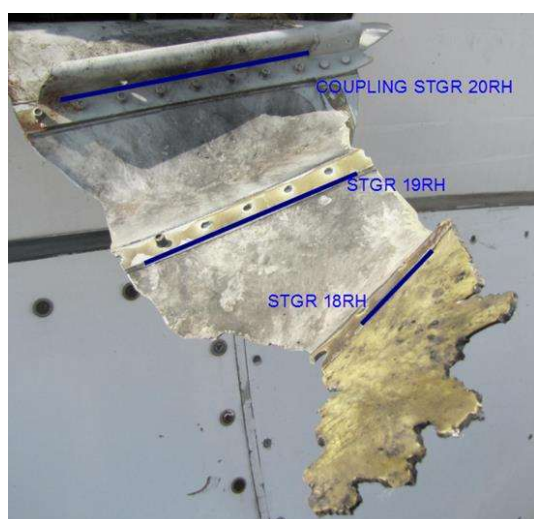


Figure 4 - Skin showing overheated and melted areas

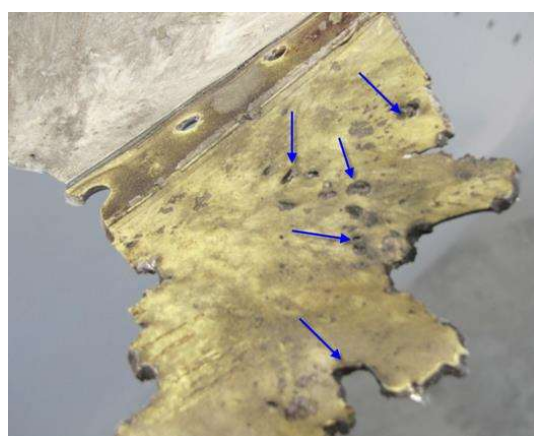


Figure 5 - Skin with burnt marks and impacts

Underneath the cabin window forward of FR 35.8 and above the “lapjoint”⁴, the skin is pulled out from the fastening line with fasteners still in place on the window.

