This document is an English translation of the Final Report on the accident involving the Boeing 737-8KN aircraft registered A6-FDN that occurred on March 19, 2016 (00:42 UTC) at Rostov-on-Don aerodrome, the Rostov Region, Russian Federation.
The translation was done as accurate as a translation may be to facilitate the understanding of the Final Report for non-Russian speaking people. The use of this translation for any purpose other than for the prevention of future accidents could lead to erroneous interpretations.
In case of any inconsistence or misunderstanding, the original text in Russian shall be used as the work of reference.

INTERSTATE AVIATION COMMITTEE

AIR ACCIDENT INVESTIGATION COMMISSION

FINAL REPORT

Type of occurrence	Fatal accident
Type of aircraft	Boeing 737-8KN, airplane
Nationality and registration marks	A6-FDN
Owner	Celestial Aviation Trading 38 Limited, Shannon, County Clare, Ireland
Operator	Dubai Aviation Corporation, P.O. Box: 353, United Arab Emirates
Aviation authority of the place of occurrence	Southern FATA Interregional Territorial Department
Place of occurrence	Russian Federation, the Rostov region, the Rostov-on-Don aerodrome, reference position: 47º15′54.7″ N, 039°49′43.8″ E
Date and time	19.03.2016, 03:42 local time (00:42 UTC), nighttime

In accordance with the ICAO Standards and Recommended Practices this report is issued with the sole objective to prevent the air accidents.
It is not the purpose of this report to apportion blame or liability.
Criminal aspects of the accident are tackled within separate criminal case.

ABBREVIATIONS

A/P	–	autopilot
A/T	–	autothrottle
AAIC	–	Air Accident Investigation Commission
AAIS	–	Air Accident Investigation Sector
AAISTSC	–	Air Accident Investigation Scientific-Technical Support Commission
ABOT	–	aircraft blocked-off time
ACCREP	–	Accredited Representative
ADF	–	automatic direction finder
ADS-B	–	automatic dependent surveillance – broadcast
AFDS	–	autopilot flight director system
AFM	–	aircraft flight manual
AIII	–	HGS Approach III mode (CAT III approach mode or status)
AIP	–	Aeronautical Information Publication
AMS	–	Aerospace Material Standards
AOA	–	angle of attack
APU	–	auxiliary power unit
AR	–	Aviation Regulations
ASTM	–	American Society of Testing Materials
ATC	–	air traffic control
ATIS	–	automatic terminal information service
ATM	–	air traffic management
ATP	–	Acceptance Test Procedure
ATPL	–	airline transport pilot's license
ATS	–	air traffic services
AV	–	automatic voice
BEA	–	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile / Bureau of Investigation and Analysis for Civil Aviation Safety (France)
C/A	–	cabin attendant
CA	–	civil aviation
CAT	–	category

CDS	–	Common Display System
CIAIAC	–	Comisión de Investigación de Accidentes e Incidentes de Aviación Civil / Civil Aviation Accident and Incident Investigation Commission (Spain)
CIS	–	Commonwealth of Independent States
CMM	–	component maintenance manual
COSPAS-SARSAT	–	satellite-based search and rescue distress alert detection and information distribution system
CPL	–	commercial pilot licence
CPT	–	captain
CT	–	computer tomography
CVR	–	cockpit voice recorder
DC	–	direct current
DH	–	decision height
DME	–	distance measurement equipment
DNA	–	deoxyribonucleic acid
DVOR	–	Doppler very high frequency omnidirectional range
E	–	eastern longitude
EASA	–	European Aviation Safety Agency
EGPWS	–	enhanced ground proximity warning system
ELT	–	emergency locator transmitter
EMERCOM	–	Ministry of the Russian Federation for Affairs for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters
F/O	–	first officer
FAA	–	Federal Aviation Administration of United States of America
FAR	–	Federal Aviation Regulations
FAR-362	–	Federal Aviation Regulations “Procedure for Radio Communication in the airspace of Russian Federation”
FATA	–	Federal Air Transport Agency
FCC	–	flight control computer
FCOM	–	Flight Crew Operating Manual
FCT 737 NG (TM)	–	Boeing 737 aircraft Flight Crew Training Manual
FCTM	–	Flight Crew Training Manual

FD	–	flight dispatcher of the airline
FDP	–	flight duration period
FDR	–	flight data recorder
FFS	–	full flight simulator
Fig.	–	figure
FIR	–	flight information region
FL	–	flight level
FMC	–	flight management computer
FMS	–	flight management system
FPM	–	flight plan manager
FR	–	frame
FSBI	–	federal state budgetary institution
FSI	–	federal state institution
FSUAE	–	Federal State Unitary Aviation Enterprise
FSUE	–	federal state unitary enterprise
ft	–	feet
FTOA	–	Federal Transport Oversight Agency
FWD	–	forward
G, g	–	gravity
G/A	–	go-around
G/S	–	glideslope
GCAA	–	General Civil Aviation Authority
GL	–	ground level
GPS	–	Global Positioning System
H24	–	twenty-four hour operation
HF	–	high-frequency
HGS	–	Head-Up Guidance System
hPa	–	hectopascal
HQC	–	High Qualification Commission
hrs	–	hours
HUD	–	head-up display
IA	–	initial approach
IAC	–	Interstate Aviation Committee

IAS	–	indicated airspeed
ICAO	–	International Civil Aviation Organization
IDG	–	integrated drive generator
IFR	–	instrument flight rules
ILS	–	instrument landing system
IMB	–	inner marker beacon
IMC	–	instrument meteorological conditions approach – HGS mode of operation
kg	–	kilogram
KRAMS-4	–	Integrated Aerodrome Radiotechnical Weather Station
kt	–	knots
kVA	–	kilovolt-ampere
lb	–	pound
LH	–	left-hand
LIM	–	locator at the inner marker
LLC	–	limited liability company
LOC	–	localizer
LOM	–	locator at the outer marker
LPC	–	line proficiency check
LVOPS	–	low visibility operations
MAC	–	mean aerodynamic chord
MAP	–	missed approach
MCP	–	Mode Control Panel
MEL	–	Minimum Equipment List
METAR	–	METeorological Aerodrome Report
MHz	–	megahertz
min	–	minutes
MRO	–	maintenance, repair and overhaul
MSN	–	manufacturer serial number
MTOW	–	maximum takeoff weight
N	–	northern latitude
ND	–	navigation display
NDB	–	non-directional beacon

nm	–	nautical mile
NTSB	–	National Transportation Safety Board
NVM	–	non-volatile memory
OEI	–	one engine inoperative
OM	–	Operations Manual
OMB	–	outer marker beacon
OMDB	–	Dubai International Airport ICAO code
OPC	–	operator proficiency check
P.O.	–	post office
p/n	–	part number
PAPI	–	precision approach path indicator
PCU	–	power control unit
PF	–	pilot flying
PFD	–	primary flight display
PIC	–	pilot-in-command
PJSC	–	public joint stock company
PM	–	pilot monitoring
PRI	–	HGS primary mode of operation
PWA	–	printed wiring assembly
PWS	–	Predictive Windshear
QFE	–	atmospheric pressure at runway threshold
QNH	–	atmospheric pressure adjusted to mean sea level
QRH	–	Quick Reference Handbook
R/T	–	radiotelephony
RAMC	–	Rostov-on-Don air meteorological center
RF	–	Russian Federation
RH	–	right-hand
RNP	–	Required Navigation Performance
Roshydromet	–	Federal Service of Russia for Hydrometeorology and Monitoring of the Environment
RQC	–	regional qualification commission
RVR	–	runway visual range
RWY	–	runway

s/n	–	serial number
SAR	–	search and rescue
SatCom	–	Satellite Communications
SB	–	service bulletin
SIGMET	–	Significant Meteorological Information
SOP	–	standard operating procedures
SSFDR	–	solid state flight data recorder
STAR	–	standard instrument arrival
STC	–	Supplementary Type Certificate
STD	–	scheduled time of departure or synthetic training device (by context)
TAF	–	terminal aerodrome forecast
TAS	–	true airspeed
TBO	–	time between overhauls
TCAS	–	traffic collision avoidance system
TO/GA	–	takeoff/go-around
TOW	–	takeoff weight
TQC	–	territorial qualification commission
TSN	–	time since new
TWY	–	taxiway
UAE	–	United Arab Emirates
UATMS	–	unified air traffic management system
URRR	–	Rostov-on-Don Airport ICAO code
USA	–	United States of America
UTC	–	coordinated universal time
Vfe	–	maximum flap extended speed
VMC	–	visual meteorological conditions
VNAV	–	vertical navigation
Vref	–	landing reference speed
vs	–	versus
WS WRNG	–	windshear warning

General Information

On March 19, 2016 at 00:42 UTC[1], at nighttime, in the progress of the go-around maneuver after the missed approach to the RWY 22 of the Rostov-on-Don international airport the fatal accident occurred to the Boeing 737-8KN A6-FDN aircraft (further on referred to as B737-8KN), operated by the Dubai Aviation Corporation airline (further on referred to under the Flydubai trading name (UAE) , having performed the international scheduled passenger flight FDB 981 on route Dubai (OMDB/DXB) – Rostov-on-Don (URRR/RVI).

There were 62 people on board (2 flight crewmembers, 5 cabin crewmembers and 55 passengers), having been the citizens of India, Spain, Cyprus, Colombia, Kyrgyzstan, Russia, Seychelles, Ukraine and Uzbekistan.

The IAC AAIC was notified of the air accident at 01:22 on 19.03.2016.

To investigate the occurrence the investigation team was assigned by the IAC AAIC Chairman Order No 9/765-p of 19.03.2016.

In compliance with ICAO Annex 13, the notifications on the air accident were forwarded to NTSB (USA) representing the aircraft State of Design and State of Manufacture, to BEA (France) representing the State of Design of the engines, to AAIS (UAE) representing the State of Registry and the State of the Operator, as well as to the air accident investigation authorities of the states of the killed occupants' citizenship. USA, France and UAE have appointed the ACCREPs to the investigation.

[1] Hereinafter, unless otherwise stated, UTC is indicated, the local time is UTC + 3 hrs

The representatives-experts of NTSB, FAA, the Boeing Company, being the aircraft manufacturer, AAIS, the Flydubai airline, FATA, the Federal Transport Oversight Agency, the Federal Service for Hydrometeorology and Environmental Monitoring of Russia, the State Air Traffic Management Corporation, the Rostov-on-Don International Airport, LLC, the Rodina scientific plant, the Gromov Flight Research Institute, as well as the command and junior flight crew and instructor personnel of several Russian airlines assisted to the investigation.

To transcript and translate the segment of communications, recorded by CVR, that had been conducted in Spanish, the investigation team addressed to CIAIAC. CIAIAC has appointed the ACCREP and granted the necessary assistance.

The investigation was opened on March 19, 2016.

The investigation was closed on November 25, 2019.

In order to render assistance to the affected persons and to the bereaved families, as well as for the assistance to the post-accident damage control and recovery the Government Commission, chaired by Minister of Transport of the Russian Federation, has been assigned by the Chairman of the Government of the Russian Federation Order No 459-p of 19.03.2016.

The pretrial criminal investigation had been conducted by the Russian Federation Investigative Committee General Directorate for Major Investigations.

1. Factual information

1.1. History of flight

At the overnight into 19.03.2016 the Flydubai airline flight crew, consisting of the PIC and F/O, was performing the round-trip international scheduled passenger flight FDB 981/982 on route Dubai (OMDB) – Rostov-on-Don (URRR) – Dubai (OMDB) on the B737-8KN A6-FDN aircraft.

At 18:37 on 18.03.2016 the aircraft took off from the Dubai airport. The flight had been performed in IFR.

At 18:59:30 FL360 was reached. The further flight has been performed on this very FL.

The descent from FL has been initiated at 22:17. Before starting the descent, the crew contacted the ATC on the Rostov-on-Don airport actual weather and the active RWY data.

In progress of the glide path descent to perform landing with magnetic heading 218° (RWY22) the crew relayed the presence of “windshear” on final to the ATC (as per the aboard windshear warning system activation). At 22:42:05 from the altitude of 1080 ft (330 m) above runway level performed go-around.

Further on the flight was proceeded at the holding area, first on FL080, then on FL150.

At 00:23 on 19.03.2016, the crew requested descent for another approach.

It was an ILS approach. The A/P was disengaged by the crew at the altitude of 2165 ft QNH (575 m QFE), and the A/T at the altitude of 1960 ft QNH (510 m QFE). .

In the progress of another approach the crew made the decision to initiate go-around and at 00:40:50, from the altitude of 830 ft (253 m) above the runway level, started the maneuver.

After the reach of the altitude of 3350 ft (1020 m) above the runway level the aircraft transitioned to a steep descent and at 00:41:49 impacted the ground (it collided the surface of the artificial runway at the distance of about 120 m off the RWY22 threshold) with the nose-down pitch of about 50º and IAS about 340 kt (630 km/h).

1.2. Injuries to Persons

Injuries to persons	Crew	Passengers	Others
Fatal	7	55	0
Serious	0	0	0
Minor/None	0/0	0/0	0/0

1.3. Damage to Aircraft

The condition of the aircraft systems and engines

Fuselage

The fuselage of the airplane is disintegrated in many fragmentary elements, of which the largest ones are:

- the fragment of the upper section of the fuselage (from FR 460 to FR 500D) with the GPS antennas;
- the fragment of the RH fuselage section (from FR 927 to FR 986.5) (the area adjacent to the aft RH service door) and the aft RH service door itself;
- FWD cabin door;
- the fragment of the LH fuselage section (from FR 578 to FR 610) with the fragment of the overwing emergency exit;
- the fragment of the skin (from FR 500F to FR 540) with the LH window openings;
- the upper fuselage section (from FR 694 to FR 727A) with the ADF antennas;
- the fragment of the pressure bulkhead.

The windshield of the cockpit and passenger cabin is totally destroyed.

The aircraft flight controls and the equipment, located inside the cockpit are almost completely destroyed (Fig. 1).

Fig. 1. The elements of the cockpit and the nose landing gear leg

The partly survived F/O control column part with the elements of the control wheel was discovered having been considerably deformed (Fig. 2). The control wheel elements integrated the partly destroyed trim switch.

Fig. 2. The element of the F/O control column

The elements of the elevator, ailerons and rudder control systems, mounted in the cockpit underfloor compartment, are presented on Fig. 3.

Fig. 3. The elements of the elevator, ailerons and rudder control systems, mounted in the cockpit underfloor compartment

Wing

The wing is disintegrated (Fig. 4, Fig. 5).

The LH and RH wingtips (winglets) with the fragments of the lower wing panels, the single unit tracks, along which the flaps travel, the fragments of the LH outboard and inboard flaps, the fragments of the skin of the RH wing panel lower section survived.

The wing to fuselage attachment fittings are destroyed.

Fig. 4. The fragments of the RH wing panel

Fig. 5. The fragments of the LH wing panel

Wing high-lift devices (flight control surfaces)

As the result of the aircraft impact with ground, the slats had been totally destroyed, in the progress of the layout only the smaller fragments of the flaps were retrieved. The transmission of the flaps, laid along the aft wing spar, is destroyed. All the eight jackscrews and eight single unit tracks of the flaps retraction/extension mechanism had been discovered (Fig. 6). The elements in question are mechanically damaged, the screw parts are destroyed and deformed.

Fig. 6. Jackscrews and single unit tracks

It has not been possible to identify the position of the wing control surfaces as of the moment of the aircraft impact with ground.[2]

Horizontal and vertical stabilizer (Fig. 7)

The vertical stabilizer, disintegrated in several parts, separated from the fuselage at the area of attachment. The composite rudder is completely destroyed as the result of the impact with ground. The skin and the frame of the vertical stabilizer are considerably damaged. There are no signs of fire and soot on the vertical stabilizer. The horizontal stabilizer had been destroyed and separated from the vertical stabilizer structure.

[2] As per the FDR data, at the moment of aircraft impact with ground the flap handle was at 15^0 position, flaps - at 10^0 position due to activation of automatic load relief function, the slats were in the intermediate position.

Fig. 7. The vertical and horizontal stabilizer elements (1 – LH half of the stabilizer, 2 - RH half of the stabilizer, 3- the vertical stabilizer elements)

Landing gear

The nose landing gear is destroyed (Fig. 8). The retraction/extension actuator with the elements of the hinge fittings is separated from the rod. The torsion link is totally destroyed, the nose landing gear steering actuator cylinders are separated from the standard attachment points. The nose landing gear wheels attachment pivot and the wheels' disks are totally destroyed.

Fig. 8. Nose landing gear

The right and left main landing gear legs (Fig. 9 and Fig. 10) are considerably damaged. The landing gear legs are separated from the fuselage attachment beams. The torsion links of the shock struts are destroyed. The retraction/extension actuators are separated off the legs main structure. The disks of the brakes are broken off. The brakes hubs are considerably damaged. The hubs of the wheels are separated off the tires.

Fig. 9. The elements of the right main landing gear leg

Fig. 10. The elements of the left main landing gear leg

Control System

Pitch control system (elevator and stabilizer)

In the progress of the post-accident inspection of the aircraft wreckage there were retrieved the PIC and the F/O control columns fragments, the right and the left elevator PCUs, the fractured stabilizer jackscrew with the cable drum and the elevator PCUs output shaft.

The cable control linkage is totally defragmented subsequent to the aircraft impact with ground and is impossible to identify.

The fragments of the elevator control system (the input rods, the PCUs and the elevator autopilot electrohydraulic actuator) (Fig. 11) are significantly damaged as the structure had disintegrated at the aircraft impact with ground.

Fig. 11. The elevator control system output shaft (pointed with arrow)

The left elevator PCU is separated off the output shaft and partially broken, the right PCU rests at its standard attachment point.

The elevator control kinematics can be seen deformed as the result of the structure disintegration after the aircraft impact with ground.

In the progress of the accident site inspection, the majority of the stabilizer trim actuator gearbox had been retrieved. The aft cable drum had been separated from its connection point on the stab trim actuator. The drive mechanism had been damaged and deformed.

The fragment of the crossbeam with the stab trim mechanism ball nut had been discovered as well. The crossbeam was disintegrated at the points of its attachment to fuselage as the result of the off-design loads application. The jackscrew with the attachment fitting to stabilizer (Fig. 12) had been discovered apart of the stabilizer being disintegrated due to the off-design loads.

Fig. 12. The recovered elements of the stab trim actuator

Roll control system

The cable linkage, passing in the fuselage, was disintegrated into separate smaller fragments at the aircraft impact with ground and is impossible to identify. The cable linkage, laid along the LH and RH half-wing aft spar, survived with the signs of the off-design mechanical loads application and the fire.

The LH and RH ailerons are almost completely destroyed.

The spoilers control system is totally destroyed. As for the system elements, there were retrieved several actuators and the control surfaces, whose position as of the moment of the accident is impossible to identify.

The directional channel of the control system

The pilots' rudder pedals are completely disintegrated. The cable control linkage, passing in the fuselage is broken off and is impossible to identify. The main control actuator is torn off its standard mounting because of the vertical stabilizer disintegration.

Hydraulic system

The hydraulic pumps of the main hydraulic systems A and B as well as the pumps of the auxiliary hydraulic system are totally disintegrated, so are the hydraulic reservoirs and accumulators. In the progress of the aircraft structure layout, only the smaller fragments of the hydraulic lines had been retrieved.

The aircraft fuel system

The integral fuel tanks, the elements of the aircraft fuel system, the assemblies and pipes are totally disintegrated and burnt out in a ground fire, the seat of which had been located at the area of the fuel tanks.

The air conditioning and pressurization system

The assemblies of the air conditioning system are completely destroyed. At the inspection of the accident site, only the recirculation system deformed fan had been retrieved.

The pressurization control assemblies are totally disintegrated as well. In the progress of the accident site inspection only the outflow valve out of this system had been discovered (Fig. 13).

Fig. 13. The air conditioning system outflow valve

Water supply system and catering equipment

The water supply system assemblies are completely destroyed.

The cabin dividers and the overhead bins had been lost. The passenger seats are disintegrated into the smaller fragments amounting to the passenger seats units' bases and frames. The seatbelts are impossible to identify. The galleys equipment is completely destroyed as well.

APU

The APU is disintegrated (Fig. 14). The inspection of the APU gas generator plumbing and wiring assemblies did not reveal the ducting and control elements uncoupling.

Fig. 14. The APU fragment with the exhaust duct and the fuselage tailcone

Engines

The left and the right engines are totally destroyed (Fig. 15, Fig. 16).

Fig. 15. The left engine fragments

Fig. 16. The right engine fragments

In the progress of the accident site inspection there were retrieved the fragments of the left and the right engines: the compressor cases with the elements of the compressor control system and the engines rotor front support, the disks of the of the engines fan stages.

Avionics

At the on-site examination of the fragments of the airframe, cockpit, passenger cabins and service bays it has been stated that subsequent to the aircraft impact with ground and the further ground fire the avionics is significantly damaged or totally destroyed.

Autopilot

The avionics units, integrated to the autopilot, are completely destroyed and impossible to identify.

The two out of four autopilot actuators had been discovered.

Radio communication equipment

The radio communication units are completely destroyed and are impossible to identify. There were retrieved the fragments of the HF radio set switching unit (p/n 822 0990 004, s/n 1871X9) (Fig. 17).

Fig. 17. The HF radio set switching unit fragments

Electrical power supply system

The electrical power supply system integrates two alternators, located on the aircraft engines - the IDG1 and IDG2 integrated drive generators, having a capacity of up to 90 kVA, the APU starter-generator with the capacity of up to 90 kVA. The direct current secondary electrical supply system consists of three transformer-rectifier units. The electrical battery is operated as the direct current emergency power supplies. The generators and electrical battery are completely destroyed subsequent to the impact. There was discovered the rotor of one of the generators (Fig. 18).

Fig. 18. The generator rotor

Several integral units to the electrical system were recovered:

– the standby power control unit (SPCU) (Fig. 19);

Fig. 19. The standby power control unit

– the transformer-rectifier unit (TRU) (Fig. 20);

Fig. 20. The transformer-rectifier unit

– the bus power control units (BPCU) (Fig. 21, Fig. 22).

Fig. 21. The bus power control unit No 1

Fig. 22. The bus power control unit No 2

All the units sustained considerable damage.

At the site of the aircraft impact with ground the debris of the aircraft electrical supply were retrieved along the impact heading (Fig. 23). The aircraft electrical supply is totally destroyed, there were no signs revealed of the short circuit, might have been evident in the electrical wiring isolation melt.

Fig. 23. The debris of the aircraft electrical supply

Fire protection system

The fire protection system comprises two cylinders of the engines bays, one APU bay fire extinguishing cylinder and three control handles in the cockpit.

The fire protection system components had not been discovered due to their total destruction in the accident sequence.

Flight management system

The part of the FCC case was retrieved. The circuit boards were not discovered.

The stab trim motor, p/n 6355C0001-01, s/n 2062had been retrieved (Fig. 24).

Fig. 24. The stab trim motor elements

The oxygen supply equipment

The flight crew main stationary oxygen cylinder had been retrieved (its mounting location is in the electronics and avionics bay). Based on the nature of its destruction it can be concluded that the cylinder had been destructed in the impact sequence (Fig. 25).

Fig. 25. Main stationary oxygen cylinder

Navigation equipment

The navigation assemblies and units, revealed at the accident scene, are totally disintegrated.

The fragments of the fuselage skin with the GPS and TCAS antennas had been discovered (Fig. 26).

Fig. 26. The GPS and TCAS antennas

On the accident site there were retrieved as well:

– the EGPWS unit (Fig. 27);

Fig. 27. The EGPWS unit

– the TCAS computer, p/n 940 0300 001, s/n TPA03476 (Fig. 28);

Fig. 28. The TCAS computer

– the standby altimeter (Fig. 29).

Fig. 29. The standby altimeter

All the units have the signs of the physical damage on them.

1.4. Other damage

As the result of the accident 332.5 m² of the RWY concrete surface at the area of its left edge, at about 150 – 200 m off the RWY 22 threshold, sustained damage. Besides the aerodrome lighting between TWYs D and C was damaged, five LH edge lights and two RH edge lights, namely, as well as two axial low-voltage cables together with four edge lights axial low-voltage cables.

1.5. Personnel information

1.5.1. Flight crew information

Position	**Pilot-in-command**
Sex	Male
Date of birth	August 05, 1978
Pilot's license (ATPL)	No 51549
License date of issue	November 7, 2012
Issued by	General Civil Aviation Authority (GCAA) of the United Arab Emirates
License expiry date	Valid till January 25, 2023
Medical report	I class medical certificate No 51549, issued on September 30, 2015, valid till October 14, 2016
Low visibility qualification	ICAO CAT IIIA
Total flying time as a pilot	5965 hrs
Transition training for Boeing 737-800	October 27, 2012
Flying time on the Boeing 737-300-900 aircraft/of which as a PIC	4682 hrs/1056 hrs
Flying time within a year (2015)	843 hrs
Flying time within 28 days	78 hrs 36 min
Flying time within 14 days	45 hrs 37 min
Flying time within 2 days	8 hrs
Flying time within last 24 hours (on the day of the accident)	06 hrs 05 min
Duty time as of the moment of the accident	07 hrs 57 min
The intervals in flights within the last year	The PIC's leave periods within 2015: March 19-25/19.03-25.03 – 7 days; April 9-15/09.04-15.04 – 7 days; June 25 – July 1/25.06-01.07 – 7 days; July 30 – August 12/30.07-12.08 – 14 days; October 8-14/08.10-14.10 – 7 days. 42 days in total in compliance with OM
The date of the last line check	December 18, 2015

Simulator training and check	January 7, 2016
Preflight preparation	Self-preparation before departure at the Dubai airport
The crew rest	15 hrs at home
English language proficiency	ICAO level 6
Air accidents and incidents in the past	None

Based on the data, submitted by the Flydubai airline, before April 2004 the PIC had been performing flights on the aircraft under 5700 kg. There are no data available on these aircraft types.

Further on he underwent the Boeing 737-300/400/500 aircraft transition training and was employed by the Helios Airways airline (Cyprus) where he was working as the first officer from April 23, 2004 until November 29, 2006.

From December 23, 2006 until September 12, 2008, he was working as the Boeing 737-300/400/500 first officer in the XL Airways (Great Britain).

