

FINAL REPORT

on
investigation of a serious incident, realized on 11.03.2018 with B737-400 aircraft, registration marks TC-TLC, operated by TAILWIND AIRLINES AO, in a flight on route Antalya - Zurich over the territory of Republic of Bulgaria.



2018

Purpose of the Report and responsibility

In accordance with Annex 13 to the Convention on International Civil Aviation of 7 December 1944, Regulation 996/2010 of the European Parliament and the Council on the investigation and prevention of accidents and incidents in civil aviation and Ordinance 13 of 27.01.1999 of the Ministry of Transport, Information Technology and Communications, the objective of the aviation occurrence investigation is to establish the causes that have led to its realisation in order these to be eliminated and not allowed in the future without apportioning blame or liability.

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01 List of Abbreviations

A/C	- Aircraft;
AAIU	- Air Accident Investigation Unit;
ALT	- Altitude;
AMRAIUD	- Aircraft, Maritime and Railway Accident Investigation Unit Directorate;
AO	- Aircraft Operator;
AP	- Autopilot;
APP	- Approach Control Unit;
ATPL	- Airline transport pilot licence;
ATS	- Air Traffic Service;
BULATSA	- Bulgarian Air Traffic Services Authority;
CAT	- Category;
CRS	- Certificate of Release to Service;
DFDR	- Digital Flight Data Recording;
DG CAA	- Directorate General “Civil Aeronautical Administration”;
EASA	- European Air Safety Agency;
F/C	- Flight crew;
FCOM	- Flight Crew Operating Manual;
FD	- Flight director;
FDR	- Flight Data Recorder;
FL	- Flight level;
FPA	- Flight Path Angle;
GAT	- General Air Traffic;
GW	- Gross Weight;
ICAO	- International Civil Aviation Organization;
LBBG	- Airport Burgas;
M	- Mach number;
MO	- Maintenance organization;
MTITC	- Ministry of Transport, Information Technology and Communications;
QAR	- Quick Access Recorder;
QRH	- Quick Reference Handbook;
RWY	- Runway;
SOP	- Standard Operating Procedures;
TLB	- Technical Logbook;
UTC	- Universal Time Coordinated;

1. Introduction

Date and time of air occurrence: 11.03.2018, 9:46 AM UTC (11:46 AM local time).

Notified: Aircraft, Maritime and Railway Accident Investigation Unit Directorate and Civil Aircraft Administration Main Directorate at the Ministry of Transport, Information Technology and Communications of the Republic of Bulgaria (MTITC); European Commission; International Civil Aviation Organization (ICAO); European Air Safety Agency (EASA); Air Accident Investigation Board of Republic of Turkey and National Transportation Safety Board of USA.

On the grounds of the provisions of Article 9, para.1 of Ordinance No 13 dated 27.01.1999 on Investigation of Aviation Accidents, the occurrence was classified as a serious incident by the Aircraft Accident Investigation Unit (AAIU) at AMRAIU Directorate at the MTITC. The materials on the aviation occurrence have been filed in case No 02/11.03.2018 of AAIU archives.

In accordance with the provisions of Article 5, Para 1 of Regulation (EU) No 996/2010 on investigation and prevention of accidents and incidents in civil aviation, Article 142, Para2 of the Civil Aviation Act of the Republic of Bulgaria dated 01.12.1972 and Article 10, Para 1 of Ordinance No 13 of the MT dated 27.01.1999 on the Investigation of Aviation Occurrences, by Order No RD-08-114/20.03.2018 of the Minister of Transport, Information Technology and Communications, a Commission was appointed for investigation of the serious incident.

The difference between the local and Universal Coordinated Time is +2 hours. All times in this report are UTC.

B737-400 aircraft, operated by TAILWIND AIRLINES, TC-TLC registration marks, was conducting an Antalya-Zurich flight with 89 passengers and 7-member crew on board. At overflying the territory of the Republic of Bulgaria, at an altitude of 33700 ft, the cabin was depressurized. The crew put on oxygen masks and released oxygen masks in the passenger compartment. The crew undertook an emergency descent and performed a forced landing at Sofia Airport at 10:08 UTC. The landing was performed without any problems for the passengers, crew and aircraft. The passengers were transferred to another airplane to continue the flight to the final destination.

The Safety Investigation Commission indicated as a reason for realization of the serious incident: Failure of the heater of the outflow valve seal and possibly icing of the valve during the flight due to its inability to move. The right safety relief valve remains in open position after its activation.

2. Factual information

2.1. Flight history

2.1.1. Flight number, type of operation, last point of departure, time of departure, destination point of intended landing:

Flight number: XC1845.

Type of operation: Commercial charter flight with passengers.

Last point of departure: Antalya Airport.

Time of departure: 8:34 h UTC.

Destination point of the intended landing: Zurich Airport.

2.1.2. Flight preparation and description of the flight

Preparation and description of the flight was made on the basis of explanations given by the captain and crew members after landing at Sofia Airport and flight-related documents.

Before the flight all crew briefings, equipment and documents checks were performed. The flight was performed during the day and weather was clear throughout the route. 89 passengers and 7 crew members were on board. The take-off from Antalya Airport was on time at 08:34. The aircraft climbed to FL 320 and kept this FL along the route. A check list for cruise speed flight was completed and it was established that the cabin parameters were stabilized. The flight continued normally as the airplane crossed the Bulgarian border at a reporting point VADEN

towards reporting point UTEKA. At about 80 nm east of Sofia Airport the crew of the aircraft decided to climb to FL 340, starting at a vertical speed of about 1000 ft / min. The flight trajectory of the airplane over the Republic of Bulgaria is shown on Fig. 12 of Enclosure 1.

When the FL 337 was reached, a sound alarm for dangerous cabin altitude was triggered, light indicator for cabin altitude was on and the captain saw, that the cabin differential pressure reaches the maximum at the red limiting line. The indicator for a cabin climb speed was at a 3 hrs position, indicating a climb up speed of 4000 ft/min. The cabin pressure altitude indicator pointer was in position between 4 and 5 hrs and the cabin altitude was about 10000 ... 13000 ft.