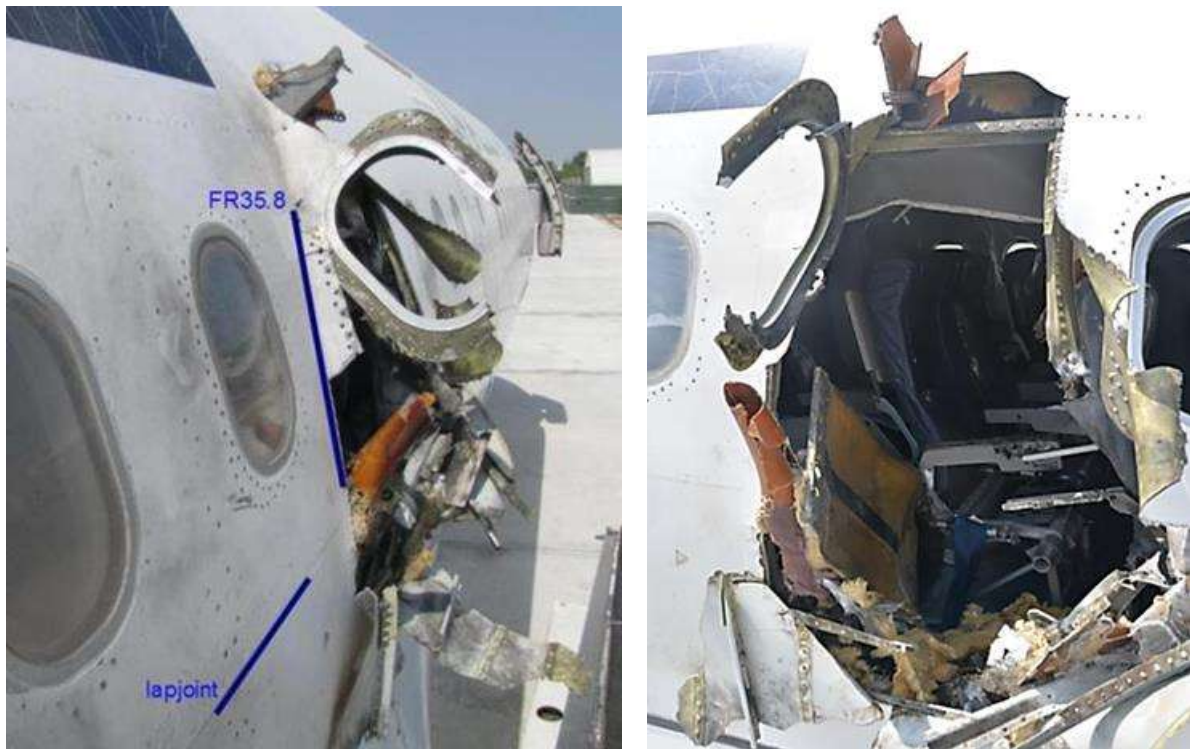


Figure 6 - Window frame area

A piece of fuselage skin is missing between FR 35.7 to FR 35.8 and STRG 13 to STRG 21, around the cabin windows. Relevant part number is PN D532-35255 with thickness from 1.2mm to 3.2mm.



Figure 7 - Skin damaged dimension

⁴ Lapjoint: longitudinal panel junction

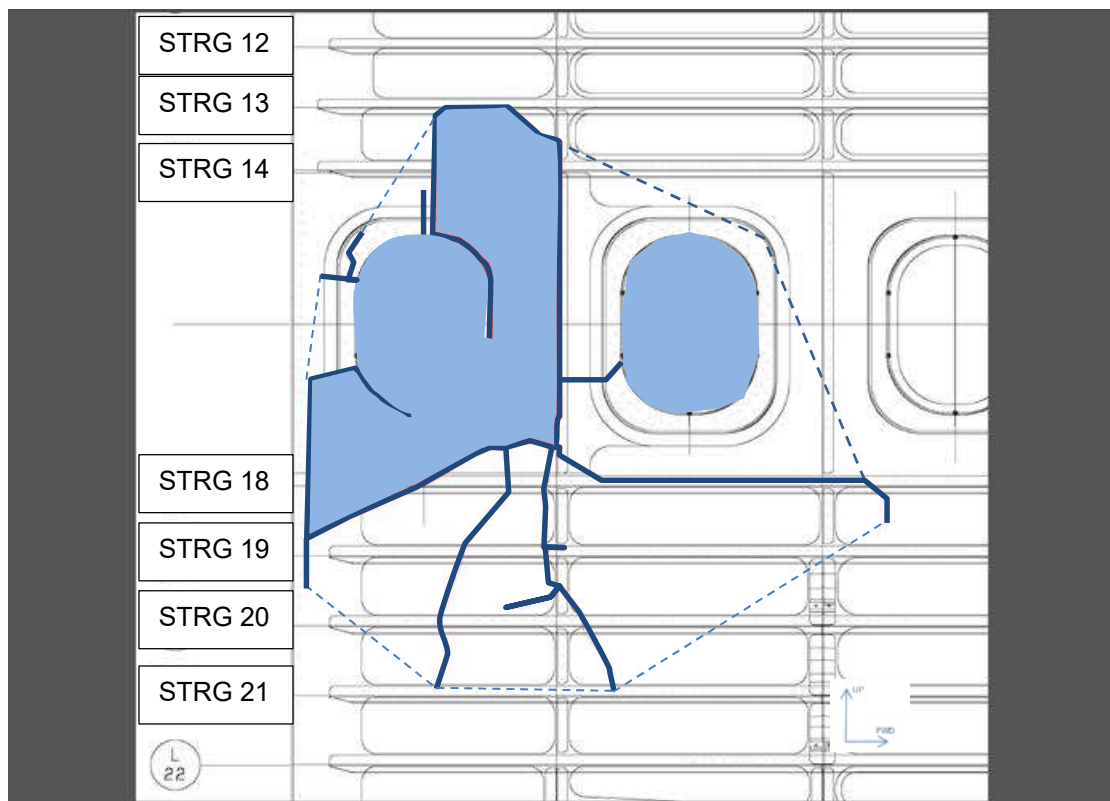


Figure 8 - Skin rupture & bending sketch - missing parts (light blue)

Rearwards FR 35.8 lapjoint, there is no evidence of major skin damage, only few minor scratches.