From February 12, 2011 until September 12, 2012 the PIC was working as the Boeing 737-300/400/500 in the Malaysian Airlines System airline (Kuala Lumpur, Malaysia).

On September 30, 2012, he was employed by the Flydubai airline as the first officer.

Through October 14-27, 2012, he has completed the Boeing 737-800 aircraft transition training in the Emirates - CAE Flight Training air training center (Dubai, United Arab Emirates) and was issued a certificate No EK-CAE/DXB/148.

In January 2015, he underwent the Boeing 737-800 command upgrade training.

Position	**First officer**
Sex	Male
Date of birth	March 23, 1979
Pilot's license (ATPL)	No 66543
License date of issue	October 21, 2014
Issued by	General Civil Aviation Authority (GCAA) of the United Arab Emirates
License date of expiry	October 20, 2022
Medical report	I class medical certificate No 66543, issued on August 31, 2015, valid till September 14, 2016
Low visibility qualification	ICAO CAT IIIA
Total flying time as a pilot	5767 hrs
Flying time/ of which as a PIC	Cessna- 421, ATR-42/72, A-320 – 4667 hrs/258 hrs

Boeing 737-800 aircraft transition training	October 20, 2014
Flying time on the Boeing-737-800 aircraft type	1100 hrs
Flying time within a year (2015)	784 hrs
Flying time within 28 days	80 hrs 47 min
Flying time within 14 days	55 hrs 47 min
Flying time within 2 days	6 hrs 21 min
Flying time within the last 24 hours (at the day of the accident)	6 hrs 05 min
Duty time as of the moment of the accident	7 hrs 57 min
The intervals in flights within the last year	The F/O's leave periods within 2015: February 26 – March 4/26.02-04.03 – 7 days; May 21-27/21.05-27.05 – 7 days; September 17 - October 07 – 21 days; November 20-26/20.11-26.11 – 7 days. 42 days in total in compliance with OM January 01-07, 2016/01.01.-07.01.2016 – 7 days
The date of last line check	October 20, 2015
The simulator training and check	September 7, 2015
Preflight preparation	As per briefing system under the authority of the PIC
The crew rest	20 hrs at home
English language proficiency	ICAO level 5
Air accidents and incidents in the past	None

Based on the data submitted by the Flydubai airline and by Spanish Aviation Safety and Security Agency (Agencia Estatal de Seguridad Aérea – AESA) the first officer on May 29, 2000, after graduating from SENASA, Services and Studies for Air Navigation and Aeronautical Safety air training center, was issued a CPL with the authorization to operate single- and multi-engine land airplanes in IFR.

From June 1, 2005 till September 30, 2005 he was working as a Cessna-421 aircraft PIC at the Regional Geodata regional carrier (Spain).

From May 31, 2006 till March 10, 2008 he was employed as the ATR-42/72 aircraft first officer at the Islas Airways airline (Spain).

From February 25, 2009 till April 17, 2014 he was working as the ATR-42/72 aircraft first officer, PIC, A320[3]aircraft first officer.

On March 25, 2009, he was issued an ATPL.

On May 8, 2012, he was authorized to operate ATR-42/72 aircraft as a PIC.

On August 24, 2014, he was employed by the Flydubai airline as a Boeing 737-800 first officer.

From September 7, 2014 till October 20, 2014 he completed the Boeing 737-800 aircraft transition training at the Emirates - CAE Flight Training air training center (Dubai, United Arab Emirates) and was issued a certificate No EK-CAE/DXB/B-077.

On February 26, 2015, he was authorized to operate the Boeing 737-300/900 aircraft.

The analysis of the submitted documents

According to the airline OM the duty cycle shall not exceed:

over 28 consecutive days – 100 hrs of flight time and 190 hrs of duty time.

The minimum rest between flying duty periods at the base aerodrome shall be not less than twelve hours.

The actual data on the flight crew flight time and duty time as well as the rest time are given in the below table.

PIC	F/O
Flying time over last 28 days: 78 hrs	Flying time over last 28 days: 80 hrs
Duty time over last 28 days: 136 hrs	Duty time over last 28 days: 139 hrs
The preflight rest: 15 hrs	The preflight rest: 20 hrs

As per their health status, the crew were approved for flight operations, had a sufficient rest period, held the valid pilot's licenses and underwent all the necessary procedures to operate solo (without the mandatory presence of the flight instructor) flights.

As per the submitted documents, the Flydubai airline the flight crews training is carried out at the certified simulators in compliance with the Program, drawn up with the FCOM as a core document that determines the standard operating procedures.

The go-around performance SOP are specified in FCOM, volume 1 (NP.21.54) with the additional instructions in the Flydubai Procedures and Policies manual (Section 12 Go-Around and Missed Approach and Appendix F (Standard Callouts)). These two documents are in use together with the FCTM guidelines. Furthermore, the Upset Recovery Training Aid, second edition of November 2008, having been relevant as of the date of the accident, integrates the additional recommendations on the go-around performance.

[3] On May 10, 2013, he completed the A320 transition training at the Baltic Aviation Academy air training center.

The go-around procedure in the initial training

Once the pilots are employed by the airline, they undergo the initial training and a Conversion course (for type-rated pilots) or a full Type Rating course (for non-type-rated pilots).

The syllabuses for both courses include go-arounds flown both with two engines operative and with one engine inoperative.

Competency demonstration for all pilots occurs at the License Skill Test (the UAE pilot's license).

Go-around in the progress of the HUD training

All the aircraft in the airline fleet are equipped with the HGS (Head-Up Display Guidance System) Model 4000 system that integrates HUD[4] as a display unit. According to the airline SOP (Annex D, Section D.1.2) the use of HUD, if it is operative, is mandatory throughout the entire flight.

HUD is a supplementary cockpit onboard avionics unit, designed by Rockwell-Collins (currently Collins). Rockwell-Collins had certified the equipment in question and was issued the Supplementary Type Certificate/STC ST00845SE, which, for the Boeing 737-800 aircraft, involves the installation of the only HUD at the PIC's duty station. This Certificate does not provide for the dual installation (including the F/O duty station)[5]. The HGS was installed on the aircraft by the Boeing Company on request of Flydubai prior to its delivery.

Before starting line operations at Flydubai all pilots undergo a Head Up Display (HUD) training dedicated simulator session that includes:

- two go-arounds with two engines operative;
- two go-arounds with one engine inoperative.

Pilots will fly the maneuver twice, one time as Pilot Flying (PF) and repeat as Pilot Monitoring (PM), the go-arounds start at different distances from the runway (from the different altitude) as recorded in relevant training form.

Irrespective of the fact that all the Flydubai aircraft have the HUD fitted only on the left side (the PIC side) all pilots, including first officers, go through the HUD training simulator session.

The PIC underwent the training and simulator session on October 27, 2012.

The First Officer underwent the training and simulator session on October 18, 2014.

There were no comments stated by the instructor staff on the pilots' simulator session go-through.

[4] Hereinafter both terms are referred to as synonyms.
[5] Currently, as for the HUD Model 6000 (STC ST02522SE) and for the Boeing 737NG and MAX, the option is certified of its installation on both flight crew's duty stations.

Go-around during low visibility operations initial training and check

During the Initial LVOPS training simulator session the flight crew members perform go-around maneuvers both with two engines operative and one engine inoperative.

The altitude at which the maneuver starts varies along the training, ranging from around 1000 feet/300 meters to DH.

Current Low Visibility Initial Simulator Training program includes go-around training as follows.

Go-arounds with two engines operative (12 go-arounds in total):

- 7 go-arounds due different systems failure occurring between 1000 feet and the appropriate minima/ DH;
- 1 go-around due insufficient RVR;
- 1 go-around due windshear;
- 1 go-around due excessive deviation from the G/S;
- 1 go-around due HGS/HUD failure with reversion for conventional instruments (PFD);
- 1 go-around due pilot incapacitation.

Go-arounds with one engine operative (2 go-arounds in total):

- 1 go-around due insufficient RVR;
- 1 go-around due system failures.

Go-around during recurrent training and operator and license proficiency checks (OPCs/LPCs)

Within the recurrent training and OPC/LPC (carried out twice a year in compliance with the OM D1), the pilots underwent the go-around training that included:

- 1 go-around with one engine inoperative from minimum altitude;
- 1 go-around on RNP approach with failure requiring go-around (two or one engine operative);
- 1 go-around from low visibility approach due engine failure, incapacitation or system failure (two engines or one engine operative).

As of the moment of the accident, in the Flydubai airline there were no simulator sessions carried out on go-around from different altitudes with low aircraft weight.

Windshear during initial training

Similar to the go-around training, windshear is included in both Conversion courses and Type Rating courses and all pilots joining Flydubai will undergo one or the other course.

Before starting line operations at Flydubai, all pilots undergo ground training course which includes theoretical training on:

- windshear avoidance and recovery;

– windshear avoidance and recovery from predictive and actual windshear using the HUD.

On completion of the ground training, the pilots undergo the windshear HUD training session that implies the training both for PF and PM.

Windshear during low visibility operations initial training and check

Low Visibility Initial Simulator Training program includes windshear. Captains are trained using the HUD and first officers use conventional head-down instruments (PFD).

Windshear during recurrent training

Windshear training is present in the Recurrent Airplane/STD Training Schedule B737-800 (OM D1 Appendix 9.A). This accounts for the inclusion of windshear training in the Recurrent Training program at least twice in a 3-year cycle during recurrent training, done every six months.

The training is based on FCOM, QRH and FCTM guidance for windshear avoidance, precautions and recovery.

In the low visibility recurrent checking program (every six months), at least one go-around (two engines) is conducted due to either insufficient RVR or windshear.

The PIC underwent the windshear training on July 6, 2015.

The first officer underwent the windshear training on September 7, 2015.

Manual stabilizer trim operation

Malfunctions requiring manual operation of the stabilizer trim are trained in both conversion course and full type rating course pilots go through before starting line operations in the Flydubai airline.

The recurrent training on the flight controls and trim system failures is specified in the respective section in the Flydubai's Recurrent Airplane/STD Training Schedule B737-800 (OM D1 Appendix 9.A).

The upset recovery training

Similar to the training on the operations at the windshear within the Conversion and the Type Rating training, all the pilots employed by the Flydubai airline, before they start performing flights, undergo the four-day ground training that includes the theoretical course in upset avoidance and recovery.

On completion of the ground training the pilots undergo the HUD/HGS simulator session that involves the flight training both for pilot flying and for pilot monitoring.

The upset recovery training is integrated in the Boeing 737-8KN flight crew members recurrent training (OM D1 Appendix 9.A) and is conducted triply within a three-year cycle, divided into 6 six-month sessions.

The training is based on the FCOM , QRH and FCTM guidance on the upset recovery.

The aircraft's PIC underwent the upset recovery training on January 7, 2016.

The first officer underwent the upset recovery training on September 6, 2015.

The PIC and the first officer underwent the FFS recurrent training at regular intervals in compliance with the airline OM.

PIC's recurrent training and checks

Date	Training type	Comments[6]
July 5-6, 2015	Recurrent training and proficiency check	1. First attempt flown within limits but became un-stabilized around 500FT. G/A carried out followed by debriefing and repetition to an acceptable standard. 2. Speed was below limits for the existing flaps, the PIC failed to recognize the dual GPS failure. Approach was discontinued later as per ATC instruction. Repetition to satisfactory standard. 3. Remember the proper call out to set the go around thrust as per FCOM I and QRH. 4. Windshear at takeoff. TOGA not pressed at first alert, and not pressed again after 400ft while VNAV used during takeoff. Briefed and repeated.
January 6-7, 2016	Recurrent training and proficiency check	Simulator instructor comments: 1. For both Normal and Non Normal checklists brief the approach before calling for the Descent checklist. 2. Arrival procedure – If cleared direct to a beacon as part of an arrival (IA) be sure to have it identified. 3. On the first attempt /name/ did not sufficiently arrest his descent rate when visual, thereby generating an APCH WARN (approach warning) and hard landing. The second maneuver was to training standards.

[6] Only the comments, related to the circumstances of the accident, are stated

F/O recurrent training and checks

Date	Training type	Comments
March 17-18, 2015	Recurrent training and proficiency check	1. Leadership and teamwork Needs to be quite a bit more assertive in what is needed from the Captain. Tell him/her what you want done and do not wait for the Captain to enquire with you or direct you in this regard. Need to be more decisive in taking actions when needed. 2. Go-around maneuver Use caution on directional control during OEI MAP. Be aware that the TOGA mode shows wings level information and is not linked to runway heading or track. 3. Always check the approach RNP when setting up/briefing
September 6-7, 2015	Recurrent training and proficiency check	1. High altitude stall Must maintain pitch altitude better during recovery, secondary stick shaker occurring. 2. Approach Did not descend until late turning base and stopped turn causing aircraft to fly through centerline. Did not recover in time but flew approach to landing. Debriefed and flown to a high standard. 3. Go-around No call for G/A thrust. Debriefed

1.5.2. Ground service personnel information

Position	The Rostov-on-Don aerodrome air operations supervisor
Sex	Male
Date of birth	April 15, 1976
Education	Higher, Ulyanovsk Higher School for Civil Aviation in 1998

Class	I class. The RF Ministry of Transport FTOA CA HQC work team protocol No 8 of 24.06.2005
Duty authorization	Authorized for duty as an air operations supervisor – the FATA Southern department RQC protocol No 3 of 11.04.2011
Duty assignment	The State ATM Corporation South Air Navigation branch general manager order No 19/ок of 04.02.2014.
ICAO language proficiency	ICAO level 4 – certificate РНД No 1219.7619, valid till 28.01.2017
Qualification and English language advanced training	At the Saint-Petersburg State University for CA air training center (the city of Saint-Petersburg) as per the program «The qualification and English language advanced training for the ATC air operations supervisors», 27.12.2014
Medical certificate validity	Till 16.10.2016
License, date of issue	СД No 019275, issued on 21.12.1998 by Federal Aviation Service of Russia
License validity	Till 05.11.2016
Competence check	Air operations supervisor – 16.02.2016
Simulator training	04.03.2016 – radar control unit 05.03.2016 – approach control unit
Total in-service time	16 years
Total in-service time as an air operations supervisor	2 years

Position	**Control tower chief officer (at the day of the accident functioned as the radar control unit officer)**
Sex	Male
Date of birth	November 5, 1966
Education	Secondary professional, Riga flight-technical college for CA in 1989
Class	I class. The RQC protocol No 5 of 12.03.1997

Duty authorization	Authorized for duty as a chief controller – The RQC protocol No 104 of 06.12.2009
Duty assignment	The State ATM Corporation South Air Navigation branch general manager order No 427/ок of 19.04.2010
ICAO language proficiency	ICAO level 4 – certificate РНД No 516.4966, valid till 21.11.2016
Qualification and English language advanced training	At the Institute for air navigation south branch (the city of Rostov-on-Don): – as per the program «The ATC officers training (for chief controllers, instructor controllers, simulator instructor-controllers)», on 27.03.2015; – the aviation English language (R/T phraseology for the ATC personnel, authorized for the international air operations support in the English language), on 14.04.2015
Medical certificate validity	Till 26.10.2017
License, date of issue	СД No 011309, issued on 20.03.1998 by Federal Aviation Service of Russia
License validity	Till 24.07.2017
Competence check	Chief controller – on 21.02.2016
Simulator training	Approach control unit – on 28.02.2016, Radar control unit – on 05.03.2016
Total ATC in-service time	26 years
Total in-service time as a chief controller	5 years 11 months

Position	**Aerodrome control center officer (at the day of the accident functioned as an approach control unit officer, further on referred as APPR-1)**
Sex	Female
Date of birth	July 19, 1975
Education	Higher, Rostov-on-Don State University in 2006, Saint-Petersburg air transport college in 2012

Class	III class. FATA HQC ATC personnel qualification subcommission Decision of 30.10.2013
Duty authorization	Approach control unit – on 05.11.2013 Radar control unit – on 28.02.2016
ICAO language proficiency	ICAO Level 4 – certificate СПБ No 1324.18026, valid till 21.06.2016
Qualification and English language advanced training	At the Institute for air navigation south branch (the city of Rostov-on-Don): – as per the program «ATC personnel training (for the ATM controllers)», on 29.05.2015; – the aviation English language (R/T phraseology for the ATC personnel, authorized for the international air operations support in the English language), on 17.06.2015
Medical certificate validity	Till 07.07.2019
License, date of issue	СД No 016828, issued on 30.10.2013 by Federal Aviation Service of Russia
License validity	Till 07.07.2017
Competence check	Approach control unit – on 13.10.2015
Simulator training	Approach control unit – on 27.02.2016
Total ATC in-service time	2 years 4 months

The assessment of the language proficiency level of the approach control unit officer is given in Section 1.16.6.

Position	**Aerodrome control center officer (at the day of the accident functioned as the radar control unit officer, further on referred as RDR-1)**
Sex	Male
Date of birth	September 1, 1985
Education	Higher, Saint-Petersburg Academy for CA in 2008
Class	II class. Southern FATA interregional territorial department RQC protocol No 17 of 20.02.2013
Duty authorization	Radar control unit – on 12.11.2015

ICAO language proficiency	ICAO Level 4 – certificate РНД No 217.2017, valid till 14.10.2016
Qualification and English language advanced training	At the Institute for air navigation south branch (the city of Rostov-on-Don): – as per the program «ATC personnel training (for the ATM controllers)», on 13.02.2015; – the aviation English language (R/T phraseology for the ATC personnel, authorized for the international air operations support in the English language), on 03.03.2015
Medical certificate validity	Till 20.08.2016
License, date of issue	СД No 013736, issued on 10.12.2009 by Federal Aviation Service of Russia
License validity	Till 21.10.2017
Competence check	Radar control unit – on 06.11.2015
Simulator training	Radar control unit – on 16.02.2016
Total ATC in-service time	6 years 3 months

Position	**Aerodrome control center officer (at the day of the accident functioned as the approach control unit, the radar control unit officer)**
Sex	Male
Date of birth	September 15, 1987
Education	Higher, Saint-Petersburg State University for CA in 2010
Class	II class. Southern FATA interregional territorial department TQC protocol No 114 of 05.12.2013
Duty authorization	Approach control unit – on 15.03.2011; radar control unit – on 24.01.2013 tower control unit – on 12.10.2015; ground control unit – on 14.01.2016
ICAO language proficiency	ICAO level 4 – certificate issued by MLS International College (the city of Bournemouth, Great Britain), valid till 30.10.2018

Qualification and English language advanced training	At the Institute for air navigation south branch (the city of Rostov-on-Don): – as per the program «The air operations support in the English language (for the ATM controllers)», on 08.10.2013; – the aviation English language (R/T phraseology for the State ATM Corporation, FSUE, ATC personnel that underwent training at MLS International College (the city of Bournemouth, Great Britain), on 06.11.2015
Medical certificate validity	Till 02.07.2019
License, date of issue	СД No 007395, issued on 11.03.2011 by Federal Aviation Service of Russia
License validity	Till 17.11.2017
Competence check	Approach control unit – on 04.06.2015, radar control unit – no data available
Simulator training	Radar control unit – on 10.03.2016; approach control unit – on 11.03.2016
Total ATC in-service time	5 years 4 months

Position	**The aerodrome control center officer (at the day of the accident functioned as the tower control unit officer, further on referred as TWR-1)**
Sex	Male
Date of birth	September 18, 1986
Education	Higher, Yeysk Air Force Higher Flight School in 2008 Saint-Petersburg State University for CA in 2012
Class	II class. The Southern FATA Interregional Territorial Department Decision No 66 of 22.12.2015
Duty authorization	Tower control unit on 26.06.2014 Ground control unit – on 15.12.2015

ICAO language proficiency	ICAO level 4 – certificate РНД No 268.1818, valid till 06.10.2017
Qualification and English language advanced training	At the Institute for air navigation south branch (the city of Rostov-on-Don): – as per the program «Air traffic management (for the ATC controllers, authorized for the international air operations support in the English language), on 30.12.2014
Medical certificate validity	Till 19.05.2019
License, date of issue	СД No 000968, issued on 03.03.2014 by Federal Aviation Service of Russia
License validity	Till 22.12.2017
Competence check	Tower control unit – 19.08.2015
Simulator training	No data available
Total ATC in-service time	1 year 8 months

Position	**The aerodrome control center officer (at the day of the accident functioned as tower control unit officer)**
Sex	Male
Date of birth	April 12, 1961
Education	Higher, Yeysk Air Force Higher Flight School in 1984
Class	II class. Southern FATA interregional territorial department TQC subcommission protocol No 30 of 10.04.2014
Duty authorization	Tower control unit – on 22.09.2010 Ground control unit – on 10.02.2012
ICAO language proficiency	ICAO level 4 – certificate РНД No 1216.7616, valid till 28.01.2017
Qualification and English language advanced training	At the Institute for air navigation south branch (the city of Rostov-on-Don): – as per the program «ATC personnel training (for the ATM controllers)», on 29.05.2015;

	– the aviation English language (R/T phraseology for the ATC personnel, authorized for the international air operations support in the English language), on 17.06.2015
Medical certificate validity	Till 01.08.2016
License, date of issue	СД No 007268, issued on 22.09.2010 by Federal Aviation Service of Russia
License validity	Till 19.09.2016
Competence check	Tower control unit – on 19.08.2015
Simulator training	No data available
Total ATC in-service time	5 years 5 months

On 18.03.2016, at nighttime, the air traffic management within the Rostov-on-Don aerodrome air traffic service area of responsibility was carried out by shift No 5 under the authority of the Rostov-on-Don aerodrome air operations supervisor.

The shift personnel in full underwent the pre-shift medical inspection prior to the duty changeover. The shift underwent a briefing in full.

The following control units exercised the FDB981 flight support:

– approach control unit;
– radar control unit;
– tower control unit.

The air traffic service/management, in compliance with the regulations in effect, is carried out by the one ATC controller at the main or standby duty station.

In the case the necessity arises to engage the relief personnel, the controller who effects the engagement in question, shall take the duty over according to the ATC officer SOP. The monitoring and the responsibility for the relief personnel engagement is held by the air operations supervisor (the chief controller).

At the point of the duty handover/takeover the radio communication with the aircraft flight crews is conducted by the controller who hands the duty over until the personal password is entered to the Alfa ATC automated system and the air operations supervisor reports the following (to the chief controller): «Controller (surname) has taken the duty over» and the respective entry is introduced by the controller who takes the duty over to the duty takeover book.

Within a period when the A6-FDN aircraft was approaching for landing, the following officers functioned as the main controllers at the control units: APPR-1, RDR-1, TWR-1, who were relieved by other controllers when required under the clearance of the air operations supervisor.

1.6. Aircraft information

Aircraft type	Boeing 737-8KN
Manufacturer	The Boeing Company (Seattle, USA)
MSN	40241
Date of manufacture	19.01.2011
Registration	A6-FDN
Registration certificate	No 06/11 of 19.01.2011, issued by GCAA of UAE
Airworthiness certificate	ARC-FZ-FDN-4 of 10.01.2016, issued by GCAA of UAE, valid till 18.01.2017
TSN	21257 hrs, 9421 landings
Service life and life limit	Not assigned by the manufacturer, the aircraft was operated on condition
TBO and service life	Not assigned by the manufacturer, the aircraft was operated on condition
Last scheduled maintenance	Base check, carried out on 21.01.2016 at TSN 20656 hrs, 9161 cycle at the facilities of the certified MRO company
Last line maintenance	At the amount of daily check – it was carried out on 18.03.2016 at the Dubai airport by the Flydubai airline maintenance personnel at the TSN 21247 hrs and 9419 cycles (logbook page No FDN02415). Prior to departure from the Dubai airport to the Rostov-on-Don airport the flight en route Dubai – Kiev – Dubai had been performed. The works were carried out at the amount of Pre-Departure Inspection/PDI (logbook page No FDN02417 and No FDN02418). On 18.03.2016 prior to departure from the Dubai airport to the Rostov-on-Don airport the Flydubai airline maintenance personnel had carried out the last line maintenance at the amount of PDI.

The CFM International engines manufactured at Snecma Corporation, Centre de Villaroche, were installed on the accident aircraft.

Engines	Left (No 1)	Right (No 2)
Type	CFM56-7B27/3B1F	CFM56-7B27/3B1F
MSN	804660	804538
Date of manufacture	January 2011	November 2010
Date of installation on the aircraft	12.07.2014	03.04.2014
Service life	20000 cycles	20000 cycles
TSN, hours/cycles	20284/8977	20994/9375
Remaining service life	11023 cycles	10625 cycles
TBO	On condition	On condition

The APU data: model 131-9B, manufactured by Honeywell International Inc. Engines & Systems on 07.12.2010, MSN 3800702-1, s/n P-8816, TSN – 15011 hrs, 10998 cycles, it was repaired once on 24.09.2013.

1.7. Meteorological information

On 18.03.2016, at 17:32, at the briefing at the Dubai airport the flight crew had been provided by the meteorological documentation as follows: the TAF and METAR reports as for the Dubai departure aerodrome, the Rostov-on-Don destination aerodrome and the alternate aerodromes of Trabzon, Volgograd, Krasnodar, Mineralnye Vody; the FL300, FL340, FL390 weather and the wind forecast charts together with the London World Area Forecast Center significant weather charts through FL100-450, FL250-630 of specific times of 18:00 on 18.03.2016 and 00:00 on 19.03.2016, two vertical profile charts, drawn up at 12:00 on 18.03.2016 for a term of 06 and 12 hrs.

The weather package did not contain the Rostov-on-Don FIR SIGMET No 6 information, valid through 17:30 – 21:00 on 18.03.2016, drawn up on 18.03.2016 at 17:04 and transmitted at 17:06 to the Vienna and Brussels Regional weather data banks.

URRV SIGMET 6 VALID 181730/182100 URRR-

URRV ROSTOV FIR SEV TURB FCST N OF N48 W OF E048 SFC/FL150 STNR NC

SIGMET 6 forecast valid through 17:30 on 18.03.2016 – 21:00 18.03.2016: stationary severe turbulence to the south of 48° N and to the west of 48° E from GL up to FL150, no change.

The Rostov-on-Don destination aerodrome METAR-coded actual weather as of 17:00 on 18.03.2016.

METAR URRR 181700Z 24011G16MPS 8000 -RA BKN020 OVC100 06/03 Q1003 R22/290057 TEMPO 25013G18MPS 1000 SHRA BR SCT003 BKN020CB RMK QFE744/0993.