The crew immediately put oxygen masks, selected the "MAN AC" mode on the cabin pressure control selector and, by means of the switch, tried to put the outflow valve in the closed position. The sound alarm for dangerous cabin pressure altitude was switched off. The attempt to close the outflow valve through the selected MAN AC mode switch didn't made the desired effect and the crew decided to perform emergency descending. This was immediately communicated to Sofia Control and the crew performed the checklist "CABIN ALTITUDE WARNING OR RAPID DEPRESSURIZATION AND EMERGENCY DESCENT". Oxygen masks in the passenger cabin were released.

The aircraft descended rapidly to FL 200 when it reaches a speed of 337 KIAS, where the airplane's pressurization system started to react, although it still remained outside of normal parameters. The aircraft reached FL 130 and was ILS approach for RWY27 at Sofia Airport. The crew decided to land at Sofia Airport without declaring a forced landing. Passengers were warned about the situation that caused forced descend and deviation to Sofia Airport.

The approach and landing at Sofia Airport were normal with a landing mass of 51311 kg, at a maximum permitted landing mass of 54884 kg and a residual fuel at landing of 7992 kg.

After the landing the cabin crew informed that during the events related to the depressurization in the front and rear kitchens, there was a sudden appearance of a damp mist and it became cold very fast. The damp mist didn't appear in the middle of the cabin.

There was no damp mist or temperature change in the cockpit, although there was a large change in the pressure felt by the pilots in their ears.

The cabin crew also informed that the passenger cab was under control and there was no panic. There were no injuries to passengers or crew members.

After the landing the aircraft was stopped at a stand and the passengers leaved it by normal exits without use of emergency means. There were no damages to the aircraft.

2.1.3. Location of aviation occurrence

The aviation occurrence was realized during a flight on the Antalya-Zurich route in the airspace of the Republic of Bulgaria at 80 nm east of Sofia Airport. The occurrence was realized during the day time – 09:46 UTC (11:46 local time).

2.2. Injuries to persons

Injuries	Crew	Passenger	Total number of occupants	Others
Fatal	0	0	0	0
Serious	0	0	0	0
None	7	89	96	0
Total	7	89	96	0

No injuries of crews, passengers or other persons in result of the aviation occurrence.

2.3. Damage to Aircraft

During the inspection of the aircraft after realization of air occurrence no damages on the airframe: The external condition of the airplane is visible from the photos shown in Enclosure 1. All oxygen masks in the passenger cabin were activated, Fig. 9 and 10 of Annex 1. A QAR memory card with flight parameters was downloaded. An inspection of the cabin pressure control system performed by CAMO of AO has revealed a failure of the outflow valve gasket

heating, failure of the outflow valve, and jamming of the right safety relief valve in open position.

2.4. Other damages

No other damages.

2.5. Personnel information

2.5.1. Commander

Person:	Male, born 1980.
Licence:	Airline transport pilot licence for airplane (ATPL (A), issued by CAA of Denmark.
Type:	B737-300-900.
ATPL valid:	valid until 31 April 2018.
Medical Certification:	valid until 28 December 2018.
Flying experience:	Total FH 8300:58 hours
	On the type 8043:58 hours
Information about duty time and rest:	
	During the last 90 days 58:55 hours
	During the last 24 hours 00:00 hours

All the information available indicates that the commander was rested and healthy when he came on duty. There are no indications that fatigue played a role at the time of the incident.

2.5.2. Co-pilot

Person:	Male, born 1980.
Licence:	Airline transport pilot licence for airplane (ATPL (A), issued by CAA of Republic of Turkey.
Type:	B737-300-900.
ATPL valid:	valid until 28 February 2019.
Medical Certification:	valid until 10 April 2018.
Flying experience:	Total FH - 2184:17 hours
	On the type 2004:57 hours
Information about duty time and rest:	
	During the last 90 days 75:40 hours
	During the last 24 hours 00:00 hours

All the available information indicates that the co-pilot was rested and healthy when he came on duty. There are no indications that fatigue played a role at the time of the incident.

2.5.3. Technical person

Person	Male, born 1981
License:	Aircraft Maintenance License B1 for B737-300/400/500 aircraft since 02.10.2012 r. The certificate was issued by CAA of Republic of Turkey and is valid till 16.01.2019.

2.6. Aircraft Information

2.6.1. Airworthiness information

B737-400 aircraft, serial number 25112, registration marks TC-TLC has been produced in year 1994, manufacturer USA, and there is Certificate of Airworthiness No 2115, issued on 17.04.2014 r. by CAA of Republic of Turkey. Airworthiness review certificate of the aircraft has been issued on 27.03.2017 and is valid till 30.03.2018.

The aircraft has flown 63 976 flight hours and 34 009 cycles since new. A Certificate of Release to Service (SRS) by CAMO with an approval number TR.145.031 for execution of CHECK A49-2018. The execution of the inspection was also reflected in the technical logbook of the aircraft with sequential number 010862.

A DAILY CHECK of the aircraft was performed before the flight, in which the occurrence was realized. No failures and deficiencies were established during the inspection.

The said documents on board of the aircraft are related with the aircraft airworthiness before the flight.

2.6.2. Short information on aircraft technical characteristics

B737-400, serial number 25112, registration marks TC-TLC, is a twin-engine short- to medium range airliner designed for passenger and cargo transportation. The aircraft is a metal structure, a low-wing monoplane with tail panels, a semi-monocogue body and tricycle landing gear.

Two power units are located on pylons under and in front of the wing. The overall composition of the airplane can be seen in pictures, Enclosure 1, Fig. from 1 to 8.

The maximum take-off mass of the airplane is 65090 kg. Empty mass of the aircraft is 35 355 kg.

At take-off from Antalya Airport according to the load and trim sheet, the take-off mass of the airplane was 56 203 kg and balance was within the permissible limits.

The maximum permitted landing mass is 54 884 kg.

The air conditioning system of the aircraft provides the required clean air for the cockpit, passenger compartment, electronic equipment compartment, front and rear luggage compartments. Air supply to the air conditioning system is supplied by the pneumatic system.

The air conditioning system, Part 21, in accordance with the unified classification system might be considered as consisting of four subsystems for: distribution, pressurization control, cooling and temperature control. The change of the cabin pressurized altitude, a basic feature for the serious incident under investigation, is related to the operation of the pressure control system. It provides in the pressurized compartments of the aircraft up to altitude of 28000 ft maximum overpressure of $7,45 \pm 0,1$ psi and at altitudes over 28000 ft maximum overpressure of $7,8 \pm 0,1$ psi. On the Fig. 11 of Enclosure 1 a layout of the pressurization control system components is shown.