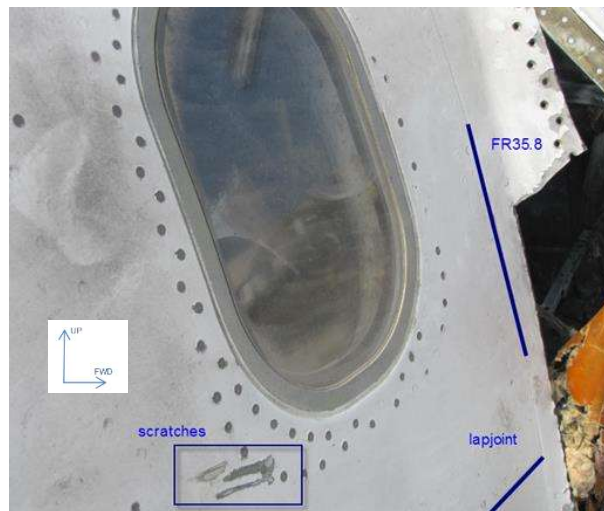


Figure 9 - Scratches after FR 35.8

Black soot traces were observed on fuselage between FR 35.8 and around FR 42.

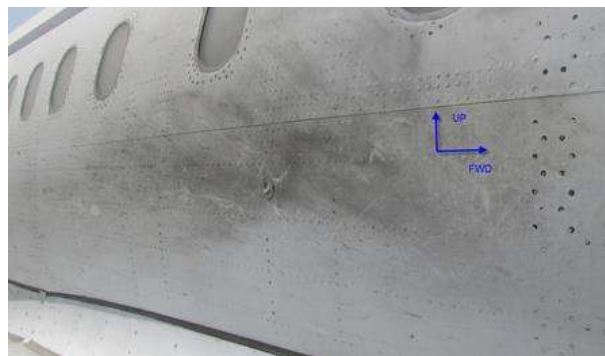


Figure 10 - Black Soot traces

Skin observations:

- The skin is multi fragmented with overall bent deformation from the inside to the outside of the aircraft.
- There is no sign of shear bent phenomenon: it is not consistent with any flight operational load.
- Overall damage is located out of fuselage skin fracture lines⁵.

⁵ Fracture lines for fuselage skin are mainly located outside section or panel junction, except some local ruptures lines at minimum net sections (rupture along the riveting line).

2. Frames

Relevant frames are detailed in SRM 53-21-12 for frames before FR 35.8 and SRM 53-31-12 for frame from FR 35.8 and after.

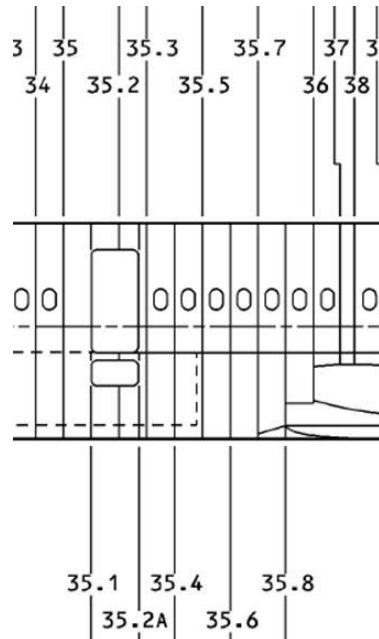


Figure 11 - Frames labelling



Figure 12 - FR 35.8 position



Figure 13- Frame FR 35.8 view from inside

Rows of fasteners were still attached the fuselage skin to the FR 35.8. There was no sign of fatigue damage initiated at this junction.

Frame 35.7 is cut with a rupture in tension without sign of shear.