Surface wind 240° 11 m/s, the gusts of 16 m/s, the visibility 8000 m, light rain, broken clouds (5-7 octants), the cloud base[7] 600 m, overcast (8 octants), cloud base 3000 m, air temperature 6°, dew point 3°, QNH 1003 hPa; RWY22: friction coefficient 0.57; temporary surface wind 250° 13 m/s, gusts 18 m/s, visibility 1000 m, rain shower, mist, cloud: scattered (3-4 octants), cloud base 90 m, broken (5-7 octants) cumulonimbus, cloud base 600 m, QFE 744 mm of mercury/993 hPa.

The TAF report of the Rostov-on-Don destination aerodrome of 18.03.2016:

TAF URRR 181401Z 1815/1915 25007G13MPS 9999 SCTC010 SCT020CB TEMPO 1815/1821 25012G18MPS 3000 -SHRA BR SCT005 BKN020CB FM182100 26010G17MPS 3000 –SHRA BR SCT005 BKN020CB TEMPO 1821/1906 28017G25MPS 1000 SHRA BR SCT003 BKN020CB TEMPO 1906/1915 30011G17MPS.

The forecast is drawn up on 18.03.2016 at 14:01, valid through 15:00 on 18.03.2016 – 15:00 on 19.03.2016: surface wind 250° 7 m/s, gusts 13 m/s, visibility 10 km or more, cloud: scattered (3-4 octants), cloud base 300 m, scattered (3-4 octants) cumulonimbus cloud base 600 m; temporary through 15:00 of 18.03.2016 – 21:00 of 18.03.2016: surface wind 250° 12 m/s, gusts 18 m/s, visibility 3000 m, light shower rain, mist, cloud: scattered (3-4 octants), cloud base 150 m, broken (5-7 octants) cumulonimbus, cloud base 600 m; from 21:00 on 18.03.2016: surface wind 260° 10 m/s, gusts 17 m/s, visibility 3000 m, light shower rain, mist, cloud: scattered (3-4 octants), cloud base 150 m, broken (5-7 octants) cumulonimbus, cloud base 600 m; temporary through 21:00 on 18.03.2016 – 06:00 on 19.03.2016: surface wind 280° 17 m/s, gusts 25 m/s, visibility 1000 m, rain shower, mist, cloud; scattered (3-4 octants), cloud base 90 m, broken (5-7 octants) cumulonimbus, cloud base 600 m; temporary through 06:00 – 15:00 on 19.03.2016: surface wind 300° 11 m/s, gusts 17 m/s.

At 18:37 on 18.03.2016, the FDB981 flight departed from the Dubai aerodrome to Rostov-on-Don. According to the forecast the wind of 270° about 200 km/h had been expected on FL360 at the first half of the route; at the second half of the route the 300° 80 km/h wind has been forecasted. The en route forecast on the FL100-450 significant weather chart indicated the jet stream of 270° and 280 km/h at the Shiraz – Isphahan area, at the Mineralnye Vody – Rostov route leg the forecast indicated the moderate icing below FL150, moderate turbulence at the layer below FL150.

The air operations meteorological support within the area of responsibility of the Rostov-on-Don UATMS area center (according to the UAMTS Rostov area center Instruction on the meteorological service, approved on 19.05.2015 by the Aviamettelecom of Roshydromet, FSBI,

[7]Hereinafter at the reference to the altitude of cloud base, the value is computed from the GL. The elevation of the Rostov-on-Don aerodrome is 85.6 m (280 ft).

North Caucasian branch General Manager and by the State ATM Corporation, FSUE, South Air Navigation branch General Manager) and at the ATM Rostov division area (according to the Instruction on the meteorological service to air operations at the Rostov-on-Don international airport, approved on 29.05.2015 by the Rostov-on-Don airport, LLC Executive director) had been accomplished by the duty shift of the Aviamettelecom of Roshydromet, FSBI, North Caucasian branch Rostov-on-Don air meteorological center (further on referred to as RAMC), licensed by Roshydromet on 26.03.2014, registration number Р/2014/2527/100/Л.

On 18.03.2016 at 20:10, the RAMC issued the next SIGMET No 7 information on the anticipated significant weather – the severe turbulence within the area of responsibility of the UAMTS Rostov-on-Don area center that was transmitted to the Meteo hardware-software complex of the Rostov-on-Don UAMTS area center and to the weather data banks.

URRV SIGMET 7 VALID 182100/190100 URRR-

URRV ROSTOV FIR SEV TURB FCST NOF N44 W OF E048 SFC/FL150 STNR NC

SIGMET 7 forecast valid from 21:00 18.03.2016 till 01:00 19.03.2016: severe turbulence to the north of 44° N and to the west of 48° E from GL up to FL150, stationary, no change.

At 21:40 on 18.03.2016, the flight FDB981 entered the area of responsibility of the Rostov-on-Don UAMTS area center (Rostov Control).

At 21:50, the Rostov UAMTS area center ATC officer transmitted the factual weather on the Rostov-on-Don aerodrome as of 21:30 to the flight crew: wind 250° 9 m/s, gusts 15 m/s, visibility 5 km, cloud base 390 m, QNH 1000 hPa, as well as the SIGMET No 7 information.

At 22:24, the FDB981 flight entered the area of responsibility of the ATM Rostov division.

At the Rostov-on-Don aerodrome the measurement and the processing of the weather parameters on the artificial RWY is carried out by the KRAMS-4 complex radio technical aerodrome weather station (the main and standby assemblies), its main and standby sensors are located at the areas of the inner markers, in the landing area and at the middle of the artificial RWY.

The values of the surface wind parameters, the visibility, the cloud base or the vertical visibility (at the inner marker), the temperature, the air humidity, the atmospheric pressure are measured automatically-remotely.

The RAMC provides with the meteorological information that is necessary to perform their functions the aircraft flight crew members, the Rostov ATM air traffic authorities (the air operations supervisor, the radar control unit, the approach control unit, the tower control unit, the ground control unit), the operations and dispatcher service, the head of the comprehensive duty, the aerodrome service, the search and rescue authorities of the EMERCOM Southern regional center air rescue service – under the agreement of 14.01.2016.

The observations are carried out at the main observation station that is located at the area of the artificial RWY threshold with the magnetic heading 038. All the sensors of the weather instruments are remotely connected to KRAMS-4. The weather equipment meets the ICAO CATII requirements for takeoff and landing operations.

On 18.03.2016 the weather conditions at the Rostov-on-Don area were determined by the rear section of the high-level trough, the axis of which passed along Samara – Makhachkala. At the ground surface they noted the interaction of the high pressure area over Turkey and the eastern sector of the Mediterranean sea and the extensive cyclone with the center over Perm that had been shifted to the south with the speed of 10 km/h. The polar and arctic front systems were allied to this cyclone.

The polar front with the waves was passing over from Aktobe to Aktau, Lagan, Kamensk-Shakhtinsky, Donetsk, Kremenchuk and was shifted along the steering current (270°-290°) to the south – south-east with the speed of about 50 km/h. The passing over Rostov-on-Don was expected at about 00 hrs on 19.03.2016.

The arctic cold front was passing over from Uralsk to Penza, Tambov, Minsk, shifted along the steering current with the speed of 60 km/h. The passing over Rostov-on-Don was expected at about 06 hrs on 19.03.2016.

This very weather pattern contributed to the increase of the atmospheric pressure gradient, the increase of the surface wind, the development of the atmospheric turbulence and windshear.

Note: *The windshear is a change in wind speed and/or direction in space, including updrafts and downdrafts (Doc 9817 Manual on Low-Level Windshear).*

Turbulence is an air circulation, at which the air particles move in an unsteady, chaotic way along the complex trajectories. The movement is characterized by the presence of vortices of different dimensions that are shifted with different speeds in a general (average) air current. The vortex nature of the air circulation specifies the presence of the fluctuating ripples of the wind speed within the turbulent area, including the ripples of the wind vertical component, which considerably affects the aircraft flight.

The windshear and turbulence are included in the local weather reports according to the data from air reports.

At 23:30 on 18.03.2016, the radiosonde was launched by the Rostov-on-Don aerological station. Based on the radiosonde data the aerological graph was constructed, of which it is evident that the labile stratification had been observed within a ground – 1300 m layer that contributed to the cumulonimbus cloud formation (with the cloud ceiling of up to 4.5 km) at the aerodrome area that caused the shower rain precipitation. The freezing level was observed at 700 m. The high humidity ratio contributed to the icing formation above the level of 700 m in the stratocumulus and cumulonimbus cloud that was confirmed by the air reports transmitted by the crews of the aircraft having approached and departed the Rostov-on-Don aerodrome. As per the air reports the moderate icing within the layer of 900-1500 m in the stratiformis cloud was reported, above 1500 m the cumulonimbus cloud was noted present that is confirmed by the NOAA-19 and Meteosat-10 weather earth satellites cloud shots of 18-19.03.2016.

Note: *The cumulonimbus cloud forecast implies the moderate/severe turbulence and moderate/severe icing.*

The wind pattern parameters based on the results of the atmospheric radiosonde by the Rostov-on-Don aerological station (as of 00:00 on 19.03.2016).

Altitude, m	Wind direction	Wind speed, m/s
100	233	8
200	235	14
300	235	21
400	239	25
500	245	28
600	248	29
900	254	29
1000	257	29
1500	261	29
2000	265	30
3000	258	33

The North Caucasian Hydrometeorological Service administration issued the storm warning into the Rostov region: *«At the overnight into 19.03.2016 and before noon on 19.03.2016 into the territory of the Rostov region the strong and high south-western, western wind with the gusts of 25-30 m/s is anticipated; at the city of Rostov-on-Don with the gusts of 23-28 m/s»*.

Note: *The storm warnings are communicated to all the concerned weather authorities, including the Aviamettelecom of Roshydromet, FSBI, North Caucasian branch Rostov-on-Don air meteorological center. This information may be used by the forecaster in drawing up forecasts. This information is not communicated to the aircraft flight crews directly.*

According to the data of the North Caucasian Hydrometeorological Service administration weather stations into the Rostov region the southwestern wind with the gusts of up to 20 m/s had been observed within a period of 12:00 on 18.03.2016 – 02:00 on 19.03.2016.

The RAMC duty forecaster at 19:59 issued the regular forecast into the Rostov-on-Don aerodrome:

TAF URRR 181959Z 1821/1921 25007G13MPS 3000 -SHRA BR SCTC010 SCT020CB TEMPO 1821/1906 25013G20MPS 1000 -SHRA BR SCT005 BKN020CB FM1906 29010G17MPS 3000 –SHRA BR SCT005 BKN020CB TEMPO 1906/1918 30017G25MPS 1000 SHSNRA BR SCT003 BKN020CB.

The forecast drawn up at 19:59 on 18.03.2016, valid within a period of 21:00 on 18.03.2016 – 21:00 on 19.03.2016: surface wind 250° 7 m/s, gusts 13 m/s, visibility 3000 m, cloud: scattered (3-4 octants), cloud base 300 m, broken (5-7 octants), cumulonimbus, cloud base 600 m; temporarily within a period of 21:00 on 18.03.2016 – 06:00 on 19.03.2016: surface wind 250° 13 m/s, gusts 20 m/s, visibility 1000 m, light shower rain, mist, cloud: scattered (3-4 octants), cloud base 150 m, broken (5-07 octants) cumulonimbus, cloud base 600 m; from 06:00 on 19.03.2016: surface wind 290° 10 m/s, gusts 17 m/s, visibility 3000 m, light shower rain, mist, cloud base: scattered (3-4 octants), cloud base 150 m, broken (5-7 octants) cumulonimbus, cloud base 600 m; temporarily within a period of 06:00 – 18:00 on 19.03.2016: surface wind 300° 17 m/s, gusts 25 m/s, visibility 1000 m, moderate snow shower with rain, cloud: scattered (3-4 octants), cloud base 90 m, broken (5-7 octants) cumulonimbus, cloud base 600 m.

At 20:00 there was issued a regular warning No 3 into the Rostov-on-Don aerodrome on the wind increase. The aerodrome warning No 3 was drawn up at 20:00 on 18.03.2016, valid within a period of 21:00 on 18.03.2016 – 06:00 on 19.03.2016: the wind speed of 13 m/s, max 20 m/s is forecasted.

This very warning as per Supplement E of the Instruction on the meteorological service to air operations at the Rostov-on-Don international airport had been transmitted to the approach control unit officer (at 20:00), ground control unit officer (at 20:01) with the delivery confirmation, to the radiotechnical communications and navigational equipment service, the operations and dispatcher service, the operations coordination and planning department, to the duty forecasters of the international air operations and air force.

As per the data of the air report, transmitted by the UTA497 flight in the progress of approach to the Rostov-on-Don aerodrome, the moderate windshear had been observed on final that was introduced in the local weather report – displayed at the MeteoDisplay automated information system – and incorporated into the Tango ATIS information.

Note: *According to the Instruction on the meteorological service to air operations at the Rostov-on-Don international airport items 3.4, 3.5 the information on the presence of the specific conditions and occurrences is transmitted by the aircraft crew to the meteorological office via the ATC officer.*

At 21:55 on 18.03.2016, the forecasted moderate windshear warning was issued into the Rostov-on-Don aerodrome:

URRR WS WRNG 1 182155 VALID 182200/1190600 MOD WS FCST.

The Rostov-on-Don aerodrome windshear warning No 1 drawn up at 21:55 on 18.03.2016, valid from 22:00 on 18.03.2016 until 06:00 on 19.03.2016: the moderate windshear is forecasted.

This very warning had been transmitted to the approach control unit officer (at 21:55), the ground control officer (at 21:57) with the delivery confirmation, the international air operations duty forecaster, and the air operations supervisor.

Note: *The windshear aerodrome warning is drawn up according to item 5.4.4 of the Instruction on the meteorological service to air operations at the Rostov-on-Don international airport. According to item 7.1.4 of the Instruction the warning shall be transmitted by the ATC officer to the aircraft throughout the period of its validity or until the receipt of the cancellation messages.*

As per item 5.3.16 of Doc 9817 Manual on Low-Level Wind Shear:

ATS units should continue to transmit information on wind shear conditions until it is confirmed, either by subsequent aircraft reports or by advice from the associated MET office, that conditions are no longer significant for operations at the aerodrome…The ATS unit should continue to relay air-reports of wind shear to other aircraft concerned until such time as the reports have been incorporated into a wind shear warning by the associated MET office. Thereafter, the wind shear warning will be transmitted to all aircraft concerned until cancelled by the MET office.

As per item 4.3.4 of Doc 9817 Manual on Low-Level Wind Shear:

The wind shear warnings, issued at an airport, serve to alert the pilot to the possibility of wind shear and permit appropriate action to be taken.

At 22:24 at the radio contact with the Rostov-on-Don ATC officer the Boeing 737-8KN A6-FDN aircraft flight crew reported that they had monitored the Uniform ATIS information.

The ATIS information Uniform of 22:00: *«…wind 240^0 10 m/s gusts 15 m/s, visibility 4200 m, light shower rain, cloud: scattered at 390 m, broken cumulonimbus at 990 m, temperature 6^0, dew point 4^0, QFE 742 mm/990 hPa, QNH 1000 hPa, moderate windshear, moderate turbulence from GL to 1000 m, moderate icing in cloud within 900-1500 m; temporarily: surface wind 250^0 13 m/s gusts 18 m/s, visibility 1000 m, shower rain, mist, cloud: scattered at 90 m, broken cumulonimbus at 600 m…».*

At 22:25 the ATC officer recommended that the crew monitored the ATIS information Whisky: *«…wind 230^0 10 m/s, gusts 17 m/s, visibility 2900 m, light shower rain, cloud: scattered* *at 480 m, broken cumulonimbus at 990 m, temperature 6* ^{o}*, dew point 3* ^{o}*, QFE 742 mm/990 hPa, QNH 1000 hPa, moderate turbulence from GL up to 1000 m, moderate icing in cloud from 900 m up 1500 m; tempo: surface wind 250*^{0} *13 m/s gusts 18 m/s, visibility 1000 m, shower rain, mist, cloud: scattered at 90 m, broken cumulonimbus at 600 m…».*

As per the air report transmitted at 22:30 by the flight crew of the Ural Airlines flight SVR 2758 having been in progress of the approach the light-to-moderate windshear and the moderate turbulence were observed on final. The air report data were incorporated into the local weather report and the ATIS information Zulu.

The ATIS information Zulu: *«… wind 230* ^{o} *10 m/s gusts 17 m/s, visibility 4100 m, light shower rain, cloud: scattered at 480 m, broken cumulonimbus at 990 m, temperature 6* ^{o}*, dew point 3* ^{o}*, QFE 742 mm/990 hPa, QNH 1000 hPa, moderate windshear, moderate turbulence from GL up to 1000 m, moderate icing in cloud from 900 m up to 1500 m; temporarily: surface wind 250* ^{o} *15 m/s gusts 20 m/s, visibility 1000 m, shower rain, mist, cloud: scattered at 90 m, broken cumulonimbus at 600 m…».*

At 22:42, the FDB981 flight crew made the decision to initiate the go-around having advised to the ATC officer the windshear as the reason to perform the maneuver.

In the progress of the climb at 22:47, the flight crew relayed the air report to the ATC and requested FL80 due to the moderate icing.

At 22:49 the ATC officer transmitted the moderate icing be present at FL50 to the RAMC duty forecaster.

At 22:55 the flight crew of the AFL1166 flight having approached the Rostov-on-Don aerodrome reported the moderate windshear on final and go-around.

At 23:07 the ATC officer transmitted to the meteo office that in the progress of the missed approach the AFL1166 crew had reported the moderate windshear at the altitude of 400-300 m.

At 23:27 the air operations supervisor reconfirmed, having transmitted the information via loudspeaker communication system, that the AFL1166 aircraft in the progress of the third go-around had reported the moderate-to-strong windshear.

Note: ***Doc 9817 Manual on Low-Level Wind Shear item 5.2.7:***

…pilots, when reporting wind shear, may use the qualifying terms 'moderate', 'strong' or 'severe', based to a large extent on their subjective assessment of the intensity of the wind shear encountered, and such qualifications have to be included unchanged in the report.

The information on the windshear presence at the aerodrome had been transmitting to ATIS up to 00:02 on 19.03.2016.

At 23:47 the FDB981 flight crew asked the tower control unit officer whether the windshear warning had been issued. The controller replied in the negative: *«Negative»*, but in no more than 15 s the tower control unit officer relayed the presence of the moderate windshear to the crew.

At 00:04 the ATC officer recommended that the crew monitored the ATIS information Bravo.

Information Bravo of 00:02: *«…wind 230º 11 m/s gusts 14 m/s, visibility 7 km, light shower rain, cloud: scattered at 570 m, broken cumulonimbus at 1200 m, temperature 6º, dew point 3º, QFE 741 mm/988 hPa, QNH 998 hPa, moderate turbulence from GL up to 1000 m, moderate icing in cloud from 900 up to 1500 m; temporarily: surface wind 250º 15 m/s gusts 20 m/s, visibility 1000 m, shower rain, mist, cloud scattered at 90 m, broken cumulonimbus at 600 m…».*

At 00:20 the tower control unit officer relayed the weather information to the aircraft: *«Weather as of 00:20: visibility 5 km, cloud base 630 m, wind 230º 13 m/s gusts 18 m/s, light shower rain, mist, on final the severe turbulence and moderate windshear»*.

At 00:22 the approach control unit officer relayed to the aircraft: *«…as of 22…230-14 gusts 18, visibility 6 km, scattered 480 m, correction 630 m, meteorological office is not reported about windshear on the RWY»*.

At that moment, the aerodrome windshear warning remained in effect and should have been displayed in red color in a form of WS WRNG conventional English language abbreviation at the controllers' MeteoDisplay automated information system display window.

At 00:23 the controller relayed to the crew: *wind 230-15 gusts 19 m/s*.

At 00:25 the ground control unit officer asked the forecaster via loudspeaker communication system: *«…you are not transmitting the moderate windshear in the ATIS now, are you? »*. The response of the meteo office via loudspeaker communication system: *«Actually we are not, but the warning is active»*. The ground control unit officer via loudspeaker communication system: *«Yes, the warning is active, at actually at 2 hrs you are not transmitting it temporarily for landing, are you? »* The meteo office response via loudspeaker communication system: *«The windshear is not transmitted for landing»*.

At 00:32, in the progress of departure from the Rostov-on-Don aerodrome the SVR2757 flight crew reported:

«In climb the wind is gusting, now… now 260 degrees, 53 knots, cloud base 2500 ft, in climb light icing in cloud».

At 00:34 the ATC controller relayed to the FDB981 crew that the departing aircraft reported the wind at 600 meters 260 degrees 53 knots and light icing.

At 00:40 the FDB981 flight crew reported go-around.

At that moment the ATIS information Echo of 00:30 had been transmitted on air: *«… surface wind 230 degrees 12 m/s gusts 19 m/s, visibility 3800 m, light shower rain, cloud: scattered at 540 m, broken cumulonimbus at 1080 m, moderate turbulence from GL up to 1000 m, moderate icing in cloud from 900 up to 1500 m; temporarily: surface wind 250 degrees 17 m/s gusts 25 m/s, visibility 1000 m, mist cloud; scattered at 90 m, broken cumulonimbus at 600 m».*

The air accident occurred at 00:42.

The actual weather parameters, withdrawn from the KRAMS-4 sensors archives as of the moment of the accident at 00:42: surface wind magnetic 230°-13 m/s gust 18 m/s, visibility 7000/7000/3700 m (touchdown/midpoint/rollout), light shower rain, cloud: scattered (4 octants), cloud base 420 m, broken (5-7 octants) cumulonimbus, cloud base 1080 m, overcast (8 octants), cloud base 3000 m, temperature +6.3°C, dew point +3.6°C, relative humidity 84%, QNH 998.0 hPa, QFE 742 mm of mercury/988 hPa; moderate icing in cloud within 900-1500 m, moderate turbulence from GL up to 1000 m.

At 00:55, the tower control unit officer via loudspeaker communication system requested the technician-forecaster that he measured the weather parameters as per the alarm signal (in 13 min after the alarm signal had been transmitted via GORN alerting system).

The actual weather as documented at the Rostov-on-Don aerodrome after the alarm signal declaration was transmitted as of 00:55: Surface wind magnetic 230°-16 m/s gust 22 m/s, visibility 3500/3900/2400 m (active heading/middle/inactive), light shower rain, cloud: broken (5-7 octants) cloud base 450 m, cumulonimbus cloud, cloud base 1100 m, middle overcast (8 octants), temperature +6.2°C, dew point +3.8°C, relative humidity 84%, QNH 997.8 hPa, QFE 740.8 mm of mercury/987.8 hPa, moderate icing in cloud within 900-1500 m, moderate turbulence from GL up to 1000 m.

1.8. Aids to navigation

The Rostov-on-Don airport is equipped with the navigation aids in compliance with the List of Equipment. The detailed information is given in the AIP of Russian Federation and CIS. There were no failures or anomalies occurred at the time of the accident flight as far as the navaids operation is concerned, all the systems were serviceable, there was no switching to the standby power supply.

The condition of the radio navigation to air operations and the aeronautical telecommunication at the moment of the accident complied with the operation and maintenance documentation requirements, FAR, Airworthiness Requirements to Aerodrome Operation. The aids were functioning as designed with the magnetic heading for landing of 218°.

The State ATM Corporation South Air Navigation Rostov division branch Radiotechnical Communications and Navigational Equipment Department carries out the operation and maintenance of the radio navaids on the Rostov-on-Don aerodrome. The Radiotechnical Communications and Navigational Equipment Department is certified within the Rostov division.