The pressurization control system includes pressurization control, pressurization relief valves and pressurization indicating and warning. The Pressurization Control System of B737-400 aircraft, serial number 25112, is with an analogue controller. Cabin pressure is controlled by positioning a cabin pressurization outflow valve to meter cabin exhaust. The valve operates electrically from three control systems. The control systems are auto, standby and manual. AUTO mode provides automatic pressure control of cabin altitude and rate of altitude change based on settings preliminary made to the pressurization control panel of flight and the elevation of the destination airport. Standby mode provides semi-automatic control of cabin altitude and rate of altitude change based on settings of the pressurization control panel of cabin altitude and rate selected. Manual mode provides control of cabin altitude and rate of altitude change by the selection of manual operated three-position switch, supplied with AC or DC. Normal control is from the auto system with the standby system acting as a backup. The manual system functions as an override over the auto and standby systems.

Pressurization relief valves include two safety relief valves, which prevent over-pressurizing the airplane, and a vacuum relief valve. In addition to the relief valves, pressure equalization valves are installed in both cargo compartments to provide a quick method of allowing cargo compartment pressure to vary, within limits, with cabin pressure.

Indicators are provided to allow monitoring cabin altitude, differential pressure, and rate of pressure change. A cabin altitude warning system sounds a horn if cabin altitude exceeds approximately 10,000 feet.

Oxygen Systems, Part 35, according to the Unified Classification System, feed oxygen with low pressure crew and passengers. Two separate oxygen systems include: oxygen system for the crew and oxygen system for passengers. There is also an emergency oxygen system consisting of portable oxygen bottles. Oxygen system for the crew is supplied with oxygen by a high pressure oxygen bottle, which is transformed into a low pressure before being supplied to the crew. The low pressure oxygen is supplied by oxygen masks.

The passenger oxygen system automatically supplies oxygen masks to passengers and cabin crew when the cabin pressure falls below altitude values equivalent to 14000 ft. The oxygen is supplied from chemical oxygen generators after the oxygen mask is pulled down by the user. The masks can also be lowered by a switch located on the front upper panel in the cockpit. On the pictures on Fig. 9 and 10 of Enclosure 1 the lowered mask may be seen in the passenger cabin and in the galley.

In Quick Reference Handbook of B737-400 aircraft for cases, when one or more of following events occur:

- Exceeded cabin altitude;
- Periodic signal of a horn sounds or a cabin altitude lamp illuminates in flight.

The aircraft crew shall act in the following order:

- „1. Don oxygen masks and set regulators to 100%.
2. Establish crew communications.
3. Pressurization mode selector MAN AC
4. Outflow Valve switch Hold in CLOSE until the outflow VALVE
Indication shows fully closed
5. If cabin altitude is uncontrollable:
 - Passenger signs.....ON
 - PASS OXYGEN switch.....ON
 - Go to the Emergency Descent check list

Emergency Descent

1. Announce the emergency descent. The pilot flying will advise the cabin crew, on the PA system, of impending rapid descent. The pilot monitoring will advise ATC and obtain the area altimeter setting.
 2. Passenger signsON
 3. Without delay, descend to the lowest safe altitude or 10,000 feet, whichever is higher.
 4. ENGINE START switches (both) CONT
 5. Thrust levers (both)Reduce thrust to minimum or as needed for anti-ice
 6. Speed brake.FLIGHT DETENT
 7. Set target speed to Mmo/Vmo.
 8. When approaching the level off altitude:
Smoothly lower the SPEED BRAKE lever to the DOWN detent and level off. Add thrust and stabilize on altitude and airspeed.
 9. Crew oxygen regulatorsNormal
- Flight crew must use oxygen when cabin altitude is above 10000 ft. To conserve oxygen, move the regulator to Normal.
10. ENGINE START switches (both).....As need
 11. The new course of action is based on weather, oxygen, fuel remaining and available airports. Use of long range cruise may be needed.“

2.6.3. Information on the fuel used

According the technical logbook record No 010866, completed before the flight, in which the air occurrence was realized, the aircraft was refuelled with 29 200 lb (13 245kg) of aviation kerosene JET A1.

The fuel quantity and its condition are not relevant to the occurrence realized.

2.7. Meteorological Information

Bulgaria is located on the periphery of a large anticyclone. At Sofia Airport and in the airspace of the region, located at 80 nm northwest of Sofia Airport, between 08:00 and 12:00 UTC on March 11, 2018, there were no meteorological phenomena dangerous to aviation.

For Sofia airport from 08:00 to 12:00 UTC on 11.03.2018 the wind was weak 2-3 kt, non-oriented, visibility over 10 km, no clouds and phenomena. The meteorological information for

the airport is enclosed to the investigation material.

For the area located at 80 nm northwest of Sofia Airport, the wind at FL 320 was northwest (300 degrees) at a speed of 60 kt, there were no clouds and dangerous phenomena.

2.8. Navigation

Standard aids to navigation of the aircraft.

2.9. Communications

Standard communication equipment of the aircraft.

2.10. Aerodrome information

The reference point of Sofia Airport (RWY centre) is with the following coordinates: N 42°41'42" и E 023°24'30". Elevation 531m. The RWY directions are 091° and 271° (designated as 09/27), 3600m and 45m wide. The landing distance available (LDA) for RWY 27 is 3600m.

2.11. Flight data recorders

B737-400 aircraft, TC-TLC registration marks, took-off from Antalya at 08:34 (UTC). At 08:50 ALT=32 000 ft was reached, and the airplane continues the flight at this level. There were no deviations in system operation and piloting during take-off and climbing.

At 09:44:05 in heading of 295° and speed CAS=278 kt A/P switched from "VNAV Path" mode to "VNAV Speed" mode. At the same time A/T switched on N1 mode and started climb from FL=320. At 09:45:00 at ALT=32768 ft and CAS=276 kt A/P changed to "Vertical Speed", A/T to "MCP Speed".

At 09:45:57 at ALT=33696 ft and CAS=268 kt appearance of "Cabin altitude above 10000 ft" signal was registered. At 09:46:19 at ALT= 34000 ft. A/P switched sequentially through "Altitude acquire" mode for 5 seconds and "Altitude hold" mode for 8 seconds. At 9:46:32, A/P was switched to "Flight level change" и "MCP Speed". A second later Cabin Altitude Above 10000 ft signal disappeared, and the total duration of the signal was 36 seconds.