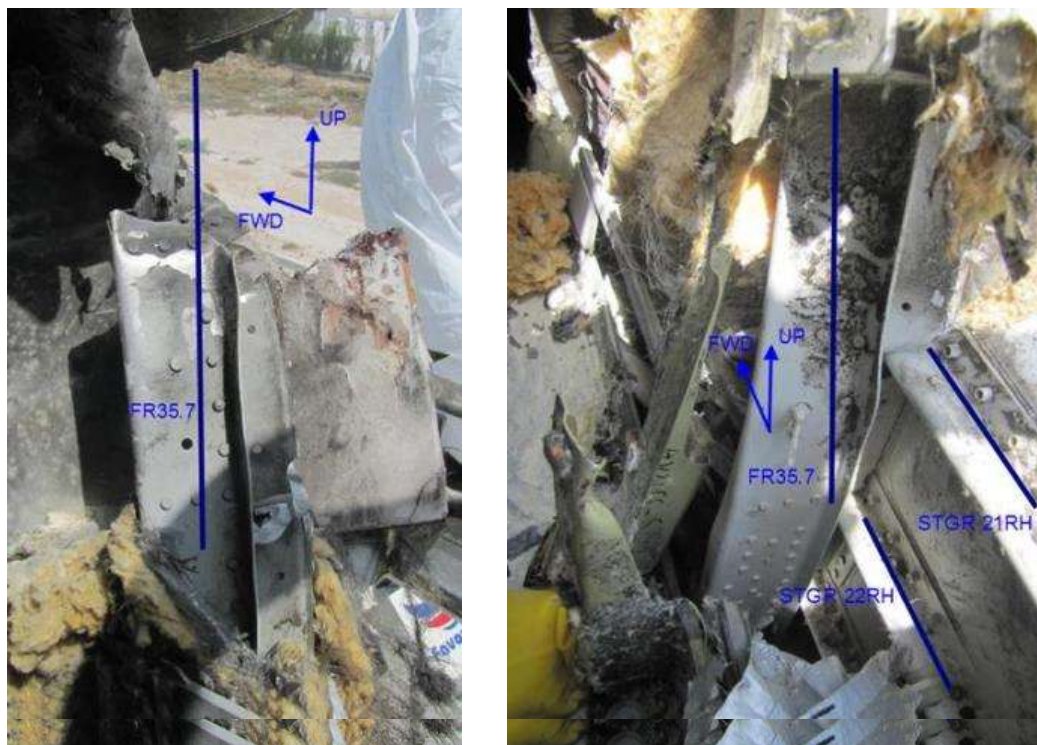


Figure 14 - Frame FR 35.7

Frames observations:

- Damaged frames present rupture mode in tension: it is not consistent with any flight operation load.

3 Stringers

Relevant stringers are detailed in SRM 53-21-13.

Stringer 14RH was still attached to the FR 35.7 and FR 35.8. The skin was pulled out at fasteners riveted lines.

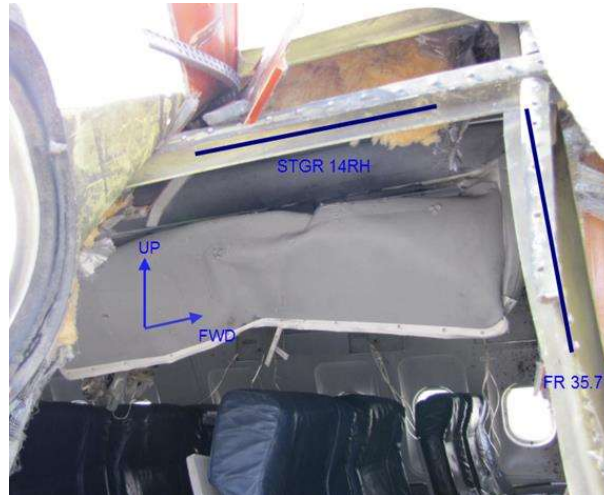


Figure 15 - Stringer 14RH view

Three consecutive stringers STRG 18, 19, 20 (RH) were broken and bent outwards.