The following radio aids to navigation ensured the operation of ATC approach, radar and tower control units:

The aids to radio navigation and landing

Air navigation data name	The air navigation data element value
Type and category	**ILS-22 (SP-80M) I category**
Radio aid designation	**LOC 22**
Antenna magnetic variation	7.8º East
Callsign	ИРВ/IRW
Frequency	110.3 MHz
Station magnetic variation	7.8º East
Reference position of the antenna installation location (latitude and longitude in degrees, minutes, seconds and centiseconds)	47º14′44.72″ N, 039º47′57.46″ E
Hours of operation (UTC)	period of flight operations
Radio aid designation	**G/S 22**
Antenna magnetic variation	7.8º East
Callsign	ИРВ/IRW
Frequency	335.0 MHz
Station magnetic variation	7.8º East
Reference position of the antenna installation location (latitude and longitude in degrees, minutes, seconds and centiseconds)	47º15′42.77″ N, 039º49′36.64″ E
Hours of operation	period of flight operations
Radio aid designation	**LOM 22**
Antenna magnetic variation	7.8º East
Callsign	РВ/RV
Frequency	320 KHz
Station magnetic variation	7.8º East
Reference position of the antenna installation location (latitude and longitude in degrees, minutes, seconds and centiseconds)	47º17′29.74″ N, 039º52′05.07″ E
Hours of operation (UTC)	period of flight operations

Radio aid designation	**OMB 22**
Callsign	2 dashes/sec
Frequency	75 MHz
Radio aid designation	**LIM 22**
Antenna magnetic variation	7.8º East
Callsign	B/V
Frequency	659 KHz
Station magnetic variation	7.8º East
Reference position of the antenna installation location (latitude and longitude in degrees, minutes, seconds and centiseconds)	47º16′21.54″ N, 039º50′23.11″ E
Hours of operation (UTC)	period of flight operations
Radio aid designation	**IMB 22**
Callsign	6 dots/sec
Frequency	75 MHz
Radio aid designation	**the Platan ADF**
Antenna magnetic variation	7.8º East
Frequency	118.0-136.975 MHz (reception)
Station magnetic variation	7.8º East
Reference position of the antenna installation location (latitude and longitude in degrees, minutes, seconds and centiseconds)	47º15′17.71″ N, 039º49′11.39″ E
Hours of operation (UTC)	H24
Radio aid designation	**the Lira aerodrome surveillance radar**
Antenna magnetic variation	7º8′ East
Frequency	1030, 2753.5-2766.5 MHz (transmission); 740, 1090, 2753.5, 2763.5, 2756.5, 2766.5 MHz (reception)
Station magnetic variation	7º8′ East
Reference position of the antenna installation location (latitude and longitude in degrees, minutes, seconds and centiseconds)	47º15′14.53″ N, 039º49′10.00″ E
Hours of operation (UTC)	H24

– the SP-80M localizer, MSN 8525, year of manufacture 1988, introduced to service on 07.09.1988, modified in compliance with the manufacturer SBs in 2003, 2006 and 2010, TSN as of February 2016 (inclusively) 95900 hrs, the last maintenance check (TO-C) carried out on 16.03.2016. Installation landing magnetic heading-218;

– the SP-80M glideslope, MSN 8525, year of manufacture 1988, introduced to service on 07.09.1988, modified in compliance with the manufacturer SBs in 2003, 2006 and 2010, TSN as of February 2016 (inclusively) 96655 hrs, the last maintenance check (TO-C) carried out on 17.03.2016. Installation landing magnetic heading-218;

– the PAR-10C locator at the outer marker, MSN 1000933, year of manufacture 1985, introduced to service on 30.12.1985, TSN as of February 2016 (inclusively) 99138 hrs, the maintenance-3 carried out on 16.02. 2016. Installation landing magnetic heading-218; the E-615.1 outer marker, MSN 19009, year of manufacture 1989, introduced to service on 26.09.1990, TSN as of February 2016 (inclusively) 89298 hrs, the last maintenance check (TO-3) carried out on 16.02.2016. Installation landing magnetic heading-218;

– the PAR-10C locator at the inner marker, MSN 1000895, year of manufacture 1985, introduced to service on 30.12.1985, TSN as of February 2016 (inclusively) 97512 hrs, the TO-3 maintenance carried out on 29.02.2016. Installation landing magnetic heading-218; the E-615.1 inner marker, MSN 19006, year of manufacture 1989, introduced to service on 26.09.1990, TSN as of February 2016 (inclusively) 87512 hrs, the last maintenance check (TO-3) carried out on 29.02.2016. Installation landing magnetic heading-218;

– the Platan (DF-2000) ADF, MSN ПЛТ-015.12, year of manufacture 2012, introduced to service on 26.12.2012, TSN as of February 2016 (inclusively) 28266 hrs. The last maintenance check (TO-3) carried out on 10.03.2016. Installed at the Rostov-on-Don aerodrome;

– the Lira-A10 aerodrome surveillance radar, MSN 210001, year of manufacture 2010, introduced to service on 21.12.2011, TSN as of February 2016 (inclusively) 36228 hrs. The last maintenance check (TO-C) carried out on 12.09.2015 (as far as the Avrora secondary radar is concerned, the last maintenance check (TO-4) was carried out on 28.12.2015). Installed at the Rostov-on-Don aerodrome;

– the 1090 ES HC-1A ADS-B ground station, MSN 063/14, year of manufacture 2015, introduced to service on 29.09.2015, TSN as of February 2016 (inclusively) 3696 hrs. The last maintenance check (TO-5) carried out on 18.11.2015. Installed at the Rostov-on-Don aerodrome.

There were no comments received on the operation of the radio navigation to air operations and the aeronautical telecommunication equipment on 18.03.2016 and 19.03.2016 from the ATC officers, other airport services and the aircraft flight crews.

There was no off-performance or the off-design operation detected of the radio navaids to air operations or the aeronautical telecommunication equipment.

The ER 22 STAR (Fig. 30) and the RWY22 ILS approach chart (Fig. 32) are given here below. The data are taken from the AIP of Russia.

The variants of charts, available to the crew are presented on Fig. 31, Fig. 33.

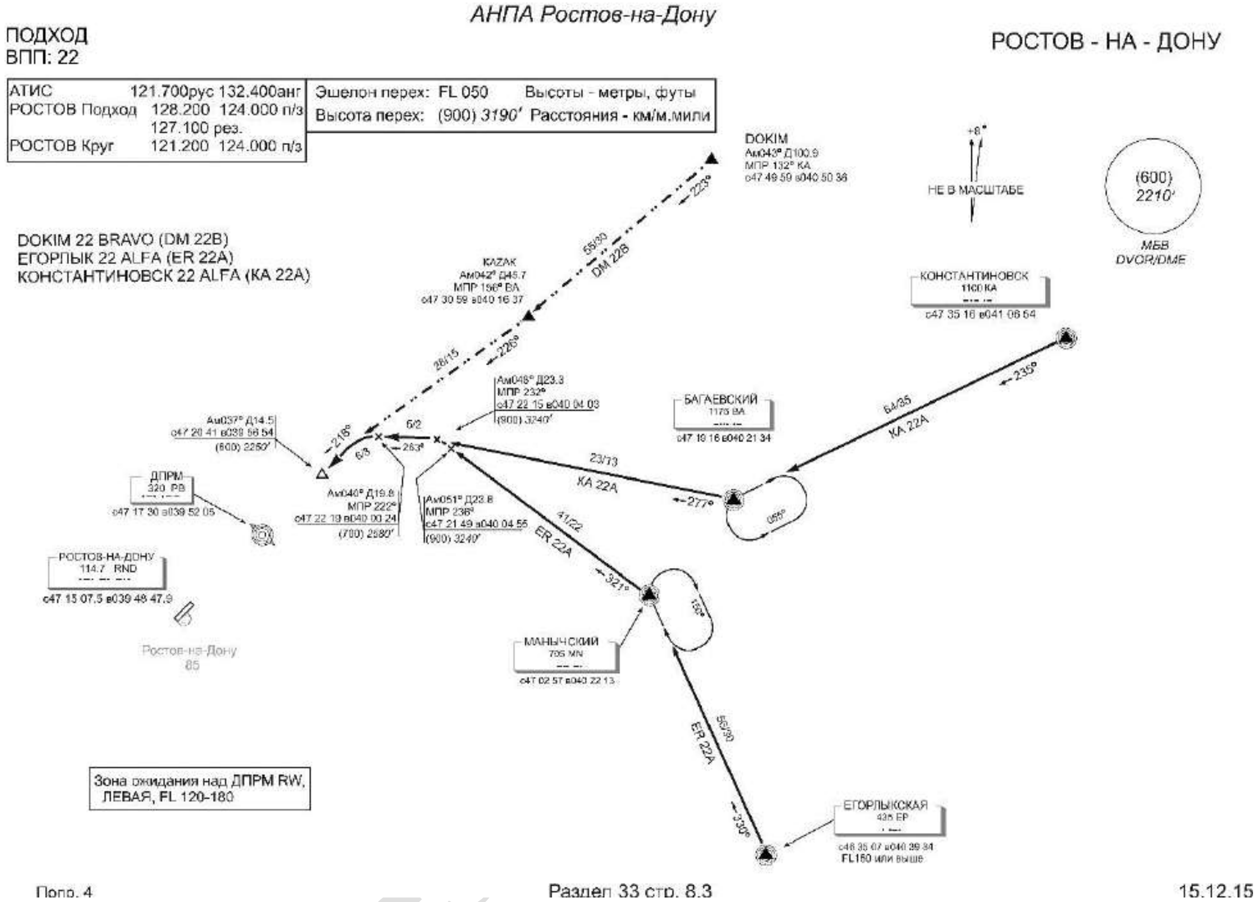


Fig. 30. The RWY22 STAR at the Rostov-on-Don airport (from the AIP of Russia)

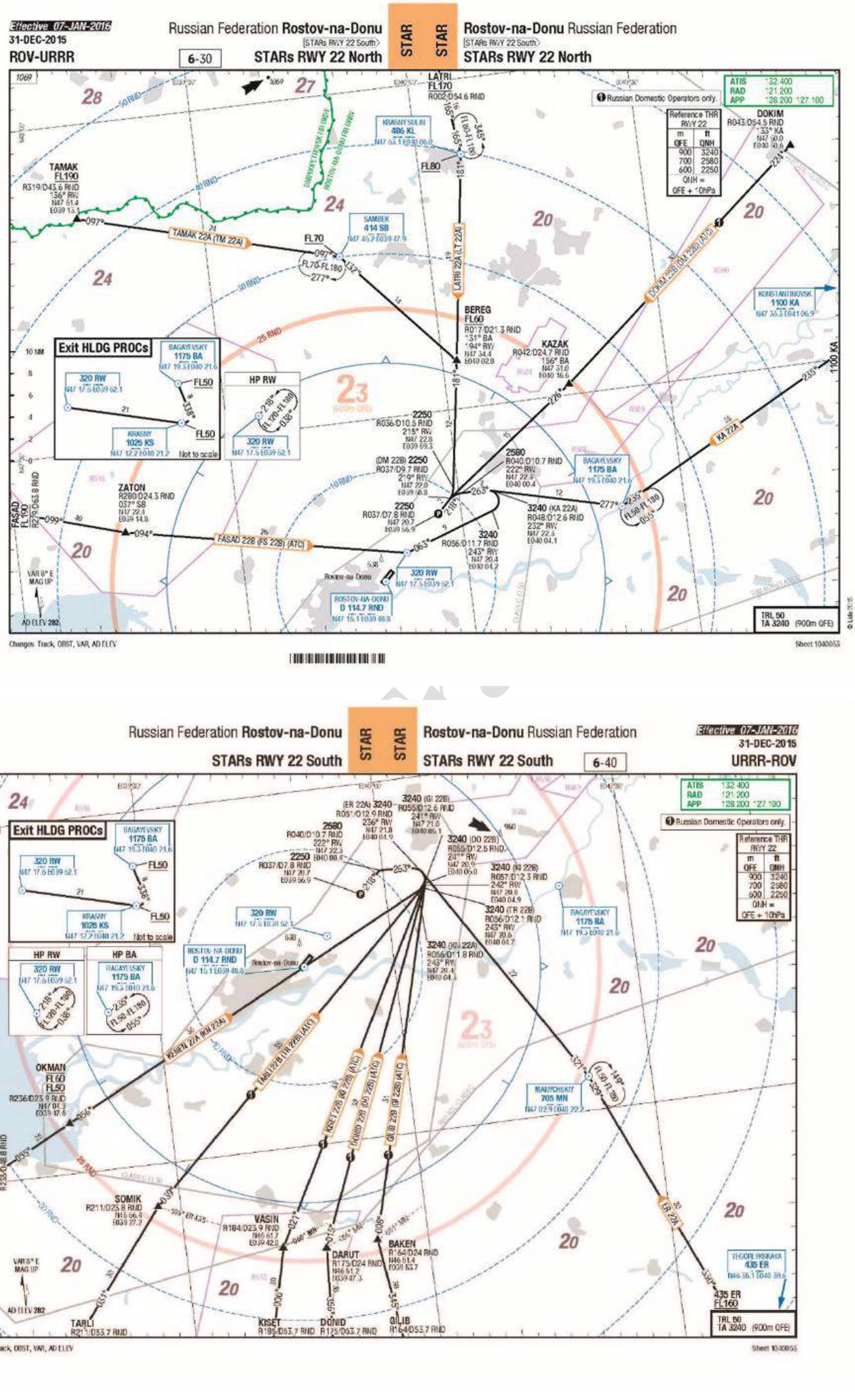
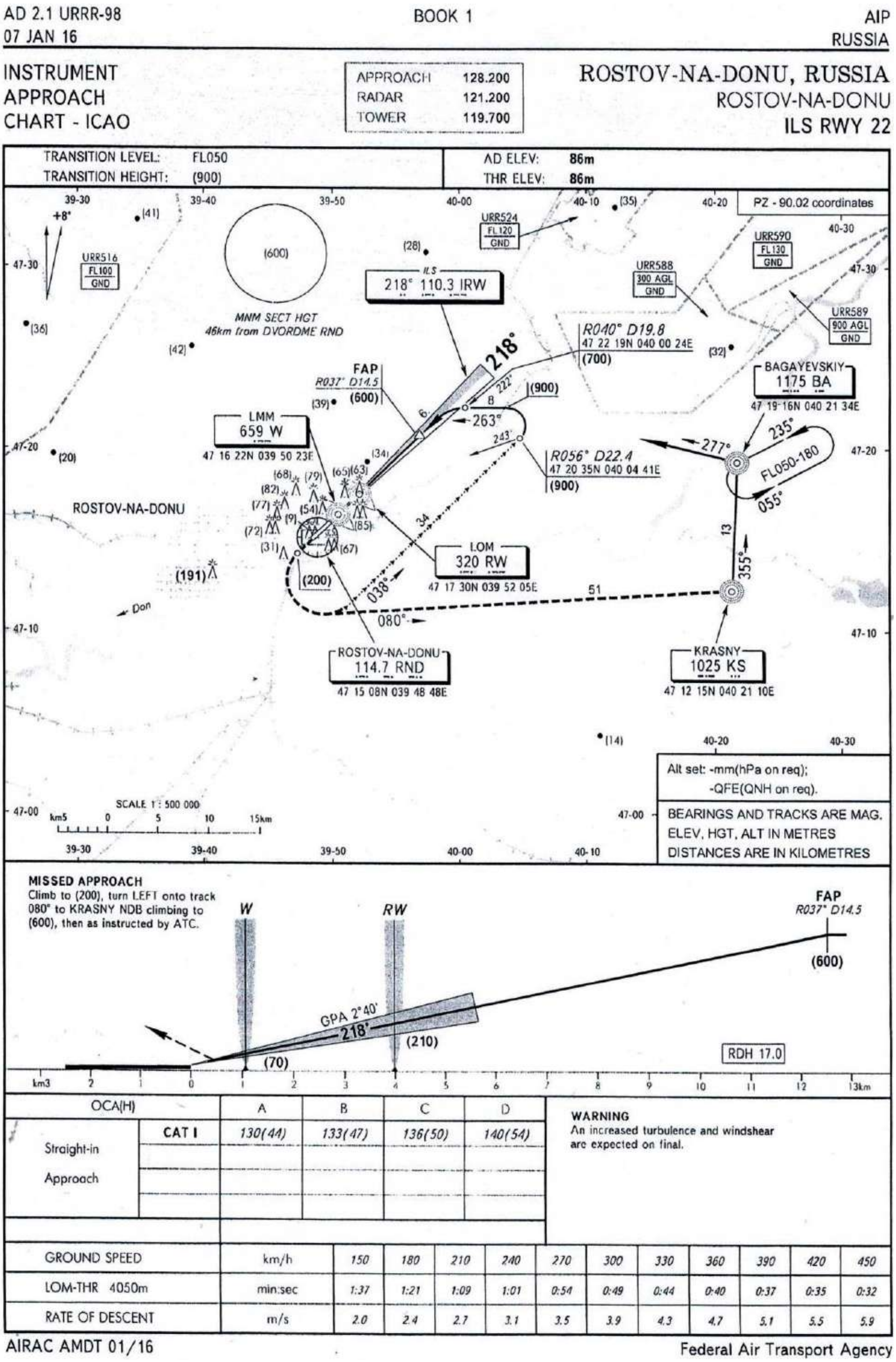


Fig. 31. The variants of the RWY22 STAR available to the crew



OCA(H)		A	B	C	D
Straight-in Approach	CAT I	130(44)	133(47)	136(50)	140(54)

GROUND SPEED	km/h	150	180	210	240	270	300	330	360	390	420	450
LOM-THR 4050m	min:sec	1:37	1:21	1:09	1:01	0:54	0:49	0:44	0:40	0:37	0:35	0:32
RATE OF DESCENT	m/s	2.0	2.4	2.7	3.1	3.5	3.9	4.3	4.7	5.1	5.5	5.9

Fig. 32. The RWY22 ILS approach chart at the Rostov-on-Don airport (from the AIP of Russia)

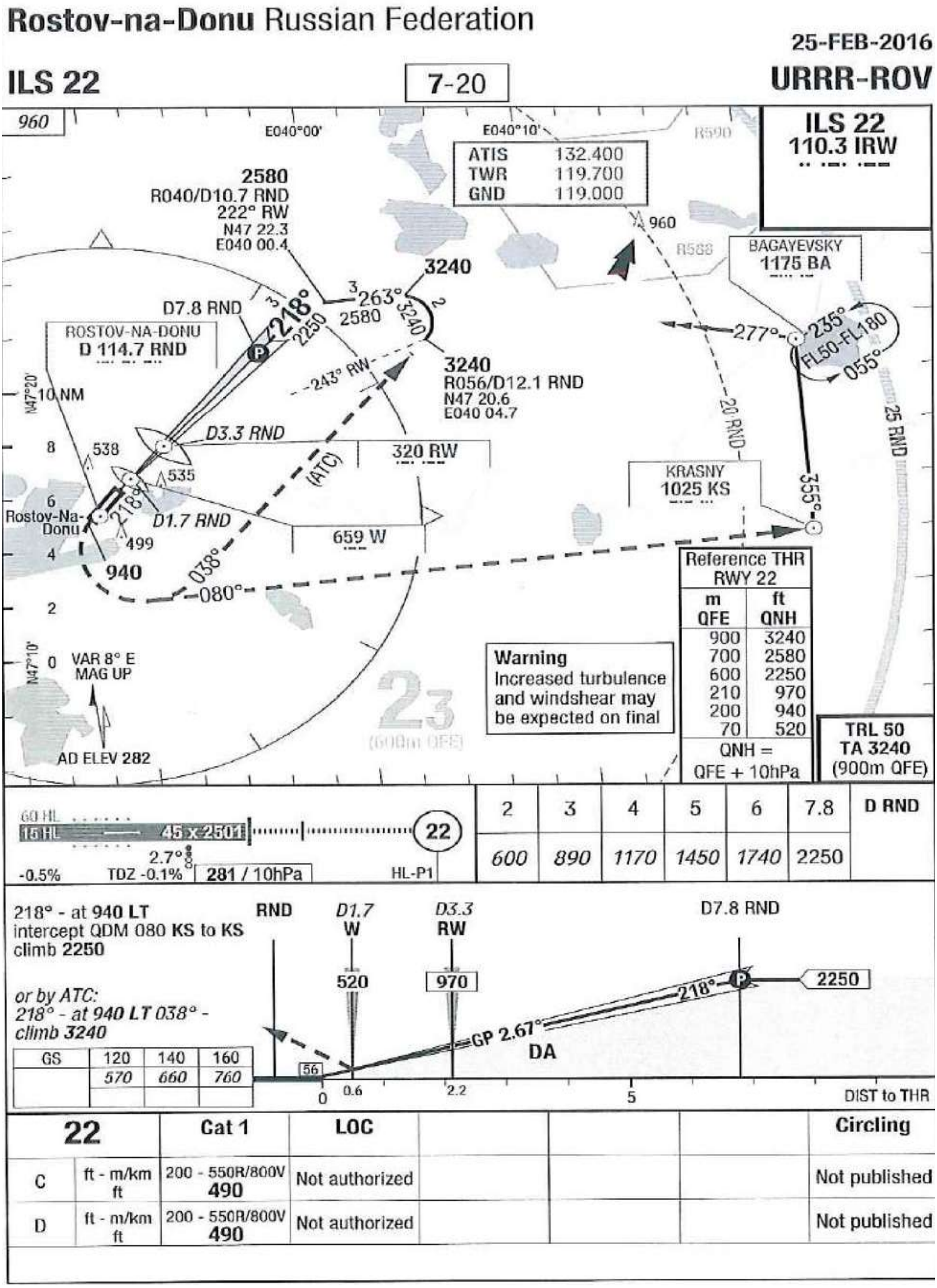


Fig. 33. The variant of the RWY22 ILS approach chart available to the crew

The Transcon lighting was installed with the landing magnetic heading 38º and landing magnetic heading 218º in 2006. It was subject to renewal in 2015. The equipment configuration complies with FAR-262.

The Rostov-on-Don aerodrome as per the landing magnetic heading 218° is equipped with a high-intensity lights lighting equipment.

No in order	**Air navigation data name**	**The air navigation data element value**
	RWY designation	**22**
1	Approach lighting system type	OVI-1 high intensity approach lighting system with centerline bar lights
2	Approach lighting system length	900 m
3	Approach lighting system luminous intensity	24000 candelas
4	RWY threshold lights (color)	green
5	Touchdown zone wing bar lights	none
6	Visual glide path indication system	PAPI
7	Approach slope	2°40'
8	Location of visual glide path indication system	to the left of the RWY at the distance of 525 m off the runway threshold
9	Length of the RWY touchdown zone lights	none
10	Length of the RWY centerline lights	2500 m
11	RWY centerline lights luminous intensity	2500 candelas
12	RWY centerline lights installation intervals	15 m
13	RWY centerline lights color	At the area up to 1600 m – white; beyond 600 m – red/white; last 300 m – red
14	RWY landing (edge) lights length	2500 m
15	RWY landing (edge) lights installation intervals	60 m
16	RWY landing (edge) lights luminous intensity	13000 candelas
17	RWY landing (edge) lights color	at the area up to 1900 m – white; the last 600 m – yellow
18	RWY end lights color	red
19	Stopway zone wing bar lights	none
20	Length and color of stopway lights	none

There was neither switching nor overvoltage registered at the lighting equipment. The equipment in question had not switched to the standby power supply.

1.9. Communications

The detailed information on the communications are not stated throughout the report, since the air accident is not anyhow related to their serviceability. Prior to the accident, the radio contact with the flight crew involved had been stable and intelligible. The crew-ATC radio communication, as well as the radio exchange at the other communication channels, subject to recording, had been stored by the ground recorders, decoded and used by the investigation team.

The last radio contact between the aircraft flight crew and the tower controller was established at 00:40:57. In reply to the crew report on the initiation of the go-around the tower controller instructed the crew that they contacted the radar controller with the indication of the frequency. The crew confirmed the receipt of information. Further on the crew did not establish any radio contact with the radar controller, did not respond to the ATC officers' calls.

At 00:42:21 the ground controller, having seen the bright flash and the subsequent fire at the area of TWY Delta, declared an alarm.

1.10. Aerodrome information

The Rostov-on-Don aerodrome (ICAO code - URRR) is a civil aerodrome of a B class (an ICAO 4D class).

The ground area is state-owned.

The RWY, TWYs, stands and apron are owned by Rostovaeroinvest, PJSC.

Hours of operation – H24.

The Rostov-on-Don aerodrome is registered in the State register of the civil aerodromes of Russian Federation. The RF Ministry of Transport Air Transport Department issued the aerodrome Certificate of registration and operability No 57 of 16.06.1993.

On 21.05.2012 FATA renewed the Certificate with an expiry on May 31, 2017 based upon the Aerodrome Compliance Audit Report to the requirements on the aerodromes operation of 15.12.2011.

The Certificate No 010 A-M of 22.10.2015, issued by the IAC aerodromes and equipment certification commission, reads the following:

«…the Rostov-on-Don aerodrome complies with the certification requirements of the AP-139.

RWY 04/22:

with magnetic landing heading 38° is equipped with OVI-II high-intensity lights, ILS-II, designed for ICAO CAT I precision approach up to DH of 60 m at the RVR not less than 550 m, ICAO CAT II up to DH of 30 at the RVR not less than 350 m;

with magnetic landing heading 218° is equipped with OVI-II high-intensity lights, ILS-II, designed for ICAO CAT I precision approach up to DH of 60 m at the RVR not less than 550 m.

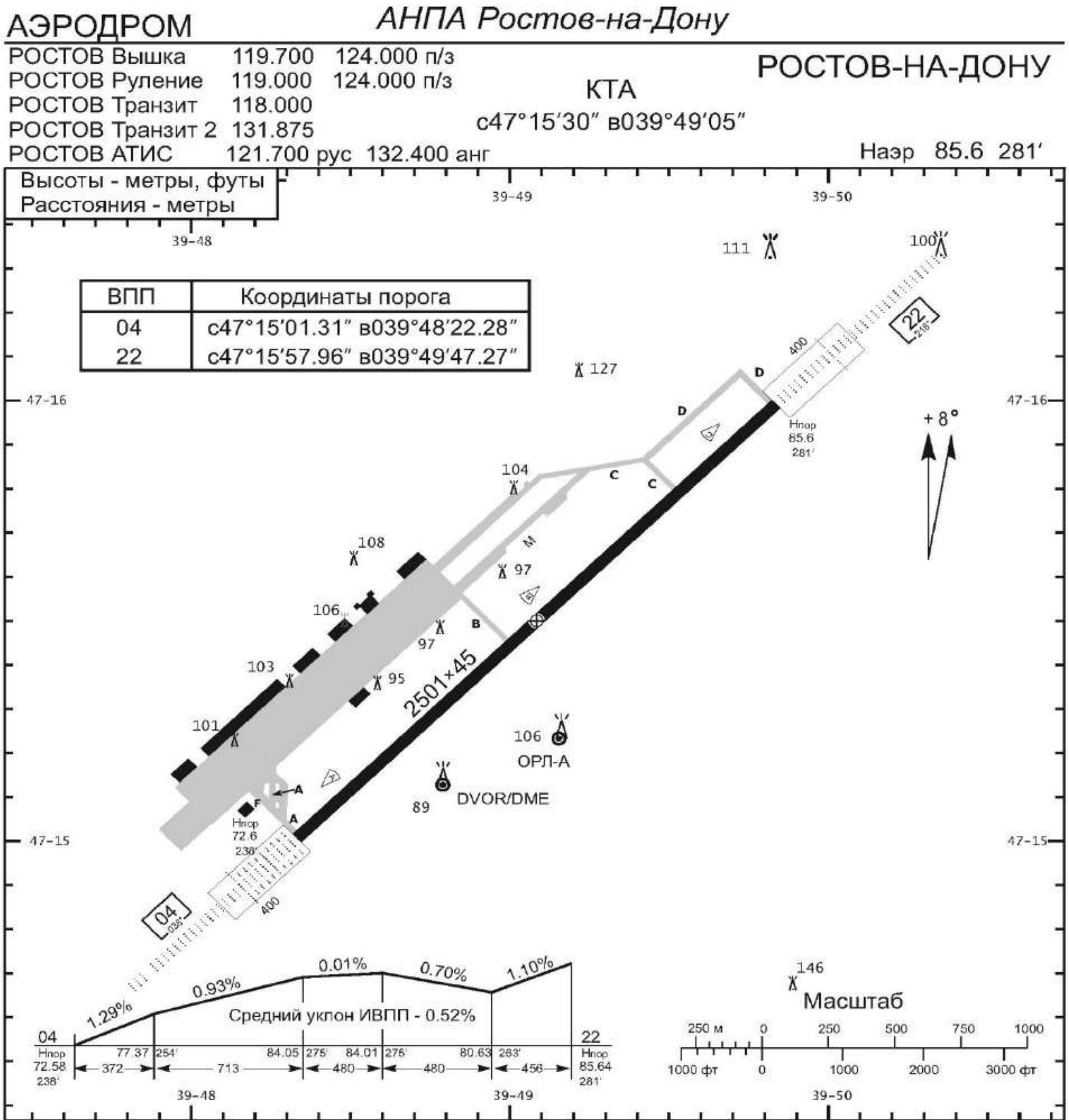
The aerodrome is qualified for international air operations…».