At 09:46:42 A/P was switched to "Vertical Speed" and the aircraft started to descend. The A/P and A/T modes are listed in the table below during descend to 8500 ft and when they were switched (time, altitude, speed).

Time	ALT (ft)	CAS (kt)	Hdg (deg)	A/P Modes								A/T Mod		Cabin altitude above 10000ft
				LNAV Engage	Heading Select	ALT Acquire	ALT Hold	Flight Level Change	MCP Speed	Vertical speed	CWS Pitch	MCP Speed	Retard	
09.46.42	33984	266	294	x						x		x		
09.47.14	32768	270	294	x				x	x				x	
09.47.28	31860	279	294	x				x	x					
09.48.58	24140	335	293	x							x	x		
09.49.26	22808	322	293	x				x	x				x	
09.49.38	22200	320	293	x				x	x					
09.50.33	17384	336	293	x							x	x		
09.51.26	14700	318	292	x				x	x				x	
09.51.31	14440	319	292	x				x	x					
09.52.25	12484	295	292		x			x	x					
09.53.51	11044	240	261		x	x						x		
09.53.57	10988	236	261		x		x					x		
09.54.53	10996	223	258		x		x					x		x
09.54.59	11004	221	248		x			x	x					x
09.56.33	8660	224	215		x	x						x		x
09.56.43	8508	224	215		x		x					x		x

During descend from FL 340 to ALT=8500ft the maximum reached speed was CAS=337kt, and the maximum vertical speed was $V_y=6000\text{ft/min}$. between FL300 and FL240.

At 09:54:53 at ALT=10996 ft, the "Cabin Altitude Above 10000ft" signal appears again, remaining for 9 minutes and 4 seconds until 10:03:56, when the aircraft reached ALT=5956 ft at a heading of 262° and the flaps were extended to 5 units.

At 10:04:25 the landing heading of 270° at ALT=5400ft was taken. At 10:06:50 the aircraft was in landing configuration with extended landing gear and flaps at 30 units at ALT=3000 ft.

The aircraft landed at 10:08:34 AM on RWY27 at a speed CAS=140 and g-load of $N_y=1.25g$. The aircraft mass at touch-down was GW=51311 kg.

2.12. Wreckage and Impact Information

The landing approach at Sofia Airport was with normally functioning systems, including:

- control systems;
- power unit;
- electrical system;
- hydraulic systems;
- landing gear retract and extend systems and

mass of 51529 kg, less than maximum allowable landing mass of 54884 kg.

The landing was realized without any problem. After the landing the aircraft was stopped at a stand and the passengers leaved it by normal exits without use of emergency means. There were no damages to the aircraft.

2.13. Medical and Pathological Information

There is no consequences for the passengers and crew resulting from the occurrence the event, and therefore medical and pathological researches wasn't performed.

There is no information that any physiological factors or loss of capacity have influenced the pilots' capacity for work.

2.14. Fire

No fire initiated during the occurrence.

2.15. Survival Aspects

When FL 337 was reached, the horn for dangerous cabin altitude was switched on and the "CABIN ALT" light was on. The crew immediately put oxygen masks, selected the "MAN AC" mode on the cabin pressure control selector and, by means of the switch, tried to put the outflow valve in the closed position. The attempt to close the outflow valve through the selected MAN AC mode switch didn't made the desired effect and the crew decided to perform emergency descending. Oxygen masks in the passenger cabin were released. The aircraft descended rapidly to FL 200 when it reached a speed of 337 KIAS, where the airplane's pressurization system started to react, although it still remained outside of normal parameters. The aircraft reached FL 130 and was on ILS approach for RWY27 at Sofia Airport. The crew decided to land at Sofia Airport.

2.16. Tests and Research

For the purposes of the safety investigation the following was done:

1. Inspection of B737-400 aircraft, serial number 25112, and registration marks TC-TLC, after the forced landing at Sofia Airport.
2. Interview with the aircraft crew realized the occurrence;
3. Interview with officials of ATC and airport operator related with the occurrence;
4. Investigation and analysis of operational documentation of the AC;
5. Evaluation of the flight and operational performance of the AC;
6. Decoding and analysing a QAR card memory of the aircraft;

7. Examination of the status of the cabin pressure control system by TAILWIND AIRLINES air operator technical staff.

8. Logical-probabilistic analysis of possible causes of air occurrence.

For Item 1, the results of the on-site inspection of the aircraft are given in Para2.3 and Para2.12.

For Item 2 the results of the interview and written explanation of the crew are given in Para2.1.2. Para2.5 and Para2.15.

For Item 3 the results of the interview with officials of ATC and airport operator related with the occurrence, are given in Para2.1.1, 2.1.3, 2.7 and 2.10.

For Item 4, the results of the study and analysis of the operational documentation of the aircraft are reflected in Para 2.6.1 and 2.6.3.

For Item 5 the results of evaluation of the aircraft flight and operational performance, related to the air occurrence realized are given in Para 2.6.2.

For the Item 7, after a ferry flight of the aircraft to the base airport in the Republic of Turkey, a number of works were carried out in order to establish the reason for raising the cabin altitude above the allowances that led to the need for oxygen masks to be used by the crew and passengers, termination of the flight along the route and emergency descending and landing at Sofia Airport.

As a result of the work carried out, represented in the technical logbooks of the aircraft with numbers 010866, 010867, 010868 and 010871, attached to the investigation materials, it was established:

The controller of the pressurization system functions normally;

The outflow valve for alteration of the output of the outgoing valve (airflow) was faulty;

The heating of the exhaust valve seal for changing the air flow out of the cabin was faulty;

The right-hand safety relief valve was stuck in the open position.

No mechanical damages to the outflow valve were detected. The faults were electrical, connected to the operation of AC and DC electric motors, driving the valve.

There are small physical damages on the outflow valve, but it was found that the heating of the seal didn't work.

The jamming of the safety relief valve in open position connects the interior of the cabin space with the atmosphere and makes it non-hermetic. According to the air operator's information, in accordance with the airplane maintenance program, a functional check of the safety valves was carried out at the last C-check in February 2018.