Figure 16 - Stringers 18 & 19RH view

Fasteners were still in place at stringer level consistent with tension rupture of the skin along the rivet line without visible sign of shear.

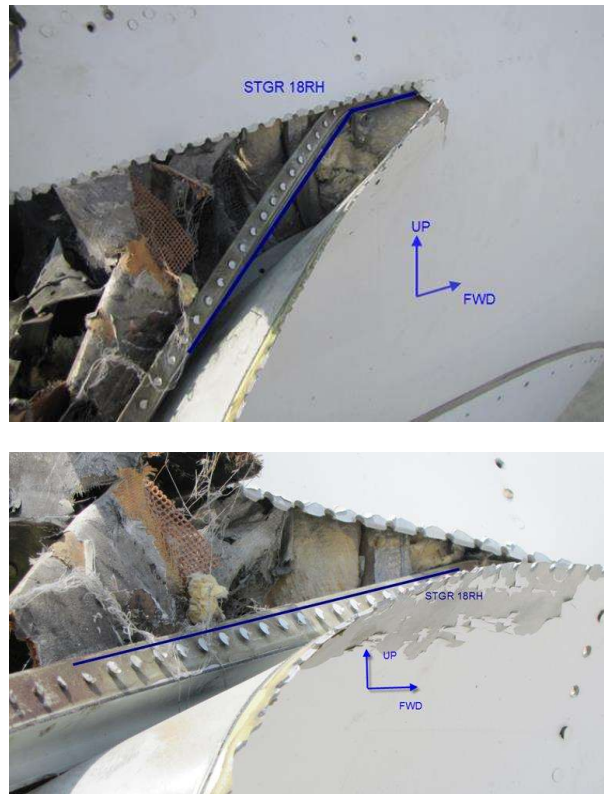


Figure 17 - Stringer 18RH view with skin tension rupture

Stringer observations:

- Damaged stringers were bent from the inside to the outside of the aircraft.
- Fasteners were still in place on the stringers consistent with tension skin rupture and did not present any sign of shear.

Right hand pylon

A hole was observed on the RH pylon cantilever panel surrounded by several dents.

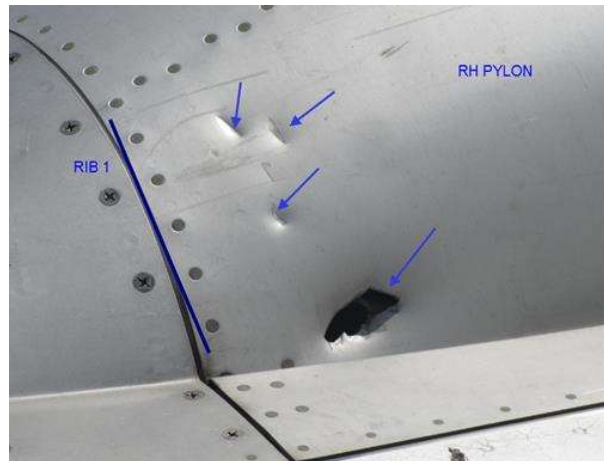


Figure 18 - Dents and hole on the RH pylon cantilever panel

Dent on the overpressure panel was also observed.



Figure 19 - Dent on the overpressure panel

Close to the cantilever panel, scratches on the upper side of the LH fan cowl were observed.

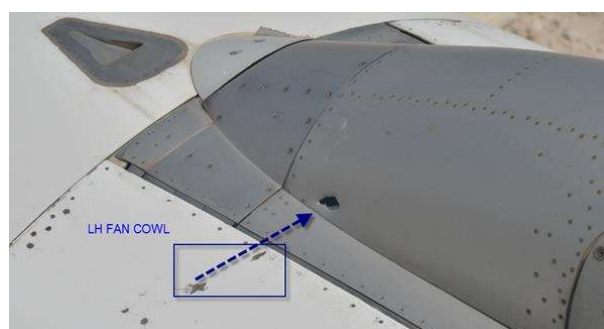


Figure 20 - Scratches on the LH fan cowl engine 2

These findings were consistent with secondary impact damage by fuselage debris.