The aerodrome is qualified for different types of aircraft to be operated, Boeing 737-800, 757, 767-200, 767-300 and their modifications among them.

The Rostov-on-Don aerodrome (Fig. 34, Fig. 34a) is located at the distance of 10.5 kilometers to the northeast of the railroad station of the same name.

The aerodrome reference point geographic position: 47°15′30″ N, 039°49′05″ E.

The aerodrome reference position elevation (the true altitude) is +85.6 m, the magnetic variation is +8º. The time zone number – 3 (UTC+3 hrs).



ВПП		СВЕТООБОРУДОВАНИЕ	РДР	РДВ	РДПВ	РПД
04	ИВПП	ОВИ - 2, огни приближения 900м, ПАПИ (2°40′)	2501	2901	2501	2501
22		ОВИ - 1 с осевыми огнями, огни приближения 900м, ПАПИ (2°40′)				
04	ивпп от РД В		1400	1800	1400	
22	ивпп от РД С		2000	2400	2000	
22	ивпп от РД В		1101	1500	1101	

МИНИМУМЫ ДЛЯ ВЗЛЁТА

Кат. ВС	ВПП 04 Н н.г.о.	ВПП 04 С огнями оси ВПП	ВПП 04 Без огней оси ВПП день	ВПП 04 Без огней оси ВПП ночь	ВПП 22 Н н.г.о.	ВПП 22 С огнями оси ВПП	ВПП 22 Без огней оси ВПП день	ВПП 22 Без огней оси ВПП ночь
A	б / о	200	300	300	б / о	200	300	300
B								
C				400				400
D								
Верт.	без ограничений				без ограничений			

Fig. 34. The Rostov-on-Don aerodrome chart as published in the Aerodrome Air Navigation Passport

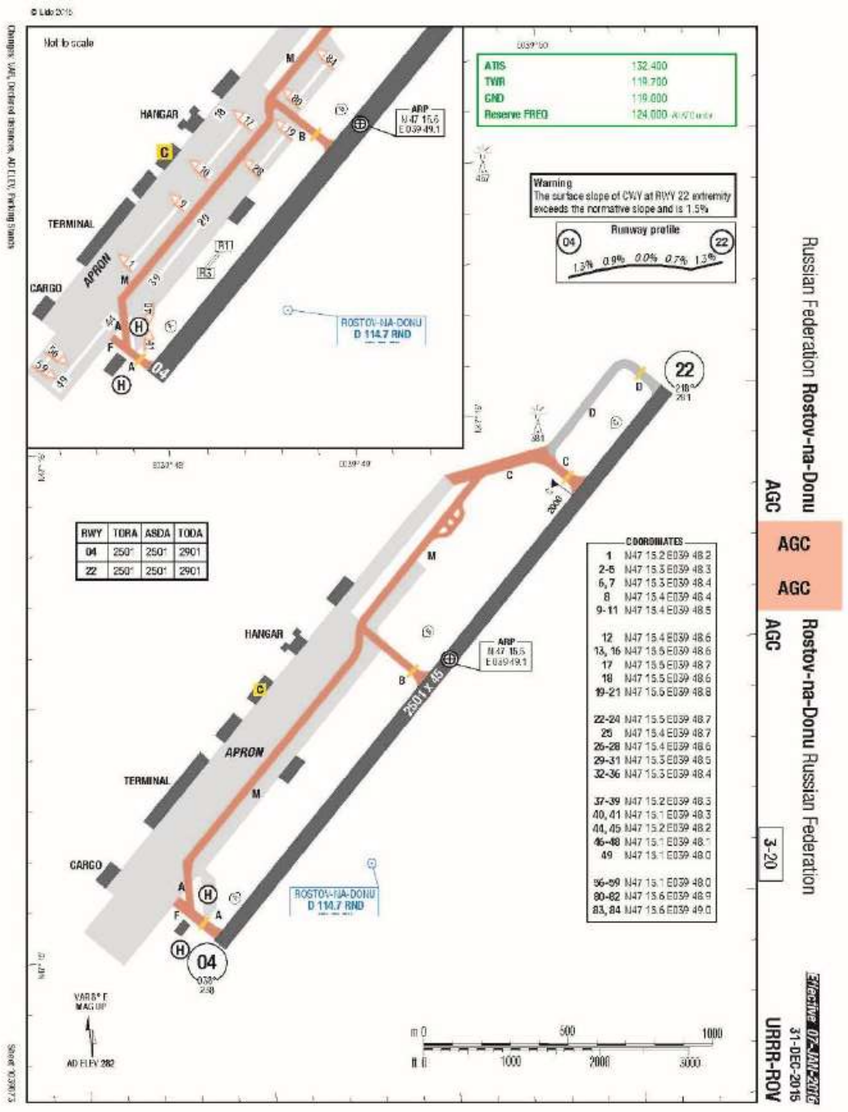


Fig. 34a. The Rostov-on-Don aerodrome chart available to the crew

The airfield is a polygon with the dimensions of 3300*260*1900*1000*1800 m. The airfield surface is flat, the ground is soft and the soil is loam. The airfield surface is unfit for the takeoff and landing operations.

The aerodrome integrates the artificial runway.

The artificial runway (RWY 04/22) is of B class, of 2501 m length with the active width of 45 m, permanent throughout the length. The surface is fibercrete, strengthened with asphalt concrete.

The RWY 04/22 thresholds are coincident with the RWY approach end.

The RWY 04/22 thresholds takeoff and landing magnetic track angles, numbers, reference positions and true altitudes are given in the table below.

Threshold No	Takeoff and landing magnetic track angle	Threshold reference position	Threshold true altitude
04	038°	47º15′01.31″ N, 039º48′22.28″ E	72.58 m
22	218°	47º15′57.96″ N, 039º49′47.27″ E	85.64 m

The runway strip runs in a lateral direction on either side of the runway axis, along the entire length of 150 m to the either side. The runway strip cleared and graded area runs 72.5 m off the runway axis.

The runway strip runs beyond the runway stop end:

– with landing magnetic heading 38°: 150 m;

– with landing magnetic heading 218°: 150 m.

The runway strip hard section dimensions amount to:

– at magnetic heading 38°: the inner width – 60 m, length – 50 m;

– at magnetic heading 218°: the inner width – 49 m, length – 50 m.

There are no objects, located within the runway strip cleared and graded area, except for those, disposed as per their functional purpose.

Within a distance of 120 m to either side off the artificial runway axis there are no obstacles.

The aerodrome operation engineer – the head of aerodrome shift at 21:15 carried out the inspection of the airfield with the aim to evaluate its condition. The friction coefficient measurement was conducted with the use of ATT-2 No 2 MSN 1505 braking cart with the subsequent entry into the Rostov-on-Don aerodrome airfield condition log. The norm friction coefficient amounted to 0.57/0.57/0.57. At 0:11 another friction coefficient measurement was done. The norm friction coefficient amounted to 0.46/0.46/0.5.

The inspection of the artificial surfaces was carried out in compliance with the provisions of the Manual on the civil aerodromes operation in Russian Federation (REGA RF-94).

After the accident at 00:52 the additional entry was introduced that the artificial runway with the magnetic heading 218° is unserviceable due to the foreign objects presence (the aircraft wreckage) and the artificial runway surface disintegration.

At 00:52 the aerodrome had been closed.

1.11. Flight recorders

Flight data recorder

The Honeywell SSFDR p/n 980-4700-042 with the secure memory unit s/n 35907 had been installed on the accident aircraft. On the accident scene, the secure memory unit was retrieved being out of the recorder case (Fig. 35).

Fig. 35. The FDR secure memory unit

The recovery and readout of the stored information was performed at the facilities of the MAK-IAC AAISTSC by the team, consisted of the following experts:

- of the Interstate Aviation Committee;
- Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA), France;
- General Civil Aviation Authority of United Arab Emirates.

The analysis of the recovered information revealed that the FDR had been serviceable and recorded all the analog parameters and the discrete signals in compliance with the Digital Flight Data Acquisition Unit 737-600/-700/-700c/-800/-900, Data Frame Interface Control And Requirements Document D226a101-2 within 17.03.2016 – 19.03.2016 (the total duration of the record amounts to 26 hrs 34 min), including the Boeing 737-800 A6-FDN flight of 19.03.2016, ended up with the air accident at the Rostov-on-Don aerodrome. The quality of the record is good.

Cockpit voice recorder

The L3 FA2100 2100-1020-00 cockpit voice recorder (CVR) had been installed on the accident aircraft. The recorder case had been removed from the accident site. At the inspection, it was noted that the case sustained considerable mechanical damage (Fig. 36).

Fig. 36. The external view of the CVR

At the MAK lab the recovery works had been performed on the removal of the memory unit from the damaged case and its re-installation in the technological unit. With the use of the standard L3 Communications software-hardware complex the readout and conversion of all the data volume of the recorder sound information was performed. The total volume of the data amounted to 02 hrs 4 min 14.5 s. The record is consistent with the Boeing 737-800 A6-FDN aircraft flight of 19.03.2016, ended up with the air accident at the Rostov-on-Don aerodrome. The quality of the record is good.

The data, withdrawn from the flight data and cockpit voice recorders, had been used in the investigation team activities.

1.12. Wreckage and impact information

The accident scene is located at the Rostov-on-Don airport airfield. The first point of impact with ground (the RWY concrete surface) occurred at the ≈ 120 m off the RWY22 threshold along the RWY left edge looking forward, reference position: 47º15′54.7″ N, 039º49′43.8″ E. The main wreckage scatter area is located at the distance of 150-400 m off the RWY22 threshold to the left (the major portion of the wreckage) and to the right of the RWY centerline (Fig. 37).

Fig. 37. First point of impact with ground (the left-to-right direction of flight)

The main wreckage scatter zone is located at the distance of 150-400 m off the RWY threshold on the left side (the larger portion of wreckage) and on the right side off the RWY centerline (Fig. 38).

Fig. 38. The general view of the accident scene (the arrow indicates the flight heading)

The impact resulted in the crater formation of about 10-12 m length, 2.5 m width and up to 1.5 m depth. After the impact, the flash of the fuel-air mixture occurred with the subsequent fire.

By the pattern of the wreckage scatter, it can be concluded that the aircraft impact with ground had occurred in a steep nose-down attitude while rolling to the left.

The largest aircraft elements, retrieved at the accident site, rested in the following sequence as per the flight heading[8]:

– the fragments of the fuselage nose section (with the cockpit), the centerwing, left wing console, left half of the stabilizer, left half of the elevator, nose landing gear leg and the fragments of the left engine (the compressor case with the elements of the compressor control system) rested inside the crater;

– the right section of the stabilizer with the attached to it right half of the elevator at the azimuth ≈ 235° at the distance of 175 m;

– the fragment of the fuselage RH half section (from FR927 up to FR986.5) (the area of the aft service door) and the aft service door at the distance of 148 m on the RWY;

– the fragment of the upper portion of the fuselage (from FR694 up to FR727A) with the ADF antennas at the distance of 160 m on the RWY;

– the damaged forward cabin door at the azimuth of ≈ 230° at the distance of 169 m;

– the disc of the fan stage of the right engine with the fragments of the blades at the azimuth ≈ 222° at the distance of 325 m;

– the disc of the fan stage of the left engine at the azimuth of ≈ 217° at the distance of 264 m;

– the fragment of the LH fuselage section (from FR578 up to FR610) with the fragment of the overwing emergency exit at the azimuth ≈ 223° at the distance of 203 m;

– left main landing gear at the azimuth ≈ 224° at the distance of 238 m;

– right main landing gear at the azimuth ≈ 216° at the distance of 259 m;

– the APU with the exhaust duct at the azimuth ≈ 237° at the distance of 147 m;

– the fragments of the right engine (compressor case with the elements of the compressor control system and the engines rotor front support) at the azimuth ≈ 217° at the distance of 255 m;

– the fragments of the elevator control system (the input rods, the control PCUs and the autopilot electrohydraulic actuator) at the azimuth ≈ 235° at the distance of 73 m;

– the ailerons autopilot electrohydraulic actuator at the azimuth ≈ 225° at the distance of 300 m;

[8] All the magnetic azimuths and distances are referred off the RWY first point of impact.

– the assemblies of the stabilizer trim system (the drum with the fragments of the cable linkage, the gearbox with the jackscrew separated in two parts, the trim motor apart from each other with the azimuth ≈ 226° at the distance of 73 m.

The origin of fire was located at the area of the crater. However, the fuselage fragments from FR500C up to 1156H, the right half of the stabilizer (having rested at the distance of 175 m off the crater) and the fin do not demonstrate the signs of fire or the thermal effect both on the outer and inner skin. Based on that it may be concluded that initially at the aircraft impact with ground, there occurred the fuselage destruction with the separation of the stabilizer and the fin and then there developed the fuel flash and fire.

The investigation team has drawn out a wreckage map (the pattern of the wreckage scatter afield) (Fig. 39).

Fig. 39. The pattern of the wreckage scatter on the accident site

The main wreckage scatter zone was located inside the А-Б-В-Г-Д polygon.

The perimeter distance between the points:

– А-Б amounts to 445 m;

– Б-В amounts to 148 m;

– В-Г amounts to 216 m;

– Г-Д amounts to 530 m;

– Д-А amounts to 385 m.

The reference position of the scatter zone points:

– point А – 47º15.844′ N, 039º39.49.411′ E.;

– point Б – 47º16.009′ N, 039º49.667′ E;

- point В – 47º15.975′ N, 039º39.49.7738′ E.;
- point Г – 47º15.896′ N, 039º39.49.890′ E;
- point Д – 47º15.687′ N, 039º49.49.611′ E.

Only two smaller fragments of the fuselage skin were discovered out of the main wreckage scatter zone (the points 116 and 117 on Fig. 39), situated at the azimuth ≈ 57º at the distance of ≈ 474 m and, most probably taken away by the wind due to their sailing capacity/windage. The actual weather observed at the Rostov-on-Don aerodrome after the alarm signal declaration as of 00:55: «*…surface wind magnetic* 230^0 *16 m/s, gusts 22 m/s…*».

1.13. Medical and pathological information

At the facilities of the Russian Federation Ministry of Health Center of Forensic Medical Expertise, FSBI there was performed the DNA identification profiling of the human remains.

4389 fragments of the human remains were submitted for the examination. 3906 fragments out of them (89%) were determined appropriate for profiling, whereas 11% were stated unsuitable to be examined. Thus, 3906 fragments subject to analysis were identified (63 individual bodies).

At the Rostov Region Ministry of Health Forensic Medical Expertise Office, FSI, there was performed the forensic medical expertise of the PIC. At the examination of the submitted materials it was determined that in the accident sequence the PIC's organism had been affected by the huge loads far beyond the structural properties of the human body. He had been subject to the rough multisystem injury with the total destruction and massive fragmentation of the body.

The specification of the flight crewmembers' working posture at the moment of the accident is based on the elaboration and the analysis of the specific (primary and secondary) injuries that the crewmembers could have sustained having operated inside the cockpit.

In this very case due to the total destruction of the PIC's body into a great number of smaller parts, the presence of the multiple irreparable bones, soft tissues, internal organs defects it turns to be impossible to sort out the primary and secondary injuries of the flight crewmembers. Consequently, it is hardly possible to identify what the PIC's working posture was at the moment of the accident.

The forensic chemical analysis of the soft tissues out of the PIC dead body was performed, based on which the following was concluded (Conclusion No 2441/276-пк, the expertise was carried out within 18.05.2016 – 09.06.2016)[9]: «In the muscular tissue out of the PIC's dead body the ethanol, isopropanol, butanol, acetone, lower aliphatic carboxylic acids, aliphatic saturated hydrocarbons (the hexane and octane) were detected. The ethanol concentration amounts to

[9] Hereinafter in the cited documents the author's wording is retained.

0.35 mg/g in the muscular tissue; the isopropanol content is 0.12 mg/g in the muscular tissue. The narcotic drugs, psychotropic substances were not detected».

At the forensic chemical analysis of the muscular tissue of all the other deceased crewmembers, the similar combination of chemicals was detected (incorporating ethanol, isopropyl, butyl alcohol, as well as acetone, lower aliphatic carboxylic acids and saturated aliphatic hydrocarbons (hexane, octane) with the similar ethanol and isopropanol quantitative distribution).

As for the evaluation of the presence and quantity of the detected ethanol, the potential newly constituted ethanol in the muscular tissue should be taken into account. This ethanol formation is the result of the putrefaction at the joint impact of several factors, justified by the nature of the injury and the remains exposure to the environment that conduce to the rapid development of the putrefactive processes…

By reference to the features of the detected substances, as well as taking into consideration that due to the massive injuries (the open wounds, the bodies fragmentation) the organism of the deceased people represented the open system, exposed to the entry of the chemicals from the outside, the presence of the ethanol in the deceased people's bodies should be interpreted as justified by the pollution of the bio objects with the mechanical fluids at the point of the aircraft fuselage destruction or due to the remains location at the aerodrome surface, polluted with such fluids.

Based on the above stated the detection of the chemicals (ethanol, isopropanol, butanol, acetone, lower aliphatic carboxylic acids and saturated aliphatic hydrocarbons – hexane, octane) in the PIC's (name, surname) muscle is estimated by the experts as being justified by the injuries nature and the remains exposure to the environment. This very result is not the evidence that the PIC had been in a state of alcohol or another toxic (including the drug one) intoxication».

The results of the forensic medical and chemical expertise of the F/O, performed within the Rostov Region Ministry of Health Forensic Medical Expertise Office, FSI, are similar to those of the PIC.

1.14. Survival aspects

In the progress of the flight, the flight crewmembers were occupying their duty stations at the flight deck. The passengers were allocated at the passenger cabin.

Fig. 40 represents the presumed passenger seating allocation.

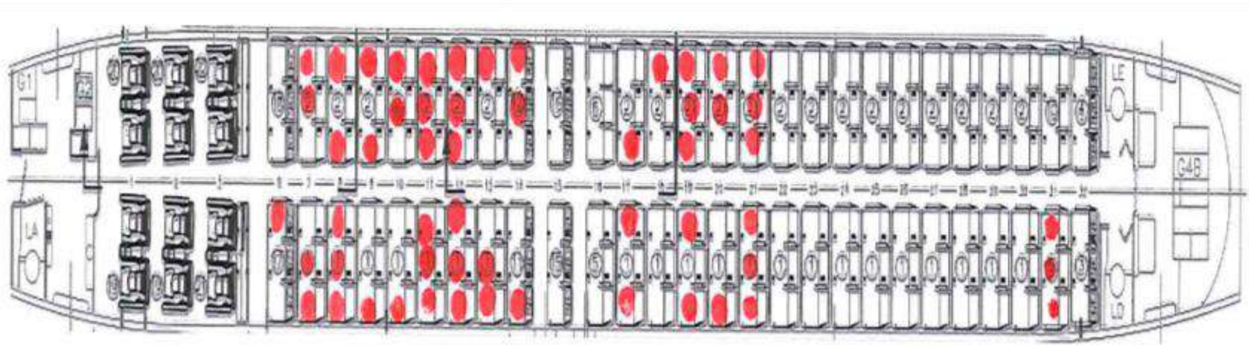


Fig. 40. Passengers' seating allocation

Due to the air accident all the people aboard were killed.

According to the conclusion of the complex forensic medical expertise, drawn up by the Russian Federation Ministry of Health Center of Forensic Medical Expertise, FSBI, the death of 55 passengers and 7 crewmembers occurred at the result of the multisystem injury with the total disintegration and massive fragmentation of the bodies. These injuries were the outcome of the huge loads application on the organism far beyond the structural properties of the human body. They might have been generated at the point and at the circumstances of the aircraft impact with the RWY on 19.03.2016 with the subsequent fuselage disintegration. The injuries in question inflicted the grievous bodily harm to the crewmembers and passengers, having been classified as the threat to life and directly correlated to the cause of death.

In studying the issue of the actual total number of passengers aboard the aircraft and specifically the number of passengers, the forensic medical DNA profiling by the Rostov Ministry of Health Forensic Medical Expertise Office, FSI was collated with the passenger manifest data, provided by the Flydubai airline. The results of the expertise in question allowed determining that the remains belonged to 63 deceased individuals. 62 persons out of them complied with the list of the crewmembers and passengers having been aboard the accident aircraft. The sixty-third identified deceased individual was a female fetus of a deceased passenger. As of the moment of the flight, the passenger had been pregnant.

1.15. SAR and firefighting operations

The air accident occurred at 00:42.

The ground control unit officer, having seen the bright flash and the subsequent fire at the area of TWY Delta, declared an alarm.

The firefighting operation by the Rostov-on-Don airport fire team was launched at 00:44.

At 00:45, the city fire teams were warned of the accident, at 00:48 the city emergency medicine center was notified of it.

At 00:50, the fire was isolated.

The Rostov region Federal Firefighting Service units' workforce and special vehicles were deployed to the accident site, including the firefighting personnel of the Crisis Management Center.

At 01:10, the Rostov region and Rostov-on-Don Federal Firefighting Service units' workforce and the special vehicles arrived to the accident site. The accident scene by the time of the arrival represented the fragmentary fire at the surface of more than 1000 sq. m.

The data on the involved workforce and special vehicles:

– the rescue teams in all – 72 persons and 21 special vehicles;

– 12 EMERCOM teams and 12 firefighting vehicles;

– the Rostov region Russian EMERCOM General Directorate Crisis Management Center response group – 3 persons, 1 vehicle;

– the Don rescue center (accident rescue vehicle-2, fire-extinguishing tanker-1) – 10 persons, 3 vehicles;

– the fire and rescue brigade response group – 2 persons, 1 vehicle;

– the Rostov region EMERCOM General Directorate psychological support team – 3 persons and 1 vehicle;

– the Rostov region Russian EMERCOM General Directorate Crisis Management Center fire control and SAR service – 4 persons, 1 vehicle;

– the fire and rescue unit – 36 persons, 10 vehicles;

– the special fire and rescue unit – 44 persons, 6 vehicles;

– the firefighting coordination directorate – 3 persons, 1 vehicle;

– the Rostov region Russian EMERCOM General Directorate emergency response team – 9 persons;

– the Russian EMERCOM Southern regional center response group – 3 persons, 1 vehicle;

– the Russian EMERCOM Southern regional center emergency response team – 14 persons;

– the Southern regional center emergency psychological assistance center – 11 persons, 2 vehicles;

– 10 emergency medicine ambulance cars.

One Ural-4352 and two Kamaz-63501 firefighting vehicles were involved in a direct fire suppression.

At 14:00 on 20.03.2016, the grouping was enhanced up to 900 persons and 200 vehicles. Seven SAR activities areas were allocated within a perimeter of 250 m x 400 m with 14 groups of rescuers out of 20 persons each.

At 06:00 on 21.03.2016 the SAR activities were completed and the airport resumed the standard air operations.

As far as the emergency-rescue works are concerned there were no shortcomings revealed that could have influenced the survivability of the crewmembers and passengers.

Emergency locator transmitter

The ELT is totally destroyed. As per the COSPAS-SARSAT coordination center data, the ELT had not been activated in the accident sequence.

1.16. Tests and research

1.16.1. Wreckage layout

The identification of the fragments of the aircraft structure had been carried out, the surface layout of the wreckage inside the hangar was performed afterwards (Fig. 41).

Fig. 41. The surface layout of the wreckage in the hangar

At the analysis of the wreckage map (Section 1.12) and the layout the signs of the inflight aircraft destruction prior to the impact with ground were not detected. All the damage of the airframe structure, engines and systems, as well as the disintegration of the avionics occurred due to the application of the huge loads in the accident sequence far beyond the tensile strength.

1.16.2. The examination of the stabilizer jackscrew

The jackscrew elements (Fig. 42) in an assembly were retrieved from the aircraft wreckage and transferred to the NTSB Material lab, where on 20.10.2016 they had been examined to perform the physical and chemical analysis of the fractured areas and the developed bend with the measurement of the inner diameter and the safety rod wall thickness. In addition, the works were carried out on the identification of the metal samples of the jackscrew and safety rod with the aim to determine whether they met the material specification requirements (AMS 6265 and AMS 6411/6427). The examination of the jackscrew of the stabilizer trim mechanism (p/n 07322P000-05, s/n 1847) was performed at the participation and under the guidance of the air accident investigation team representatives, as well as with the participation of the AAIS experts.