After sharing the above-mentioned information on the deficiencies found in the service performed on B737-400 aircraft, serial number 25112, TC-TLC, registration marks after its transfer to the Republic of Turkey, the AO shares the following opinion with the investigating Commission in relation with the aviation occurrence, expressed in e-mail of March 30, 2018:

"In line with our investigation, during the flight the first thing faulted was the seal heater, and after that the outflow valve was ice-covered in half-open position (not fully closed). The jammed outflow valve couldn't operate in any mode (automatic, backup and manual). Then, due to overloading of the outflow valve motors, they also failed. Thus the overpressure in the airplane has increased and the safety relief valves were activated automatically. Due to the high discharge pressure, one of the safety relief valves (right-hand one) fails and didn't return to closed position."

Logical and probabilistic analysis of the possible causes of the serious air occurrence has been made in Chapter 3 of this Report.

2.17. Additional information

According In accordance with Para5.1.2 of Annex 13 to the International Civil Aviation Convention, the State of Event shall conduct an investigation on the circumstances of a serious incident when the maximum take-off mass is over 2 250 kg. This requirement raises some difficulties in conducting the investigation. These difficulties arise from the fact that the aircraft with which the event occurred, mainly due to financial considerations related to its recovery, leaves the country of realization of the occurrence. (In case of serious incidents usually there are

no damage to the aircraft, or the damages are of such nature, which allow making a ferry flight). The place of stationing of an aircraft usually is the base airport in the air operator's country. The aircraft crew also leaves the country of realization of the occurrence. The crew also is from the country of air operator. The aircraft technical documentation is stored by the air operator.

These circumstances do not allow the investigation commission to conduct a second inspection of the aircraft after the commission has been already aware of the circumstances of the occurrence. It is difficult to make repeated interview with the crew in order to clarify the circumstances of the occurrence. Most often, this is done using the phone or e-mail, in which the live connection lacks. It is difficult to use information related to the technical condition of the aircraft and resulting from the aircraft maintenance, especially information about the implementation of the aircraft maintenance program. It is difficult to make recommendations for improvement of safety immediately after the event, due to complicated procedural practices between authorities of more than one country.

In view of the above, the Commission for investigation of the serious incident expresses an opinion, that the investigation of serious air incidents with a take-off mass over 2 250 kg should be assigned to the State of the air operator as more rational.

3. Analysis

It is clear from the above that the serious incident was associated with depressurization of pressurized compartments (increasing of cabin altitude) of the B737-400 aircraft, serial number 25112, TC-TLC registration marks. This depressurization resulted in the necessity of usage of oxygen masks, extreme descent to altitudes, at which the passengers and crew will not experience oxygen starvation and termination of a flight associated with a forced landing at the nearest appropriate airport.

In this case, the increase in cabin altitude above the permissible values was accompanied by audible alert that warned the crew to take immediate measures for elimination of the occurring conditions that pose a safety hazard to the flight, including endangering the lives of passengers and crew. Immediate actions to be taken by the crew are set out in procedures described in the airplane QRH. These procedures in their sequence are described in Para2.6.2. The crew consistently followed these procedures. The crew made an unsuccessful attempt to manually adjust the position of the flap of outflow valve, then activated the oxygen masks and undertook extreme descending to an altitude, which do not endanger the lives of passengers and crew. This process can be traced by the decrypted data of the flight parameters, described in Para2.11. Under this circumstances the crew decided to land at the nearest appropriate airport - Sofia Airport.

The foregoing is related to crew actions to counter the consequences of in-flight situation, which have threatened the safety of flight. As a result of these actions, the flight was terminated by a normal landing at Sofia Airport, with no consequences for the passengers, the crew and the airplane.

Logically, the question arises as to why this situation was threatening the safety of the flight. Its occurrence is related to the disturbance of the difference between the external and the internal pressure maintained in the cabin of the airplane and which is controlled by a pressurization control system. A brief description of this system is made in Para2.6.2 of this report, and in Fig. 11 of Enclosure 1 shows a layout diagram of the components of the system. A study of this system, performed by the AO in order to restore the aircraft airworthiness, reflected in paragraph 2.16 of this report, revealed three failures of components of this system:

- faulty heating of the outflow valve seal;
- the outflow valve flap for changing the exhaust air output from the cabin doesn't function (cannot change its position); It was found that this failure was due to the failure of the two electric motors for driving the flap of the valve, one of them on AC and another one on DC;
- The right-hand safety relief valve was stuck in open position. The jamming of the safety relief valve in open position connects the interior of the cabin space with the atmosphere and makes it non-hermetic.

Given that in accordance with the requirements of the standards, an aircraft should not be fitted with components with failure rate is greater than 10^{-3} and that the electric drive of the flap is reserved by duplication, in the heaviest case the frequency of simultaneous occurrence of the said failures should be 10^{-12} s⁻¹. Such an event in terms of the general theory of reliability is practically unauthentic.

If the events themselves occur consecutively, and each of them is preceded and is a prerequisite for the occurrence of the next one, the probability of realization of the event, leading to increasing the cabin altitude above the allowable values can be measured with the probability of occurrence of the first of a group of interrelated events.

Paragraph 2.16 quotes Air Operator's opinion, expressed in an e-mail received by the Commission for investigation on March 30, 2018, about the possible cause of the event being realized:

"In line with our investigation, during the flight the first thing faulted was the seal heater, and after that the outflow valve was ice-covered in half-open position (not fully closed). The jammed outflow valve could not operate in any mode (automatic, backup and manual). Then, due to overloading of the exhaust valve motors, they also failed. Thus the overpressure in the airplane has increased and the safety relief valves were activated automatically. Due to the high discharge pressure, one of the safety valves (right-hand one) fails and didn't return to closed position."

The Commission has accepted this opinion as probable, assuming that the cause of the serious incident was the failure of the heating first and the subsequent ice-coverage of the outflow valve. The weather conditions during this period of the year, when the occurrence was realized, has been related with increased humidity, favouring the realization of the event.

The cause of the jamming of the safety valve may also be related to the quality of its maintenance, but the Commission has no evidences of any breaches in this respect.