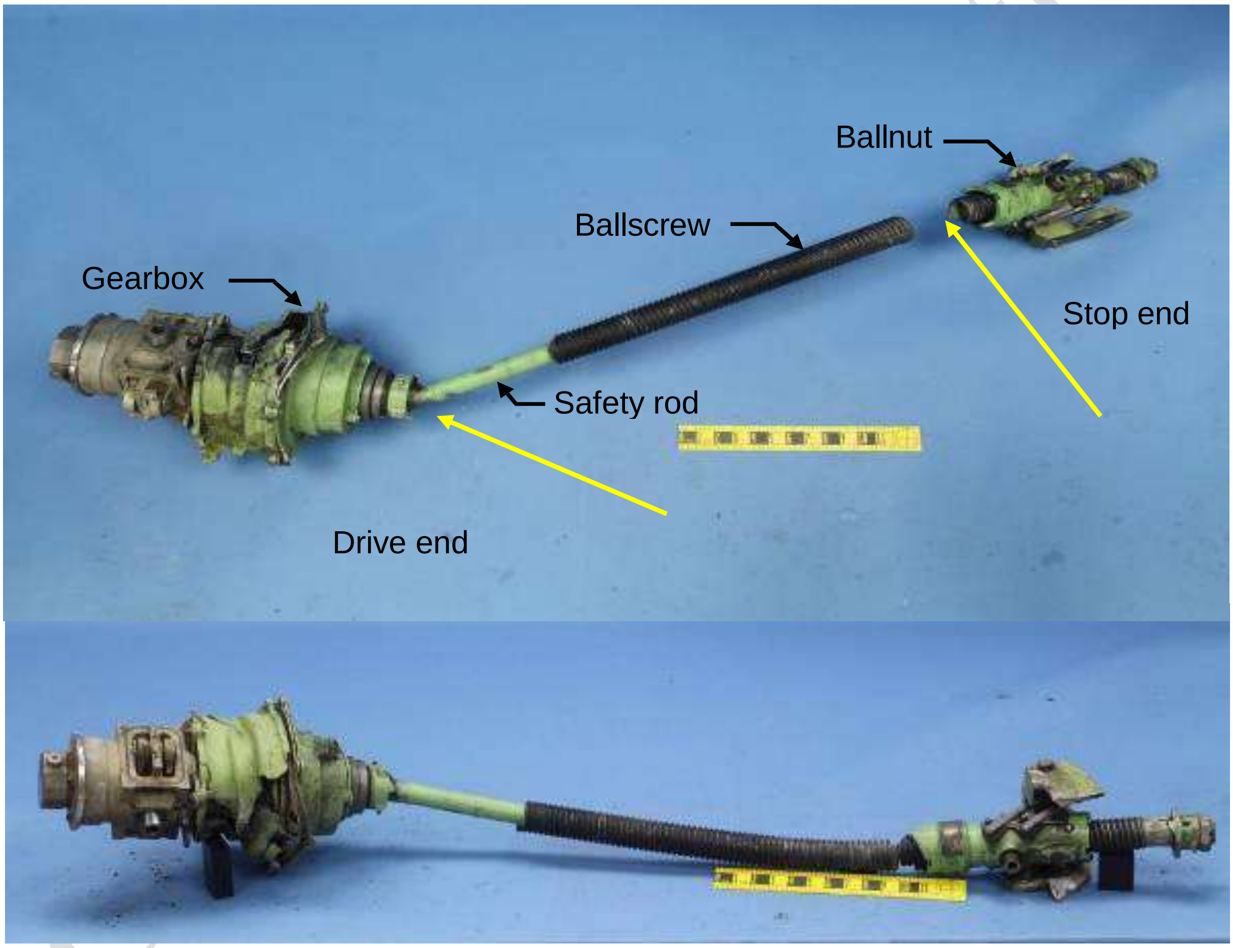


Fig. 42. The jackscrew assembly with the fractures (the fractures are pointed with arrows)

At the outcome of the examination the following was established:

– all the fractures are characteristic of the overstress loads application. The fracture surface does not demonstrate the apparent preexisting cracks or any other anomalies;

– the fracture planes on both halves of the jackscrew were inclined to the longitudinal axis by 45° and exhibited a comparatively rough surface;

– the fracture through the safety rod exhibited similar features to the jackscrew fractures;

– the features of the both parts material meet the requirements;

– the wall thickness of the jackscrew and safety rod as well as the inner diameter of the safety rod meets the drawing requirements;

– the chemical composition of the jackscrew and safety rod material met the requirements of the AMS 6265 and AMS 6411/6427.

It should be noted that the position of the jackscrew gimbal is consistent with the value of the stabilizer position as per the FDR data.

1.16.3. Stabilizer trim control switch of the F/O control wheel

On the accident scene the stabilizer trim control switch (ensuring the "power supply")[10], integrated to the F/O control wheel, had been discovered (Fig. 43).

Fig. 43. Stabilizer trim control switch of the F/O control wheel

Upon the investigation team decision on 24.10.2016 the trim switch (s/n 306-4305, Boeing p/n 10-60705-1 Y) was examined at the facilities of the manufacturer Esterline Mason in the town of Sylmar (California). The F/O control wheel trim switch examination was performed at the participation and under the guidance of the air accident investigation team representatives, as well as with the participation of the NTSB and AAIS experts.

The following was stated on the results of the examination:

– the trim switch sustained significant damage;

– the testing of the trim switch against the Acceptance Test Procedure is impossible;

– the continuity of the electric circuit is disrupted.

[10] See also Section 1.18.2 of the present Report.

Throughout the service history of the stabilizer trim control switches, there were no events of its short circuit.

1.16.4. The examinations of the elevator control system PCUs

The examinations of the Boeing 737-800 A6-FDN aircraft elevator PCUs had been conducted.

PCU	Boeing p/n	s/n	Date of manufacture	Overhauls
Left	251A2160-2	14254	November 2010	-
Right	251A2160-2	14257	November 2010	-

The elevator control system PCUs examinations were conducted on 25.10.2016 – 28.10.2016 at the facilities of Parker Aerospace being their designer (the town of Irvine, California, United States of America) and within Parker Aerospace (the town of Ogden, Utah, United States of America) being their manufacturer (the further examinations of the control valves are referred to in the case). The elevator control system PCUs examination was performed at the participation and under the guidance of the air accident investigation team representatives, as well as with the participation of the NTSB and AAIS experts.

The following works were carried out throughout the examination:

Visual inspection

Left PCU

The external surfaces of the PCU are significantly dirtied.

Left PCU (Fig. 44) sustained considerable damage in the accident sequence as follows:

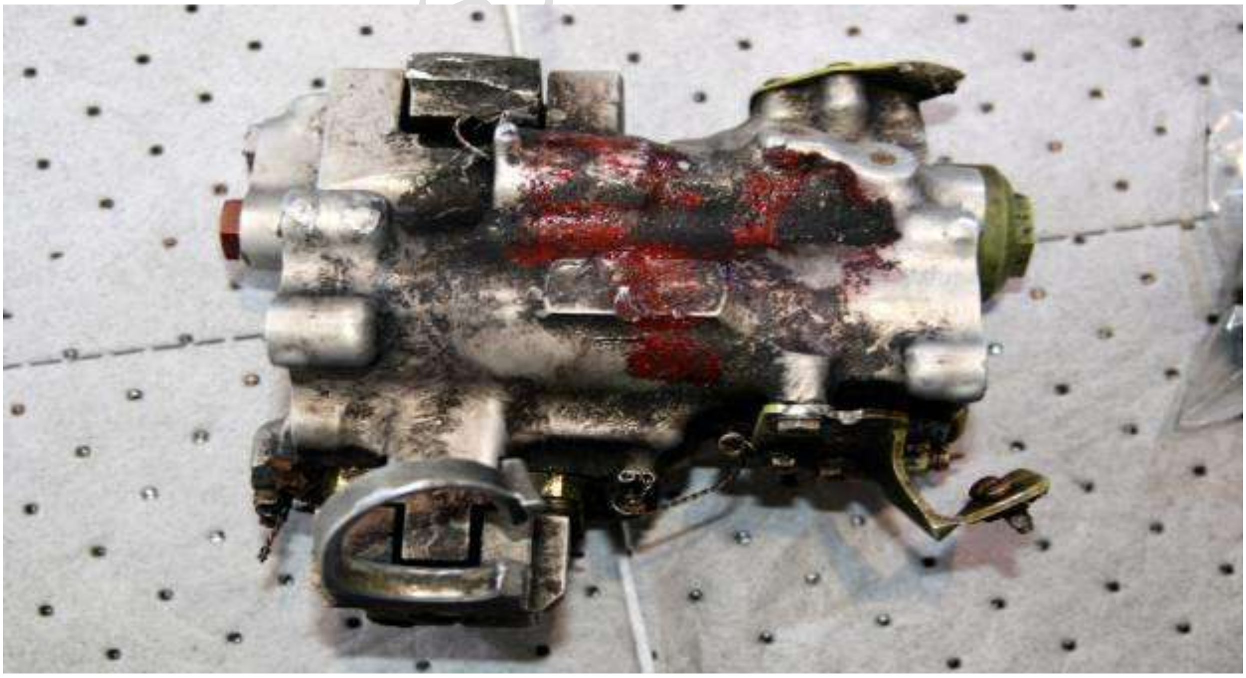


Fig. 44. The left PCU external view

– the unions (supply, drain) are damaged, severed up to the retainers;

– the primary input arm is partly disintegrated, the portion of the arm with the bearing is missing;

– the secondary input arm is partly destroyed – the housing of the secondary input arm is disintegrated;

– the tailstock and the piston, the piston link and the actuator sealing bushings are missing.

Right PCU

The right PCU (Fig. 45) had been submitted for the examination with the elements of the input pogos. The external surfaces of the PCU are significantly dirtied.

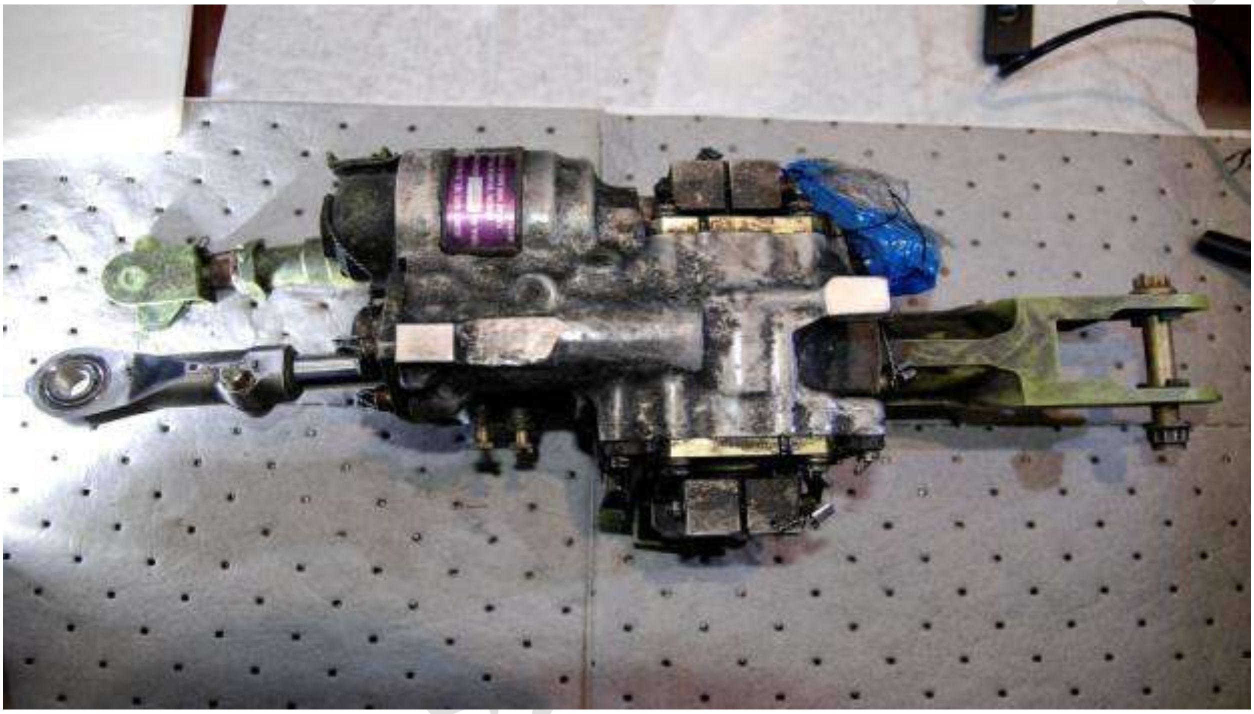


Fig. 45. The external view of the right PCU

The PCU sustained considerable damage in the accident sequence as follows:

– the actuator tailstock is deformed (bent);

– the secondary input arm housing is destroyed.

Computed tomography scanning

Prior to the teardown and bench test the CT scanning of the PCUs was performed by Varian Medical Systems, Inc in Chicago, Illinois. The images were then examined, processed, and analyzed by the NTSB in Washington, DC., USA with the participation and under the guidance of the air accident investigation team representatives. The examination aimed at the evaluation of the condition of the internal parts and assemblies of the PCUs in order to state the absence of the damaged components and no event of the off-design configuration. The CT scanning results in the PCUs 3D images with a capability to acquire the 2D images along any necessary cross-section.

The CT scanning results analysis was the evidence of the following:

over the left PCU:

– the internal components of the PCU do not exhibit any visible damage;

– all the internal parts and assemblies of the PCU are normally positioned at their standard locations;

over the right PCU:

– the internal components of the PCU do not exhibit any visible damage;

– all the internal parts and assemblies of the PCU are normally positioned at their standard locations.

The PCUs testing against the manufacturer ATP

The PCUs were tested to evaluate:

– the forces, required to move the input arms;

– the forces, required to move the one input arm against another one fixed;

– the full travel of the input arms;

– the bypass valve actuation pressure (the test was performed with the use of the MIL-H-083 hydraulic fluid).

The PCUs parameters meet the requirements.

The PCUs teardown. The parts and assemblies visual inspection

The PCU were subject to the partial teardown in order to evaluate the condition of the internal parts and assemblies, test the control and bypass valves against the manufacturer ATP.

The left PCU

The internal cavities were unsealed due to the partial destruction of the PCU. The internal cavities were exposed to environment.

In the progress of the teardown the following parts and components were disassembled:

– the input filter F1: the condition of the filter screen is satisfactory, no external ruptures were detected. On the bottom part of the filter frame, the corrosion traces were discovered[11].

– the leverage: the primary input arm is partially destroyed. The retainer sustained damage. The bearing unit of the primary input arm is in satisfactory condition – the bearing races rotate smoothly without seizure;

– the bypass valve: the bypass valve parts exhibit traces of corrosion;

– the control valve: the parts of the control valve exhibit the traces of corrosion. The primary slide crank input slot had a burr on one side with the raise of the material.

[11] The investigation team is of the opinion that the traces of corrosion on this and the other parts were developed after the accident due to their exposure to the environment.

Prior to the bench testing of the control and bypass valves their parts were soaked in Derust PA HD250 solution to remove the corrosion deposits and then cleaned using a combination of manual brushes and an ultrasonic cleaner.

The filter was flushed with isopropyl alcohol. The alcohol was collected in glass bottles and retained for further examinations.

The right PCU

In the progress of the teardown the following parts and components were disassembled:

– the input filter F1: the condition of the filter screen is satisfactory no external ruptures were detected;

– the leverage: the leverage system parts are in satisfactory condition;

– the bypass valve: the bypass valve parts are in satisfactory condition;

– the control valve: the control valve parts are in the satisfactory condition;

– the actuator: the piston rod and tailstock are bent. The sealing bushings are in the satisfactory condition.

The filter was flushed with isopropyl alcohol. The alcohol was collected in glass bottles and retained for further examinations.

The testing of the control valves against the manufacturer ATP

To perform the flow tests the left and right PCU control valves were assembled to the required level. The assembled control valves were alternatively placed on the bench in the test fixture that simulates the function of the control valve inside the PCU. The test was carried out with the use of the MIL-H-6083 hydraulic fluid.

The control valves parameters meet the requirements, determined for the new assemblies.

The test of the bypass valves against the manufacturer ATP

The test was carried out with the use of the MIL-H-6083 hydraulic fluid.

The left and right PCUs bypass valves parameters meet the requirements, determined for the new assemblies.

Borescope inspection

The following particles were subject to the borescopic inspection:

– the control valve secondary slide of the right PCU;

– the control valve secondary slide of the left PCU;

– the control valve sleeve of the right PCU;

– the control valve sleeve of the left PCU;

– the bypass valve sleeve of the right PCU;

– the bypass valve sleeve of the left PCU;

– the actuator cylinder of the right PCU;

– the actuator cylinder of the left PCU.

The traces (marks) were noted on the surfaces of the examined parts that may be characteristic of the normal operation, as well as the marks of corrosion on the inner surfaces of the left PCU. The parts that were subject to the borescope inspection do not exhibit any specific marks of the mechanical jamming, seizure or the abnormal operation of the PCUs.

The diameter clearance measurement

Prior to the measurement the left and right PCU control valves parts surfaces were thoroughly cleaned out from the hydraulic fluid flow marks and any other deposits.

As informed by the PCU designer the performance (flow) tests are the major criterion of acceptance. However, there is a 0.00015 inch requirement to the minimum diameter clearance as far as the primary slide – secondary slide assembly of the control valve is concerned.

The primary slide – secondary slide assembly of the right PCU does not meet the minimum diameter clearance requirement. The results of the measurement are the evidence that this very assembly had been manufactured with a deviation from the drawing or in the progress of the manufacture it might be case of the deficient technological dimensional stabilization. The reduced diameter clearance may cause chocking of the control valve slide due to the sleeve deformation, being affected by different loads throughout the operation. At the same time all the parameters of the control valve meet the requirements of the ATP. The control valve, having been integrated into the PCU, had been operated for a long time against different external impact. Thus the mentioned discrepancy of the minimum diameter clearance against the technological documentation requirement had not anyhow affected the PCU serviceability.

1.16.5. The evaluation of the condition and the serviceability of the electric stab trim motor

The examinations of the condition and the serviceability of the electric stab trim motor were carried out within 25.10.2017 – 26.10.2017 at the Eaton facilities in the Grand Rapids, United States of America. The NVM microchip and the stab trim motor p/n 6355C0001-01, s/n 2062, were tested on the bench. The stab trim motor examination was performed at the participation and under the guidance of the air accident investigation team representatives, as well as with the participation of the NTSB and AAIS experts.

The NVM with the U8 integrated circuit, mounted to the 6355-0230-13 PWA, is incorporated into the motor assembly. The NVM only records latched faults (faults that result in the stabilizer trim motor becoming inoperative until the next power cycle) and corresponding operational data. The NVM also records one initial cold boot record. The NVM can store up to 5459 faults. The faults are stored in order of occurrence. The non-latched faults are not stored in the NVM. In case of repair performance at the manufacturer facilities (Eaton) the NVM is downloaded and then cleared as a part of release to service.

The integrated circuit was soldered onto a verified good 6355-0230-13 PWA. The PWA was then connected to an engineering test bench.

There were no faults recorded in the NVM.

The brushless DC motor, p/n 6355-0210-05 (Rev. C), s/n AM0039 was installed into a known good 6355C0001-0l stabilizer trim motor assembly and then an assembly level acceptance test was carried out.

The stab trim motor assembly with the accident motor installed was subjected to an acceptance test per Eaton document CMM 27-40-10 Rev 7, paragraph 1G. The results were recorded on an Eaton Acceptance Test Data Sheet.

The assembly passed all performed portions of the bench test.

1.16.6. The assessment of the language proficiency level of the approach control unit officer

To assess the level of the language proficiency «The analysis of the assessment adequacy of the overall and air English language proficiency level based on the results of the ATC officer testing of 21.06.2013 and 15.03.2016» had been carried out. The activities were performed by the Consulting and Analytic Agency for Flight Safety experts upon the investigation team enquiry. At the outcome of the works, it was noted that in both cases the submitted rater assessment protocol cannot be considered as the documented evidence of the ICAO Level 4 language proficiency. The protocols incorporate the quotes from the ICAO Language Proficiency Requirements that describe Level 4 but in the first case (of 21.06.2013), they do not contain any examples of the speech pattern, indicative of its compliance with these descriptions. As for the second case of 16.03.2016, only some mistakes in pronunciation, grammar structures and vocabulary out of speech pattern are noted.

Based on the analysis of the audio recording of the both tests the following was concluded: the concerned speech pattern does not comply with the ICAO Level 4 proficiency description.

The rater conclusion based on the results of both tests on the ICAO level 4 general and aviation English language proficiency had been drawn up unjustified.

1.16.7. Engineering simulation (Mathematical modelling)

With the aim to determine the stability and controllability performance of the aircraft in the progress of the accident flight against the performance of the type aircraft, to evaluate the range of the potential external disturbances, which the aircraft had been affected by, as well as to compute the non-registered parameters the engineering simulation of the flight has been performed together with the kinematic consistency of the recorded data.

The kinematic consistency has been applied to correct the potential reciprocal imbalance of the recorded data that is often observed due to the different (sometimes, insufficient) sampling rate, the record of the same parameters by different means and the instrument errors. The kinematic consistency allows integrating the recorded acceleration values to check the compatibility of the primary inertial parameters: altitude, ground speed and drift angle. The mutually corresponded and adjusted set of parameters is the output that allows computing the wind disturbances together with the other parameters such as AOA and sideslip, TAS, etc.

The simulation was set up for about last 90 s of the flight (the simulation was stopped 3 s before the impact with ground due to the model constraints). At the simulation the Boeing 737-800 six-degree-of-freedom mathematical model, adjusted as per the results of the flight tests, has been used. The similar mathematical model is used into the Level D FFS.

The initiation (balance) of the mathematical model was carried out with the estimated values of weight and CG, as well as for the actual parameters of flight (airspeed, etc.), the controls deflection and the engines power mode, recorded by FDR. At the simulation, the estimated values of the horizontal components of the wind were taken into account. The vertical component of the wind, including the gusts, was disregarded as per the calculations it was inconsiderable.

The position of the high-lift devices, stabilizer and landing gear were taken according to the actual data as per the FDR record.

In the progress of the simulation with the use of the “mathematical autopilot” the small biases were applied to the recorded deflections of the control surfaces and controls to ensure the correspondence of the estimated and recorded values of the pitch, bank and heading angles with the verification on the other parameters, Fig. 46, Fig. 47 present the results of the simulation. On figures the signs of the parameters comply with the convention, enacted in USA.

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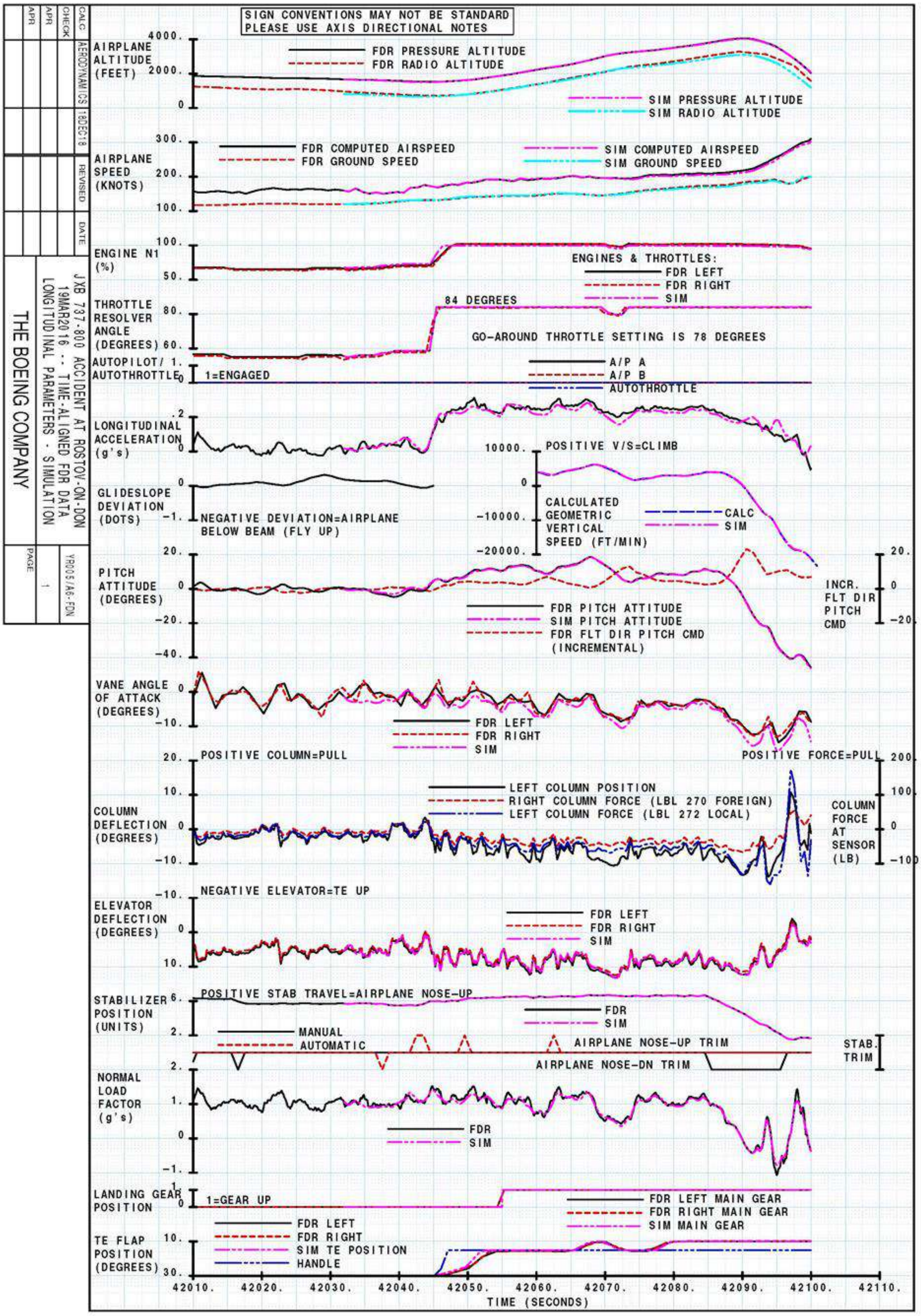

Fig. 46. The results of the engineering simulation (the pitch channel)

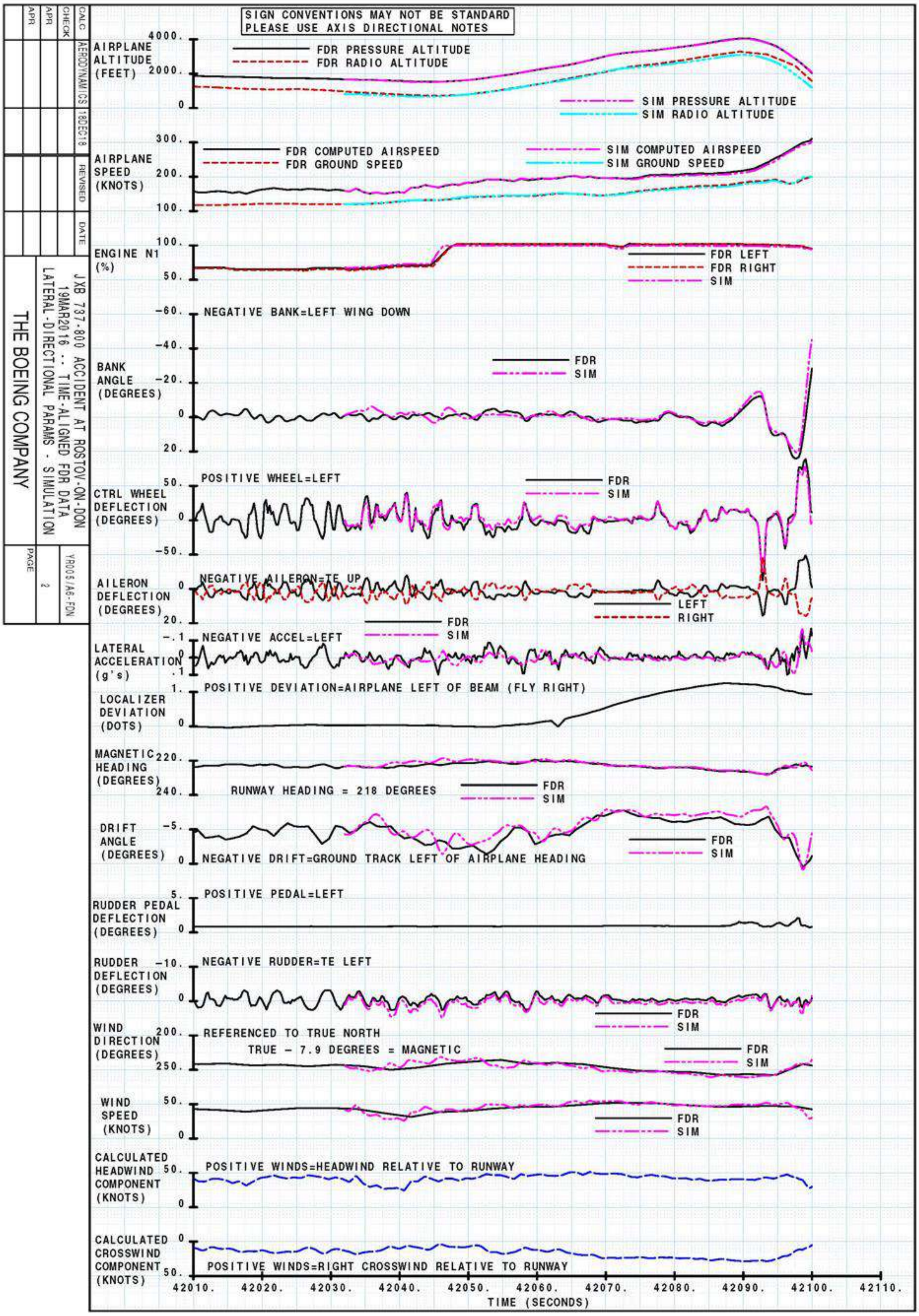

Fig. 47. The results of the engineering simulation (the lateral and directional channels)

On the results of the engineering simulation, the estimated data match the FDR ones very closely. It means that the aerodynamic performance of the aircraft in the accident flight complied with the performance of the type aircraft, the airplane motion was determined by the control surfaces deflection, the engines power mode and actual wind disturbances. The airplane was not anyhow affected by the other factors, for example by the icing.