4. Conclusion

4.1. Findings

As a result of the investigation, the Commission concluded:

1. B737-400 aircraft, serial number 25112, registration marks TC-TLC, was manufactured in year 1994, manufacturer USA.
2. The aircraft has a Certificate of Airworthiness No 2115, issued on 17.04.2014 by the CAA of the Republic of Turkey.
3. Airworthiness review certificate of the aircraft has been issued on 27.03.2017 and is valid till 30.03.2018.
4. The aircraft has flown 63 976 flight hours and 34 009 cycles since new.
5. A DAILY check of the aircraft was performed before the flight, in which the occurrence was realized. No failures and deficiencies were established during the inspection.
6. The maximum take-off mass of the airplane is 65090 kg. Empty mass of the aircraft is 35 355 kg.
7. At take-off from Antalya Airport according to the load and trim sheet, the take-off mass of the airplane was 56 203 kg and balance was within the permissible limits.
8. The Pressurization Control System of B737-400 aircraft, serial number 25112, is with an analogue controller.
9. When FL 337 was reached, the horn for dangerous cabin altitude was activated and the "CABIN ALT" light was on.
10. The crew performed the sequence of actions provided in the Quick Reference Handbook of B737-400 aircraft for cases when cabin altitude was exceeded.
11. The attempt to close the outflow valve by selection of MAN AC mode switch didn't made the desired effect and the crew decided to perform emergency descending.
12. Oxygen masks in the passenger cabin were released.

13. The aircraft descended rapidly to FL 200 when it reached a speed of 337 KIAS, where the airplane's pressurization system started to react, although it still remained outside of normal parameters.

14. The crew decided to land at Sofia Airport.

15. The approach and landing at Sofia Airport were normal with a landing mass of 51 311 kg, at a maximum permitted landing mass of 54 884 kg and a residual fuel at landing of 7 992 kg.

16. After the landing the aircraft was stopped at a stand and the passengers leaved it by normal exits without use of emergency means.

17. There is no information that any physiological factors or losses of capacity have influenced the pilots' capacity for work.

18. During the occurrence no dangerous meteorological phenomena have been observed that could affect the flight.

19. An inspection of the cabin pressure control system performed by CAMO of AO has revealed a failure of the outflow valve, failure of the outflow valve gasket heating, and jamming of the right-hand safety relief valve in open position.

20. A functional check of the safety valves was carried out during the last "C" check in February 2018.

4.2. Causes

Based on the analysis performed, the Commission points out that the serious incident resulted based on the circumstances set out in this report and their analysis, the Commission pointed out as a reason for realization of the serious incident:

Failure of the heater of the outflow valve seal and possibly icing of the valve during the flight due to its inability to move. The right safety relief valve remains in open position after its activation.

5. Safety Recommendations

Taking into account the causes of the serious incident and the deficiencies found during the investigation, the Commission recommends the following safety measures to be implemented:

BG.SIA-2018/02/01. Having in mind the potentially high threat related to the consequences of an event similar to the one under investigation, the safety investigation commission recommends that the aviation operator to make a review B737-300/400/500 aircraft maintenance programs operated by this air operator, in the part relating to the service of the cabin pressurization control system and, if necessary, to increase the frequency of the outflow valve gasket heating and safety relief valves checks.

BG.SIA-2018/02/02. The outflow valve of the pressurization control system of B737-400 aircraft, serial 25112, TC-TLC registration marks, shall be sent to a service workshop for dismantling and flaw detection in order to identify the reasons for disturbance of its normal operation.

BG.SIA-2018/02/03. The right-hand safety relief valve of the pressurization control system of B737-400 aircraft, serial 25112, TC-TLC registration marks, shall be sent to a service workshop for dismantling and flaw detection in order to identify the reason for its jamming in open position.

BG.SIA-2018/02/04. The Safety Investigation Commission recommends the Executive Body of ICAO to reconsider the content of Para5.1.2 of Annex 13 to the International Civil Aviation Convention, according to which the investigation of the circumstances of a serious incident when the maximum take-off the mass of the aircraft is over 2250 kg, to be assigned to the State of the Air Operator instead of the State of occurrence, which controls a major part of the information for aircraft and operating personnel.

On the grounds of Art.18, § 5 of Regulation 996/2010, the safety measures instructed shall be recorded in the centralized European System of Safety Measures.

Follows: Enclosure 1, which is an integral part of this Report.

The Investigation Commission reminds all organizations to which safety measures have been sent, that on the basis of Article 18 of Regulation 996/2010 on Investigation and Prevention of Accidents and Incidents in Civil Aviation and Art19, Para7 of Ordinance No. 13 for investigation of aviation accidents, that are obliged to notify in writing the Directorate AMRAIUD of MTITC for the actions taken on the recommendations made.

20 August 2018

BULGARIAN AIRCRAFT ACCIDENT INVESTIGATION UNIT

ENCLOSURE 1



Fig.1.

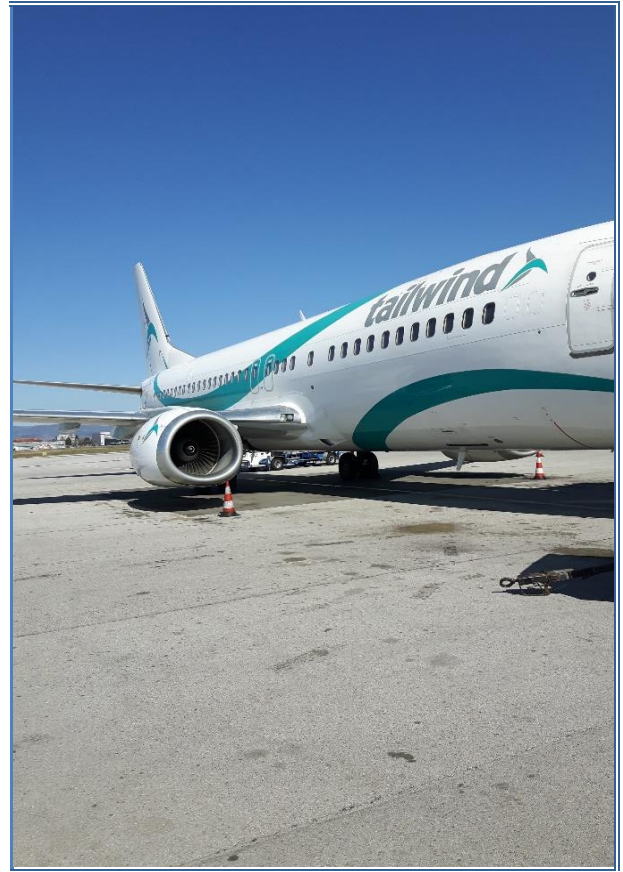


Fig. 2.



Fig.3.



Fig. 4.



Fig.5.

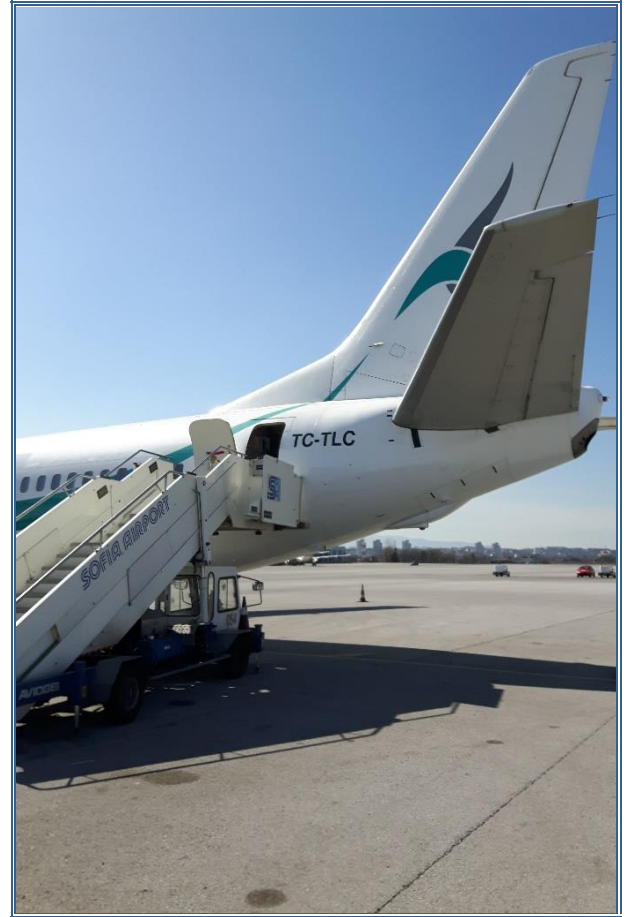


Fig. 6.



Fig.7.



Fig. 8.



Fig. 9.



Fig. 10.

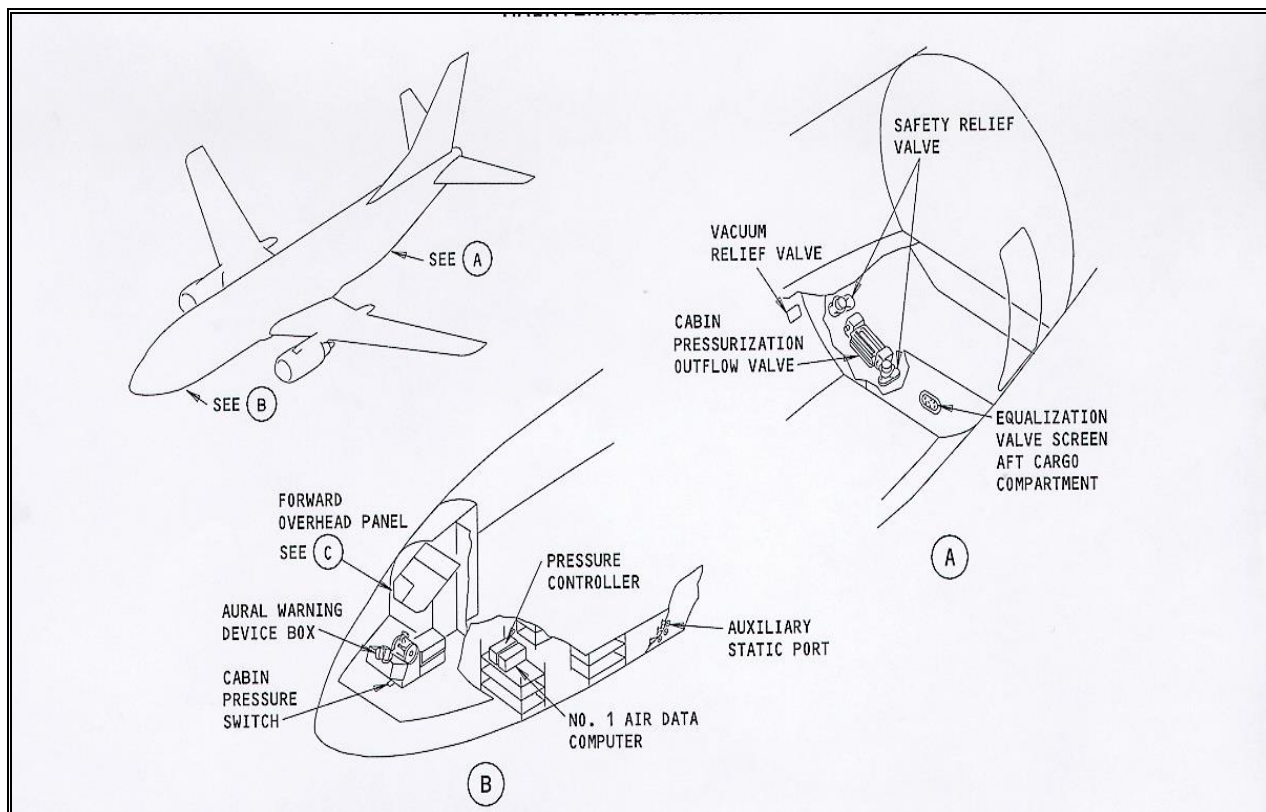


Fig. 11.