The flight leg within the time of 0:41:14 – 0:41:21 (42068 – 42075 on the plots above), on which the rapid decrease of vertical G from ≈ 1.35 g to ≈ 0.4 g with its subsequent restoration up to ≈ 1.25 g occurred, has been analyzed apart. The load factor change in question was accompanied by the “emotional” exhale of one of the crewmembers. It was found that this very change was entirely due to the control inputs.

The crew capability to recover from the current state of the airplane by the control column deflection only was assessed as well (while keeping current positions of all other controls including stab trim, throttles and flaps). The simulation of the scenario, at which the control column full pull position (the corresponding forces amount to about 125 lb (55 kg)) occurred at the point of time[12], concurrent to the stabilizer trim stop, when the aircraft in descent had been passing the true altitude of ≈ 2000 ft (610 m), was the evidence that the aircraft recovery from the descent had occurred at the true altitude of about 500 ft (150 m) with the further transition to climb (Fig. 48a).

As per FDR immediately prior to the aircraft impact with ground (IAS ≈ 340 kt) at the full aft position of the control column the elevator deflection amounted to 5^0. According to the materials, submitted by the aircraft manufacturer, because the maximum output force of the PCUs is limited, the maximum elevator deflection for the given conditions (the altitude of the flight, the stabilizer position, AOA and sideslip angle values) is dependent on the airspeed.

The maximum elevator deflection vs airspeed dependency Fig. 48 represents the notional dependency of the maximum available elevator deflection vs IAS. The numerical values of the scales are not given as they constitute the Boeing Company trade secret. In the progress of the investigation, the investigation team had been provided with the stated dependency, comprising the numerical values. The convergence of the factual and calculated elevator deflection is satisfactory.

[12] As per the FDR data, at that very moment the control column had been momentarily deflected to a pull position at approximately 2/3 off the neutral.

PCU Blowdown

737

Request: Plot the elevator position where the PCU is at maximum output force (also known as "blowdown").

Answer: See plot to the right that shows a notional chart of how the maximum elevator deflection is affected by airspeed.

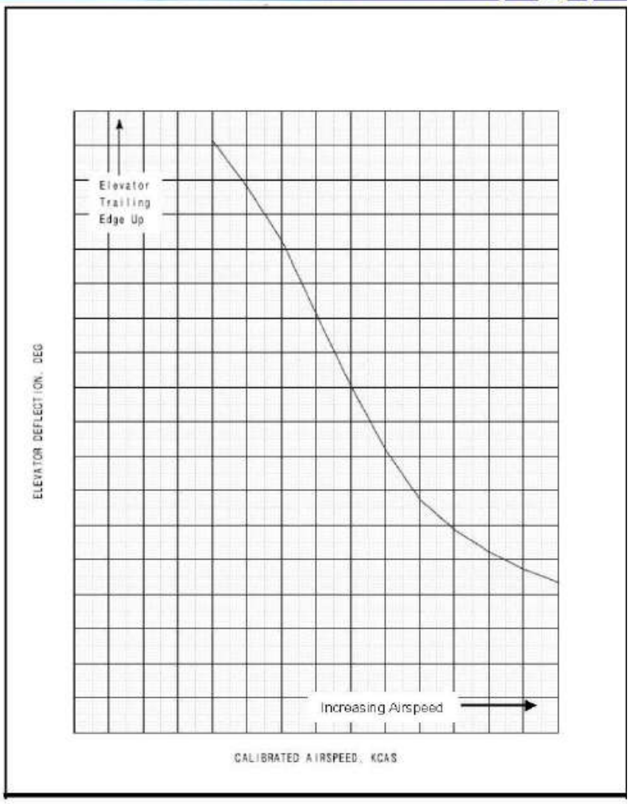

Fig. 48. The maximum elevator deflection vs airspeed dependency

Pilot Total Column Force

Further Discussion

- It is understood that MAK would like to determine when the airplane was still recoverable with a full aft column input.
- As part of the Boeing simulation data match effort, analysis was performed where FDR column data was replaced with full aft column.
- Analysis data is shown on the plot to the right.
- Full column was applied at time 42097 seconds (pink trace). Column force of 125 lb was sufficient to reach maximum column aft position.
- **Conclusion**: With a full and sustained aft column applied at time 42097 seconds, the aircraft would have been recoverable with about 500 feet minimum ground clearance. This is about 2 seconds after the FO said "No! Pull it! Pull it!", and just after the FO re-stated "Pull it!"
- The airplane was also fully recoverable with column input any time prior to 42097 seconds.

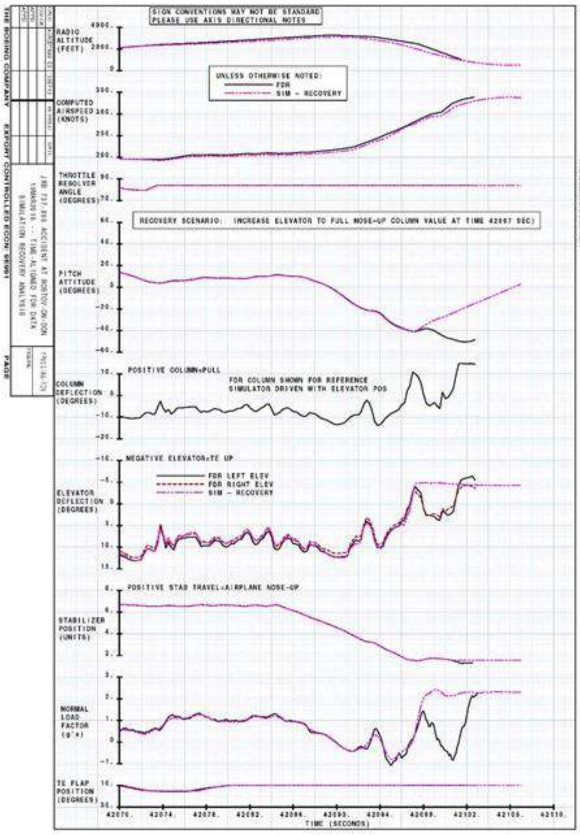

Fig. 48a. Simulation of airplane recovery

1.16.8. On the control column forces

The pilots command the elevator, deflecting left or right control columns, which via the system of cables, rods, pogos and the input torque tube transfer the control input to the PCUs input rods. Mechanically, the PCUs with the pressure of the power fluid via the output torque tube move the elevator. The aerodynamic forces of the elevator are not transferred to the control columns. The Elevator Feel and Centering Unit is designed to provide feedback "on forces". The force value depends on the columns deflection, the stabilizer position and IAS of the flight. The forces, generated at the control columns movement, are measured with the pitch control wheel steering force transducers, which, in their turn, transfer the signals, proportionate to the forces value, to the FCC. The separate force sensors are integrated to each of the control columns. The actual position of the left and right control columns is measured by the control column position sensors. The values, measured by the sensors in question, are recorded by the FDR. It is important to understand that the measured forces values are the forces on sensors and not the forces on the control columns themselves (i.e. these are not the forces that the pilots sense). For example at the application of forces on the left column only, because of the mechanical coupling of the linkages, as normal both columns will move simultaneously, with that the specific forces will be measured both with the right and the left sensor, still in general their value will be different. If one pilot is on the controls, the forces value "by his sensor" will be greater.

The control linkage integrates the control column breakout mechanism, which is activated, when the forces by either sensor exceed 66 lb (30 kg). With that, the control column may be actually deflected by only one pilot, whereas another pilot may be off the controls. At the decrease of forces less than the threshold value, the linkages are again "coupled".

Based on the FDR record (Fig. 49)[13], in the accident flight until the time of 00:41:32 (42088 on the plot below), the forces, measured by sensors had not exceeded 66 lb and the breakout had not occurred. After the indicated point of time the breakout of the control columns occurred, in this throughout the entire interval the active control was carried out from the PIC's duty station.

[13] On figure the signs of the parameters comply with the convention, enacted in USA.

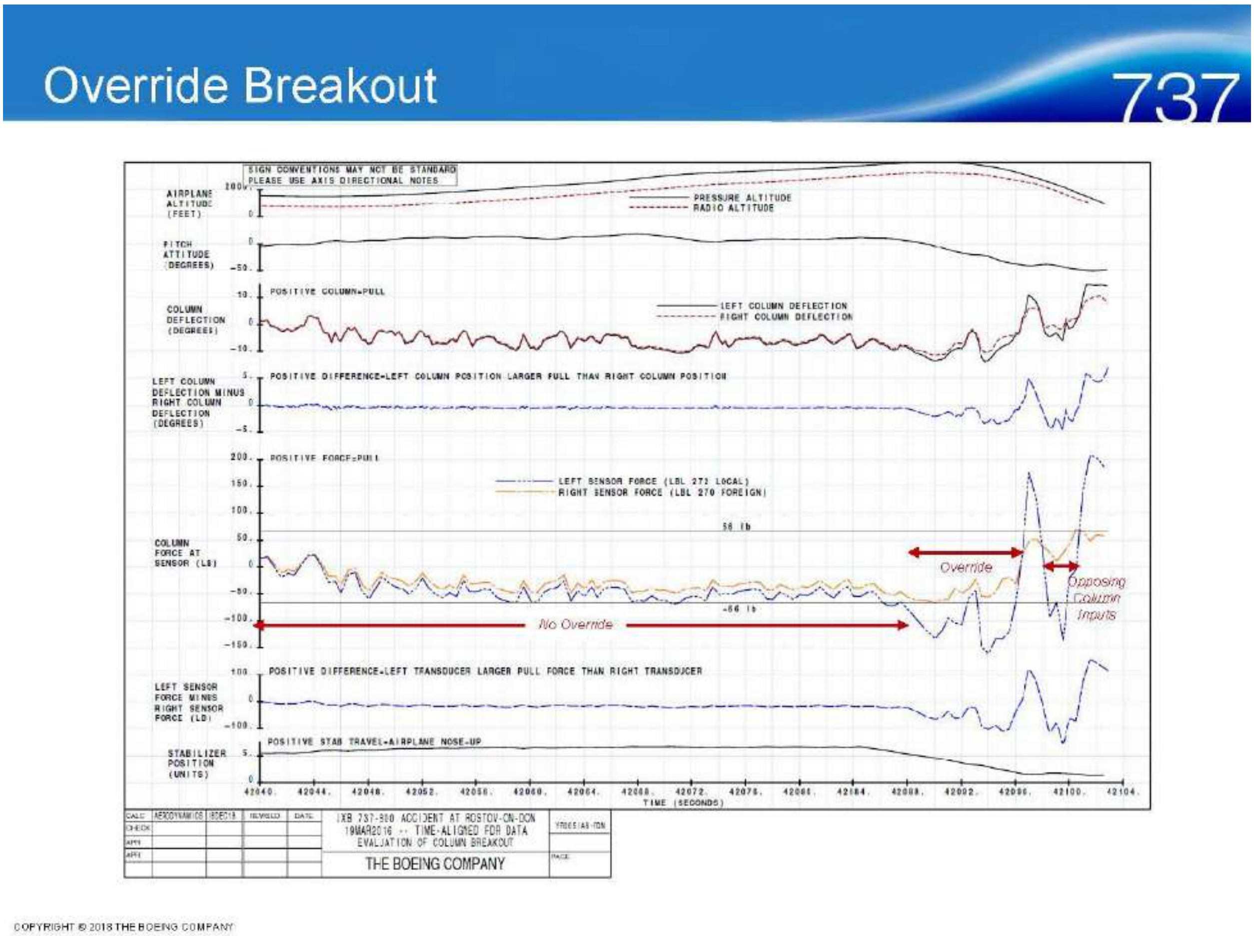

Fig. 49. The control column breakout mechanism activation and the "dual" pitch control

Within the time of 00:41:44 – 00:41:47 (42098 – 42101 on Fig. 49) the forces by the left and the right sensor have the opposite signs that is the evidence of the divergent actions of the pilots, of the PIC - to nose down, the F/O – to nose up. The indicated interval correlates to the activation of the EGPWS alert.

Following the request of the investigation team, the aircraft manufacturer evaluated the forces on the PIC's control column itself. The predicted data are valid only if the control is exercised from the one duty station. The computation results are given on Fig. 50. On figure the signs of the parameters comply with the convention, enacted in USA.

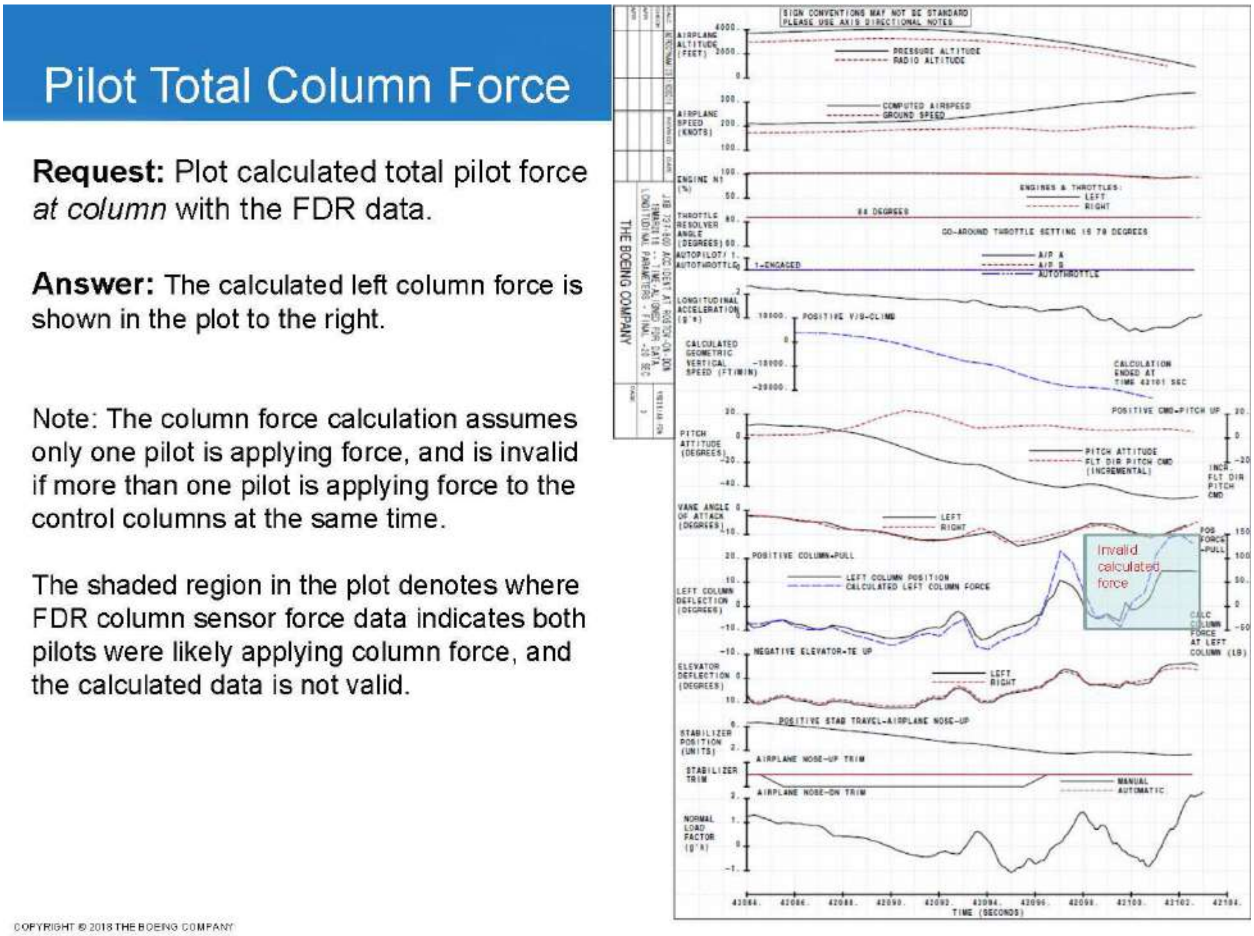

Fig. 50. The estimated forces on the PIC's control column

The results inside the crosshatched region may be unreliable as the control was exercised with both pilots. The computations were the evidence that at the moment of the stabilizer trim initiation to nose down the pilot flying, for the considerable time, had been applying the "pushing" forces of about 50 lb (23 kg)[14].

1.16.9. The reconstruction of the Head-Up Display/HUD readings

According to Rockwell Collins, the HUD manufacturer (USA), as of the moment of the examination the method to recover the HUD readings, based on the data, recorded by FDR, through the stream video was quite complicated and time-consuming (inclusive of the limitation of the sampling rate of the parameters, recorded by FDR) and allowed obtain the result within the limited time interval only. Following the investigation team request the manufacturer reconstructed the HUD images at specific time instants. The reconstructed images and their description are presented in the Analysis section of the Report.

The HUD manufacturer emphasized that the represented images were the reconstruction of the indication only (and not the accurate depiction), among others implemented through the interpolation of the available FDR data. The presented images should not be considered *"the*

[14] Hereinafter the "pushing" ("pressing") forces mean these that are generated on the control column at its forward deflection (to nose-down). At the aft deflection of the control column (to nose-up) the "pulling" forces are generated.

complete and accurate reproduction of what the pilot was actually seeing". They (the images) are the most accurate one out of possible approximations of what should have been displayed on HUD as per the available FDR data. The reconstructed images do not contain the data on a range of the flight parameters, of which there is no information, as well as on the settings of the display itself (for example the brightness) or on the possible impact of the outside environment (for example clouds) on the display picture.

The comprehensive description of the HUD indication symbology is stated in the HGS Model 4000 Pilot Guide for the Boeing 737 Series.

1.17. Organizational and management information

The postal address of the Rostov-on-Don airport: 344009, Russia, Rostov-on-Don, 270/1, Sholokhov avenue. The airport is in the area of responsibility of the Southern FATA Interregional Territorial Department.

The Dubai Aviation Corporation, trading as Flydubai.

Legal address: PO Box 353.

Dubai Aviation Building, Ittehad Road 353, Dubai, United Arab Emirates.

The UAE GCAA carries out the supervision of the corporation activities.

1.18. Additional information

1.18.1. On the fatal accident to the Ilyushin Il-86 RA-86060 aircraft at the Sheremetyevo airport

On July 28, 2002 at 11:20 UTC, at daytime in VMC after takeoff the fatal air accident occurred to the Ilyushin Il-86 RA-86060 aircraft, owned by the Pulkovo airline, FSUAE. The aircraft was performing a ferry flight with no passengers aboard. The air accident resulted in the death of 14 crewmembers, two persons sustained serious injuries.

The investigation team concluded the following[15]: The accident occurred because the aircraft reached the critical AOA at the climb out and entered the stall owing to stabilizer trim to the full nose up position (-12°) at the rate, consistent with the function of 4 hydraulic motors. The created pitch-up moment could not have been counteracted by the pilots with the elevator.

The discrete signal "The press of the stabilizer primary control switches", recorded by the MSRP-256 FDR is the evidence of the stabilizer trim control input by one of the pilots in 2-3 s after the aircraft liftoff from the runway".

As the result of the examination of the survived structure elements, the stabilizer control system failures had not been detected. The analysis of the schematic and structural design of the

[15] This section cites the excerpts out of the investigation team conclusion on the investigation of the Il-86 RA-86060 aircraft fatal accident, which help to figure out the analysis and conclusion of the investigation team on the fatal accident to the Boeing 737-8KN A6-FDN aircraft.

Il-86 aircraft stabilizer control system had not identified the potential failures which could have led directly to the uncommanded stabilizer movement with a probability greater than “practically improbable”.

Fig. 51 presents the takeoff parameters. It is notable that the stabilizer control switches remained pressed 15 s more after the stabilizer setting reached the limit position. The release of the switches is most probably related to the intensive control column input that could have led to the change of the control wheel “grasp”.

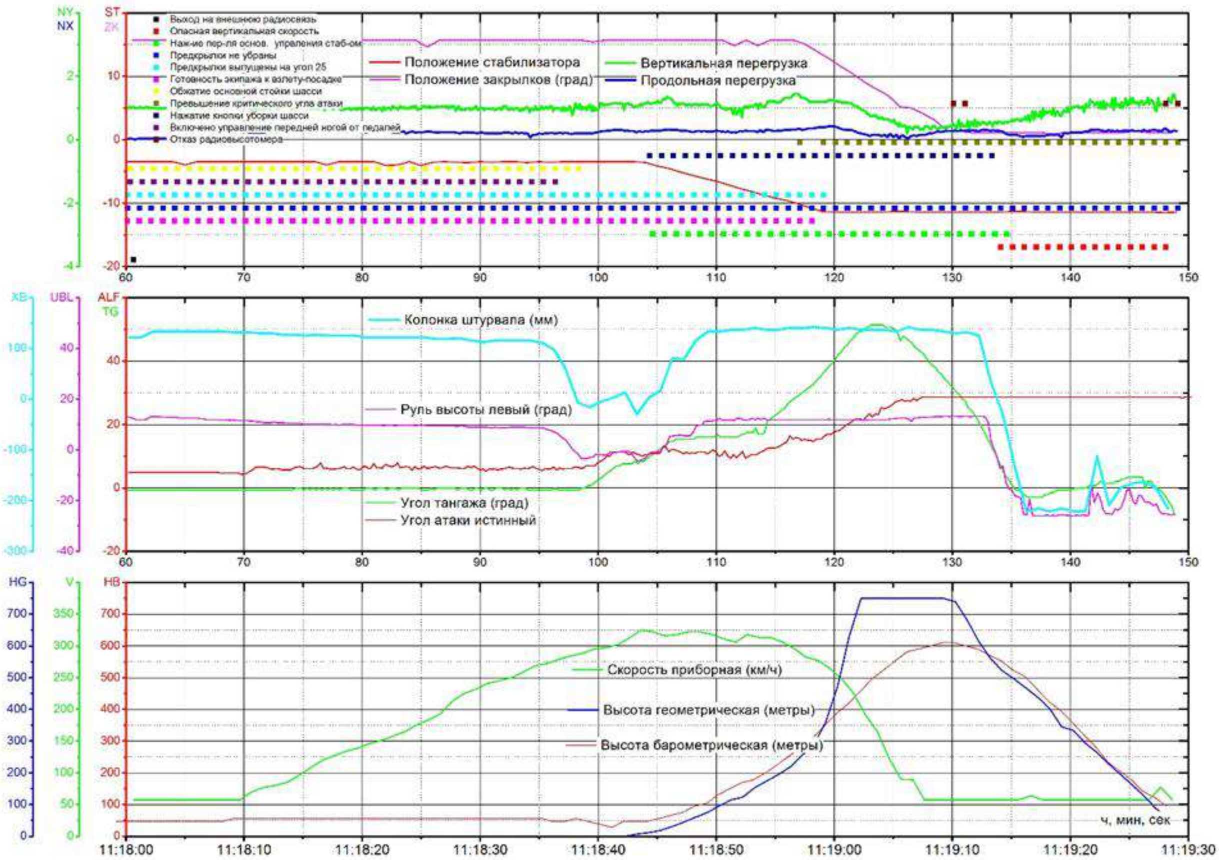

Fig. 51. The takeoff parameters of the Ilyushin Il-86 RA-86060 aircraft on 28.07.2002

Legend to Fig. 51 (colors of filled dots):

■	black	external radio communications
■	red	GPWS warning
■	bright green	pressing of the horizontal stabilizer main control switches
■	blue	leading-edge slats are extended
■	azure	leading-edge slats are deployed to 25 degrees
■	violet	the crew readiness for takeoff/landing
■	yellow	weight-on-wheels
■	khaki	AOA too high
■	dark blue	pressing of the landing gear retraction button
■	dark violet	nose landing gear control by pedal ON
■	purple	radioaltimeter failure

Legend to Fig. 51 (colors of lines):

first graph:

red — horizontal stabilizer position
violet — flaps' position
bright green — vertical G
blue — longitudinal G

second graph:
azure — control column position
violet — LH elevator (degrees)
bright green — pitch attitude angle (degrees)
red — true angle-of-attack

third graph:
bright green — IAS (km/h)
blue — radioheight (meters)
red — pressure altitude (meters)

In the progress of work, the investigation team identified the following hazards that correlate with the circumstances of the Boeing 737-8KN A6-FDN fatal accident:

– at the flight legs that imply the increased workload of the crewmembers or at their non-optimal working condition, the time, within which the fact of the stabilizer trim is identified, is significantly increased;

– throughout the operation the crewmembers get used to the stabilizer trim alert (as for the Il-86 aircraft it is the callback signal on every 0.5^0 of the stabilizer trim) and it is not “alarming” for them;

– the stabilizer position indicator is not very good readable;

– at the long press of the stabilizer control switches the feeling of feedback forces (on a finger that presses trim switches) may be lost as these are little and, consequently, the uncontrolled stabilizer trim (the prolongation of the earlier started action) may occur, for example, at the distraction of the pilot flying or at his non-optimal working condition (in the progress of the investigation the occurrences of the switches “keeping be pressed” up to 34 s had been revealed[16]);

– the crewmembers consider the stabilizer control system reliable and do not anticipate its failures that degrade the in-flight stabilizer position monitoring;

– not all the pilots have the necessary knowledge on the forces trim principle as for the aircraft with the trimmable stabilizer.