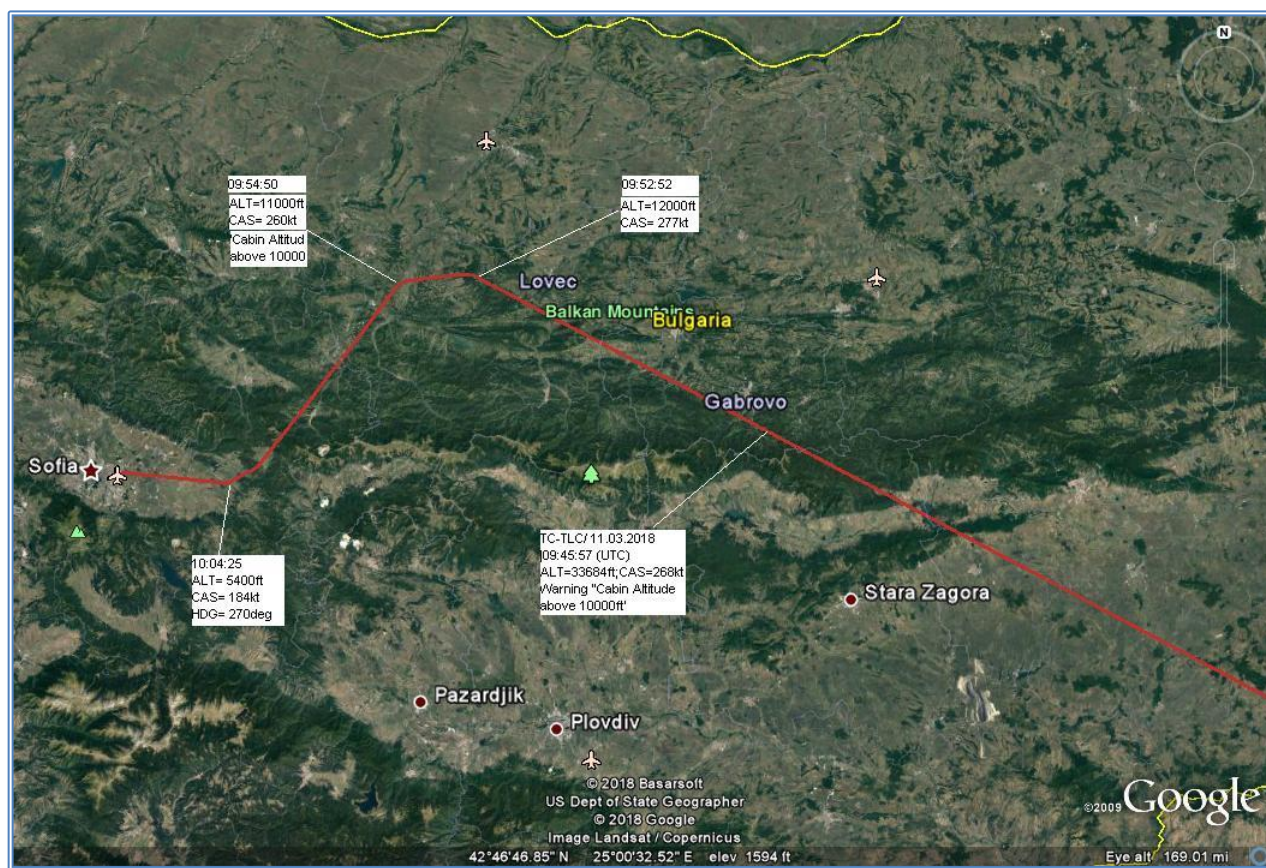


Fig. 12.

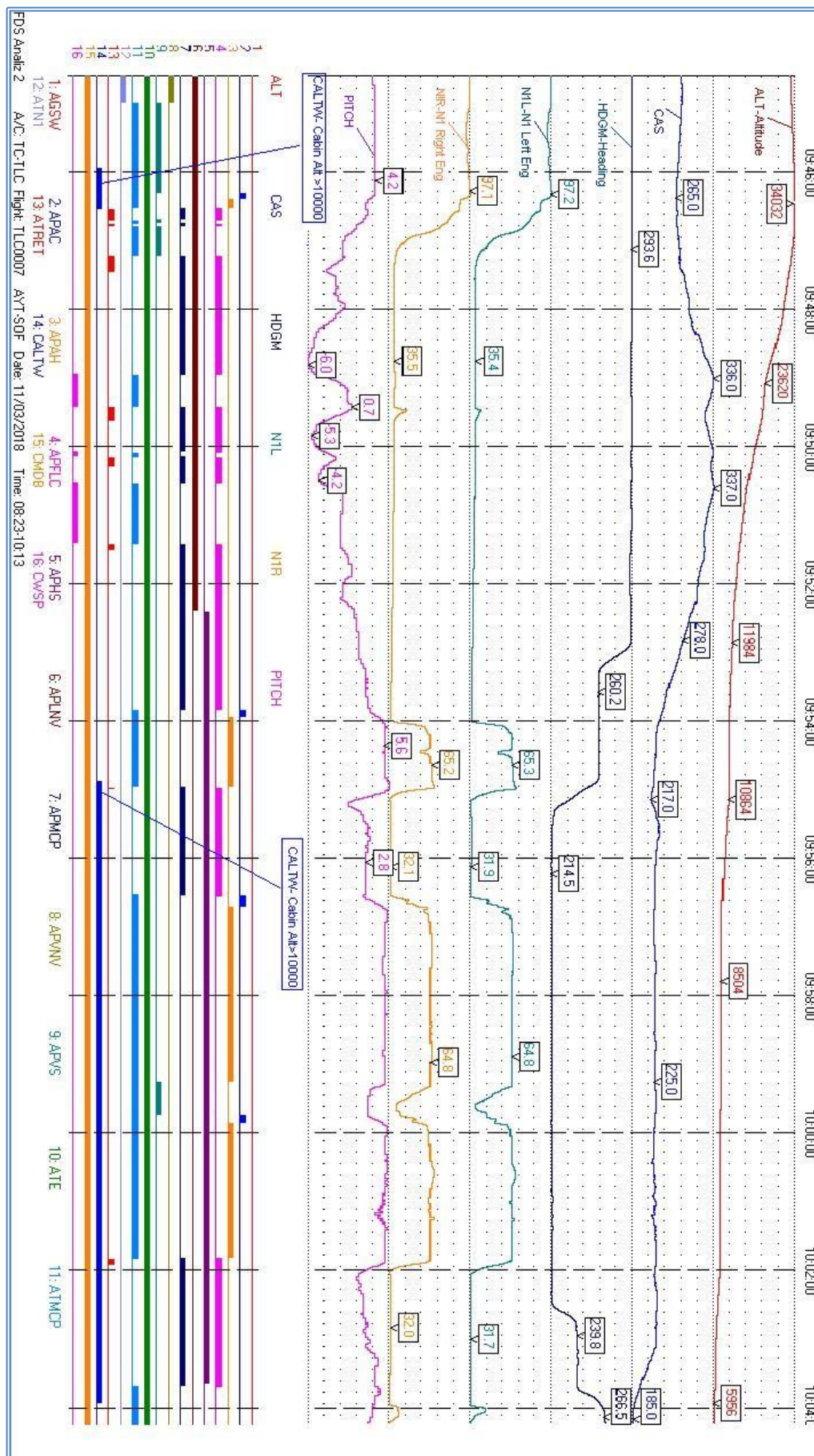


Fig. 13.