1.18.2. On the stabilizer control at the Boeing 737-800 aircraft

According to FCOM, Volume 2, page 9.20.7, the horizontal stabilizer is positioned (controlled) by a single electric trim motor controlled through either the stab trim switches on the PIC and F/O control wheels (on the left horn of the control wheel at the PIC’s duty station and on the right one at the F/O’s duty station) or autopilot trim.

[16] The “keeping be pressed” occurrences had been noted with both the crewmembers of the accident aircraft, and the other crewmembers of Pulkovo airline.

Note: *The stabilizer trim is only possible with the simultaneous press of two independent switches on the either control wheel. One of the switches ensures the direction of trim, whereas another one ensures "power supply".*

Stabilizer trim switches on each control wheel actuate the electric trim motor through the main electric stabilizer trim circuit when the airplane is flown manually. With the autopilot engaged, stabilizer trim is accomplished through the autopilot stabilizer trim circuit. The main electric and autopilot stabilizer trim have two speed modes: high speed with flaps extended and low speed with flaps retracted. If the autopilot is engaged, actuating either pair of stabilizer trim switches automatically disengages the autopilot.

The STAB TRIM MAIN ELECT cutout switch and the STAB TRIM AUTOPILOT cutout switch, located on the control stand, are provided to allow the main electric trim and/or autopilot inputs to be disconnected from the stabilizer trim motor.

There are also control column actuated stabilizer trim cutout switches. These switches ensure the stop of the stabilizer trim through the main electric stabilizer trim circuit or autopilot stabilizer trim circuit at the actual deflection (position) of the control column by more than the threshold value (≈4°) to the direction, opposing the stabilizer trim.

Note: *FCOM in the description of the stated function reads the following: «Control column actuated stabilizer trim cutout switches stop operation of the main electric and autopilot trim when the control column* ***movement opposes trim direction****». The investigation team notes that the applied term "movement" is ambiguous. For example, at the full push of the control column and press of the trim switches in the same direction the stabilizer will move. If now, without the release of the stabilizer trim switches, start the control column aft movement the stabilizer will not stop. The stabilizer movement will only stop when the control column will pass through neutral and will be positioned to a pull by more than the threshold value.*

When the STAB TRIM override switch is positioned to OVERRIDE, electric trim can be used regardless of control column position.

Manual stabilizer control is accomplished through cables, which allow the pilot to position the stabilizer by rotating the stabilizer trim wheels (two of these trim wheels are installed, one for PIC and one for F/O). The stabilizer is held in position by two independent brake systems.

The stabilizer trim wheels rotate (making the hum), when the stabilizer control (trim) is carried out on the either circuit: main electric or autopilot one. Manual rotation of the trim wheels can be used to override autopilot or main electric trim. Grasping the stabilizer trim wheel will stop stabilizer motion. With that, the effort required to manually rotate the stabilizer trim wheels may be considerable under certain flight conditions.

The presence of the cutout switches, which are actuated at the control columns deflection, establishes another feature at controlling the stabilizer with the trim switches on control wheels. At the control columns position close to neutral the stabilizer movement, commanded by one of the pilots (for example to nose-down) may be stopped by the other pilot by pressing “his own” trim switches to the opposite direction (to nose-up). At the control column deflection and the cutout switches actuation the stop of the stabilizer movement (which, as mentioned above, in this case is only possible in the direction of the control column deflection) by another control wheel is not possible. All the cases of the possible response of the stabilizer to the trim switches actuation at the forward deflection of the control columns are given in the table below:

The control column position (no mismatch as for their position)	The trim switches position on the PIC’s control wheel	The trim switches position on the F/O’s control wheel	The stabilizer movement
< 4° «forward» (the cutout switches are not actuated)	To nose-up	To nose-up	To nose-up
	To nose-up	To nose-down	No movement (due to the control commands mismatch)
	To nose-down	To nose-up	No movement (due to the control commands mismatch)
> 4° «forward» (the cutout switches have been actuated)	To nose-up	To nose-up	No movement (due to the cutout switches actuation)
	To nose-up	To nose-down	To nose-down (the control command to nose-up does not pass (cuts out))
	To nose-down	To nose-up	To nose-down (the control command to nose-up does not pass (cuts out))

1.18.3. On the PFD monitoring at the forward deflection of the control column

In the progress of the investigation team activities, a number of pilots noted that at the correct posture at the seat with the gradual forward deflection of the control wheel the view of the PFD indication is degraded (Fig. 52). At the deflection by ¾ of control column full travel the significant part of the PFD “is blocked” to the pilot. The investigation team is of the opinion that, as for the accident flight, this specific factor had no significant impact, as the PIC had been controlling the aircraft by HUD, whereas the F/O had the correct concept of the aircraft attitude and had granted the appropriate prompts to the PIC. At the same time, these features should be additionally analyzed and briefed to the pilots in order to monitor the relevant risks.

Control column full forward position **Control column ½ forward position**

Fig. 52. The pictures of the PFD visibility at different positions of the control column

1.19. Useful or effective investigation techniques

Within the investigation, the reconstructed images of the HUD were used. Refer to the 1.16.9 and Analysis sections for details.

2. Analysis

2.1. Description of the flight

At the overnight into 19.03.2016 the Flydubai airline flight crew, consisting of the PIC and F/O, was performing the round-trip international scheduled passenger flight FDB 981/982 en route Dubai (OMDB) – Rostov-on-Don (URRR) – Dubai (OMDB) aboard the B737-8KN A6-FDN aircraft.

The FDB 981 flight departure was scheduled for 17:45 (21:45 local time). Reportedly, the crew arrived for the preflight check one hour before STD, which met the airline OM provisions. The preflight preparation was carried out by the crew themselves in full under the supervision of the PIC.

The PIC and F/O had never flown together prior to the accident flight. Furthermore, it was the first flight to the Rostov-on-Don aerodrome for both crewmembers. As of the day of the accident the PIC had performed 14 flights to the RF aerodromes, eight of which as a PIC. The F/O had not performed any flights to the RF aerodromes before.

Note: *The crew formation so composed had been consistent with the UAE GCAA and the airline OM requirements. Specifically, OMA item 5.2.10.2 allows for the performance of flight to the aerodrome, both flight crewmembers are not familiar with, if there are the instrument approach charts for this aerodrome and they are available to the crew at the flight preparation.*

At the preparation and performance of the flights, the airline uses the Lufthansa Systems LIDO aeronautical information. Every crewmember has an iPad with the installed software.

At the preparation of the flights to the RF aerodromes, the crewmembers undergo additional briefings on the specific aspects of such flights performance.

The airline OM Part C incorporates specific sections on all the destination aerodromes. As for the Rostov-on-Don aerodrome (Section 16.B.136), there is a warning on the application of the specific restrictions "FLYDUBAI RESTRICTIONS APPLY". Specifically it is determined that the approach, landing and takeoff is performed by the PIC only ("CAPTAIN ONLY approach, landing and take-off"). The non-standard glideslope angle of 2°40' and the necessity to confirm the setting in use, QNH or QFE, are noted as well. Additionally, there is a notice that the crew should be aware of possible turbulence and windshear on final.

The investigation team considers that the airline OM reflected the specific features of the flights both to RF in general and to the Rostov-on-Don aerodrome in particular.

According to the airline standards, the crewmembers receive their monthly flight schedule before 25th of the previous month that ensures (if necessary) the sufficient amount of time for self-study (including the study of the specific features of the destination aerodromes).

As per the available information (Section 1.5.1), the crewmembers held the valid pilot's licenses, have undergone all the necessary training and were ready to operate the flight.

The crewmembers were issued valid medical certificates.

Note: *As it is indicated in Section 1.13, as per the results of the forensic medical expertise of the PIC and F/O, some chemical substances, including ethanol, were detected. With that, the expert team concluded that the presence of the chemical substances was associated with the nature of the injuries and the remains location environment and that it is not the evidence that the PIC and F/O, as of the moment of the accident, had been in a state of alcohol or another toxic (including the drug one) intoxication. Thus, the investigation team did not reveal any signs of the consumption of alcohol and another psychoactive substances by the PIC or F/O.*

The analysis of compliance of the work and rest schedule within a record period (28 consecutive days) did not identify any violations. The crew had a sufficient amount of the preflight rest. As per the submitted data, the Fatigue Management System is implemented in the airline. The system encourages the fatigue-related confidential reports by the crewmembers for any stage of the flight operations (the preflight, in-flight, post-flight one). For a number of quantitative indicators the system goes beyond the national aviation legislation (that is it ensures the improved conditions for the crewmembers). Since 2009, the airline has accumulated 450 000 flights with a total flight time of more than 1 million hours. Within the period, 70 fatigue-related confidential reports were submitted. The majority of them were proactive by nature – as the crewmembers reported the fatigue presence and were removed from duty until they felt fit for flight operations.

The forecast and actual weather en route, for the Rostov-on-Don destination aerodrome and the alternative aerodromes of Trabzon (LTCG) and Volgograd (URWW) did not impede the performance of the flight mission and met the IFR. The crew took the appropriate decision to depart. At the same time the weather package, that the crew were provided with, did not contain SIGMET No 6 into the Rostov-on-Don FIR that incorporated the information on the forecast severe turbulence to the south of 48° N and to the west of 48° E from GL up to FL150.

In the progress of the preflight check there were no anomalies detected as for the aircraft systems and equipment functioning. As of the moment of departure, there were no MEL A and B deferred defects. There was one C defect, deferred until 25.03.2016: «F/O FMC Alert Light remaining ON upon self test». The defect in question is covered by MEL Section 34-36-02-01A. The aircraft is valid for flight provided the respective FMC is not used for the autopilot guidance during approach. There were another 7 D defects. The indicated deferred defects did not anyhow affect the outcome of the flight. On the results of all the performed works, including the conducted examinations, the investigation team did not identify any evidences of the technical failures in the accident flight that could have affected the flight outcome.

Based on the data stated in the loadsheet and the computations, made by the investigation team, the aircraft TOW at the departure from the Dubai aerodrome amounted to 68 tons with the CG of 17.3% MAC, which did not exceed the limitations determined by the AFM (79015 kg and 10-31% MAC respectively).

The aircraft was refueled with a sufficient amount of fuel to perform the flight along the approved route with the consideration of the selected alternative aerodromes.

At 18:20 ABOT, the aircraft commenced movement after the passengers' boarding was completed. The delay of 35 minutes against STD was due to the late arrival of the aircraft from the previous flight. At 18:37, the crew took off from the Dubai aerodrome.

At the altitude of ≈2700 ft (820 m) the engage of the right autopilot (autopilot B) is recorded that may be indicative of the active control by F/O on this stage of the flight. The A/T was engaged prior to takeoff. Further, it was an automatic flight.

At 18:59:30 FL360 was reached. The cruise flight was proceeded as assigned at the IAS ≈260 kt.

At 21:19, the crew disengaged the right autopilot and engaged the left one. Most probably, from this point of time the PIC functioned as PF.

At 21:35:00 the FDR recording of the discrete signal "HUD IN USE COMBINER POSN" ("Not stowed") stopped. From the beginning of the flight up to this moment, the HUD functioned in a primary mode/PRI. According to the airline SOP (Supplement D, Section 1.2) the use of HUD, if it is operative is mandatory throughout the entire flight. All the airline flight personnel undergoes the HUD initial and recurrent training (see Section 1.5.1). At 21:50:53, the HUD was again reactivated in an IMC mode. It has not been possible to determine the reasons for such "manipulations" with the HUD. The investigation team did not reveal any signs of the anomalies of the HUD operation in the accident flight. There were no HUD operation anomalies, detected by the crews that performed the previous flights either.

At 21:40 at the LAPTO reporting point the PIC contacted the UAMTS Rostov area center B-1/B-2 combined sector radar control officer: *«Rostov-Control, Good evening. SkyDubai 981, flight level 360»*[17]. The controller relayed to the crew that the aircraft had been identified.

As requested by the crew at 21:51:30 the controller relayed the actual weather at the Rostov-on-Don aerodrome and the information about the active runway: *«Actual weather for*

[17] The crew communication with the ATC and between them was conducted in the English language. In the Report the translation into the Russian language, made by the investigation team with the consideration of the circumstances of the flight, is given as well.

Uniform - Romeo - Romeo - Romeo at 21:30 Zulu time: wind – 250 degrees, 9 meters per second, gusting – 15 meters per second, visibility – 5 kilometers, light shower rain, scattered clouds, ceiling – 390 meters, broken clouds, cumulonimbus – 900 meters, overcast clouds, 3000 meters ceiling, temperature + 6C degrees, dew point +3C degrees, runway in use – 22, braking action – good, temporary wind – 250 degrees, 13 meters per second, gusting – 18 meters per second, visibility – 1000 meters, shower rain, mist..».

At 22:12, the aircraft was transferred under the control of the UAMTS Rostov area center P-3/P-6 combined sector. In contacting the P-3/P-6 sector controller the crew reported: *«Rostov-control, good evening or morning, Sky Dubai 981, maintaining FL 360, inbound KULOM».*

The controller informed the crew that a SIGMET was in force: «*Sky Dubai 981, and for your information, we have SIGMET in our area from surface up to FL 150 for severe turbulence*».

The crew asked to specify the area with a severe turbulence, for which the controller communicated that SIGMET was valid into almost the entire area, but no aircraft had reported turbulence.

At 22:17 the crew requested and was cleared by ATC for descent to FL190, after which started the descent.

The CVR stored the record of the crewmembers communication within little more than 2 hours of flight[18]. With that, due to the long flight in the holding area (see here below) there was no record of the landing briefing stored. In view of this the investigation team is not aware what features of the approach had been discussed by the crewmembers (the communication on what go-around procedure would be applied and under what conditions, namely).

At 22:24, while passing FL220, the crew requested clearance to continue descent, for which the controller instructed the crew that they contacted Rostov Approach.

At 22:24:25 the Rostov Approach controller, after the crew reported approaching the ER/YEGORLYKSKAYA reporting point and having ATIS UNIFORM that incorporated the information on the moderate windshear, issued clearance for descent to FL60 on the ER 22A STAR (Fig. 30).

At 22:33, in the progress of reaching FL60, the aircraft was transferred under the control of the Rostov Radar officer. At 22:33:14, the crew contacted the Rostov Radar controller, reported passing FL60 and requested further descent: *«Control, good evening! SkyDubai 981. Passing FL 60, further descending, FL 60»*. The controller issued clearance for further descent on ER 22A STAR to 600 meters, QFE 990 hPa. According to the approach chart (Fig. 32 and Fig. 33) the QFE altitude 600 m corresponds to 2250 ft QNH.

[18] The record duration meets the established requirements.

The crew at their callout reported the descent to 800 m, but not to 600 m, however the controller did not correct the crew that is inconsistent with FAR-362 item 2.13.3.

Note: ***FAR-362 item 2.13.3:***

If the aircraft crew repeated the clearance or instruction incorrectly, then the controller relays the word "correction" ("wrong"), followed by the content of the correct clearance or instruction.

At this flight stage, the crew set 3300 ft[19] (1000 m) as the target altitude. The flight parameters of the first approach are given on Fig. 53. On the plot the parameter "relative altitude (adjusted for baro correction)" stands for QFE altitude (the altitude above the aerodrome level).

[19] According to the approach chart (Fig. 30) the altitude of passing of one of the fixes (magnetic azimuth 051^{0}, distance 23.8) is 3240 ft QNH (900 m QFE).

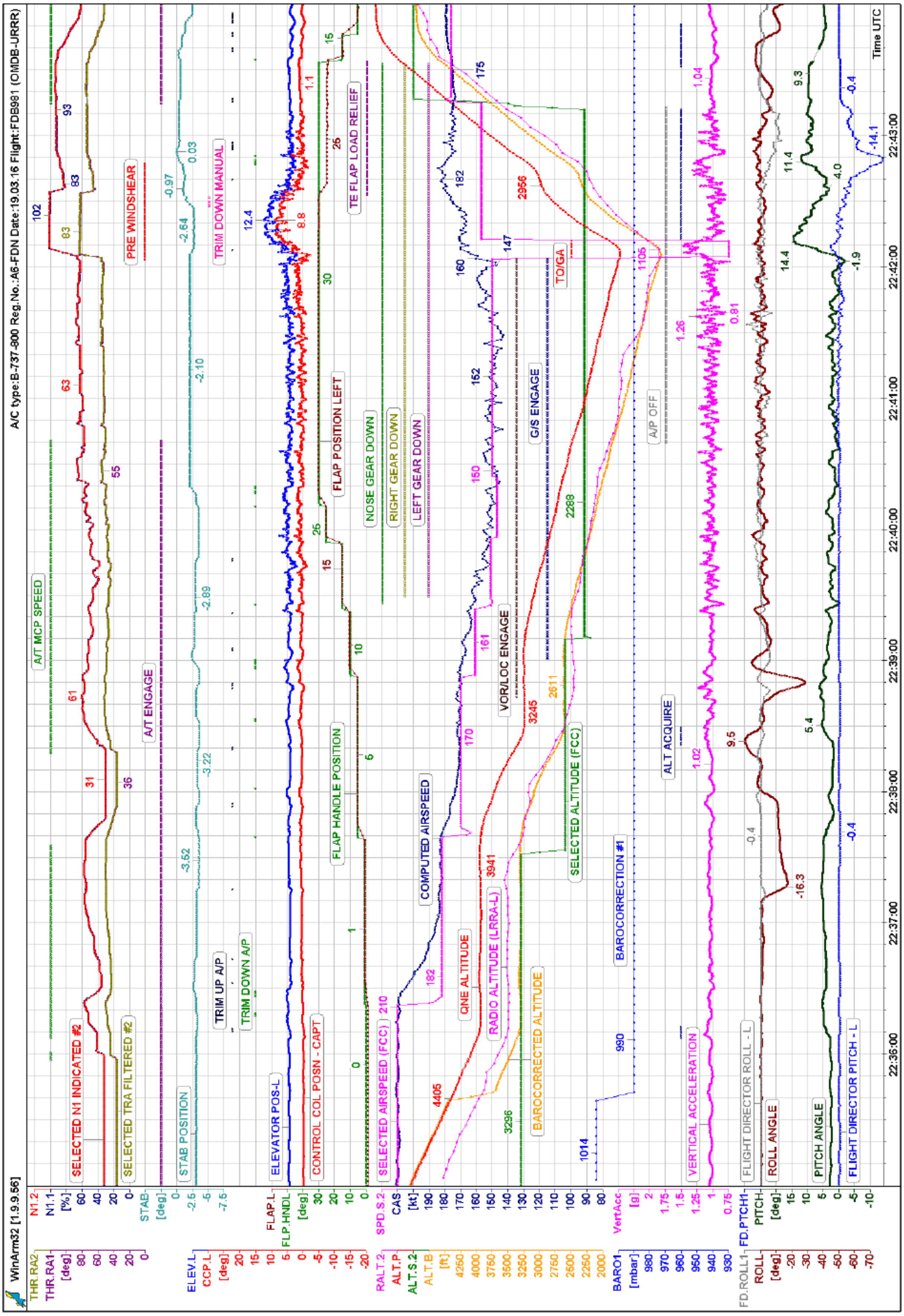

Fig. 53. The flight parameters at the first approach

At 22:35:42, the crew set the pressure of 990 hPa on the pressure altimeters. At this time in descent, the aircraft was passing FL44 (with the established transition level 50).

The set value of the atmospheric pressure was consistent with QFE. The airline aircraft are not equipped for the flights on QFE. Consequently, the airline OM prescribes the flights on QNH only with the use of altitude in feet. As for the flights to countries with the metric system and/or to those that use QFE, the crews undergo specific training on the use of the conversion tables. As mentioned above, the crew clarified the QNH value (1000 hPa) with the ATC. All the further actions by the crew are the evidence that the altitudes set on MCP and reached (including the go-around altitude) were set based on QNH, that is the 990 hPa pressure was an incorrect setting. The difference in pressure of 10 hPa is consistent with the difference in altitude of 280 ft (85 m) that corresponds to the aerodrome elevation. That is to say until the glideslope interception the crew was proceeding the flight on altitudes by a certain amount higher, than the target one. The error of the pressure setting did not affect the outcome of the accident flight. Still the investigation team notes that the use of QFE at the RF airports instead of QNH that is used practically in all the other countries, presents extra risks.

At 22:36:11, the Rostov Radar controller contacted the crew and issued clearance for an ILS approach to RWY 22.

At 22:37:44 the aircraft was transferred under the control of the Rostov Tower controller: *«Sky Dubai 981, contact Rostov Tower, 119,7. Have a nice landing! See you later».*

At 22:38:00[20], the F/O contacted the Rostov Tower controller and reported the descent to 2600 ft[21] and the readiness to capture the localizer.

At 22:38:26, the aircraft reached the altitude of 2600 ft (800 m)[22]. The PIC informed the F/O that 2300 ft (700 m) would be the next target altitude[23].

The controller relayed to the crew the actual wind data: *«wind 240º, 11, gusts 15mps»* and issued the clearance to land to RWY 22.

At 22:38:43, the localizer was captured, at 22:39:00 so was the glideslope. By the moment of the glideslope capture the flaps were extended to 10° (the crew incrementally extended flaps to 1°, 5° and 10° at the respective speeds). At the moment of the glideslope capture the distance to runway amounted to ≈16.5 km (the glide path interception point is located at the distance of 12.52 km (6.76 nm)). The aircraft was proceeding at the altitude of 2600 ft (800 m) in a horizontal flight, with that the altitude of the glideslope capture is 600 m.

[20] It is with this sentence that the CVR record begins.
[21] According to the approach chart (Fig. 30), the altitude of passing of one of the fixes (magnetic azimuth 040º distance 19.8) is 2580 ft QNH (700 m on QFE).
[22] Hereinafter at the description of the first approach and go-around, the altitudes are given in relation to the runway level (on QFE).
[23] According to the approach chart (Fig. 32) the altitude of the G/S capture is 2250 ft QNH (600 m QFE). According to the CVR record, the PIC intentionally increased the target altitude by 50 ft.

After the glideslope was captured, the F/O, commanded by the PIC, set the go-around altitude, equal to 2300 ft[24].

After the initiation of the glide path descent the flaps were incrementally extended to 15°, 25° and 30°, the landing gear was extended as well. By the point of time of 22:40:17, at the altitude of 2050 ft (625 m) at the distance of 12.2 km, the aircraft was in landing configuration.

The current weight was equal to ≈58.5 t. The Vref as for the approach with flaps 30° is 140 kt. After the flaps extension to 30° the crew set the approach speed of 150 kt on MCP, that is the correction to Vref amounted to +10 kt (according to the cockpit communication it is these Vref values and corrections that the crew had calculated). The last weather information, relayed to the crew by the Rostov Tower controller: *wind 240 degrees*[25] *11 m/s gusts 15 m/s.* According to FCT 737 NG (TM), the Command Speed section, pages 1.11-1.12, when calculating the approach speed, the half stable headwind component is counted plus the full value of gusts that exceeds the stable headwind component. With that, the maximum correction should not exceed 20 kt. For the actual conditions the stable headwind component value amounted to: $11*1.94*cos(240°-218°) \approx 20$ *kt*, the exceedance of the gust value against the stable component: $(15-11)*1.94 \approx 8$ *kt*. Thus, the recommended correction amounted to $20/2+8 = 18$ *kt*, that is the speed, selected by the crew, was even 8 kt less against the recommended one.

After setting of the approach speed, the crew performed the LANDING section of the Checklist.

Up to the altitude of 1850 ft (560 m), the approach was performed with the A/P and A/T engaged. At 22:40:40, the PIC (PF) made the decision to proceed the approach in a manual mode and disengaged the A/P and A/T, having called it out to the F/O. At the point of disengage the A/P ensured the glide path descent (the flight, driven by the localizer and glideslope signals), the A/T maintained the speed, set on MCP. There were no deviations off the beam, the IAS altered within a range of 145–155 kt, with that from the altitude of ≈2600 ft (800 m) the aircraft entered the area of turbulence (the vertical G altered within a range of 0.8–1.25 g).

It has not been possible to clearly determine the reasons for the A/P disengage. Probably, it was caused by intensified turbulence. After the A/P disengage the PIC spoke out that *"It should be a bit bumpy and then later should calm"* and then that he is *"flying the cue the speed will come back slowly"*.

Note: *In the communication, the PIC used the term «cue». This sentence context, as well as with the consideration of the airline OM provisions and the HUD, being active (in working condition) (as per the FDR data), the investigation team*

[24] According to the missed approach procedure, the pattern altitude is 2250 ft QNH (600 m QFE).
[25] The landing magnetic heading was equal to 218 °.

makes the conclusion that the PIC was controlling the aircraft, following the HUD indications. At this flight stage the Guidance Cue was obviously used. In this case, the pilot's task is "to overlay" the Guidance Cue by the Flight Path Symbol (Fig. 54).

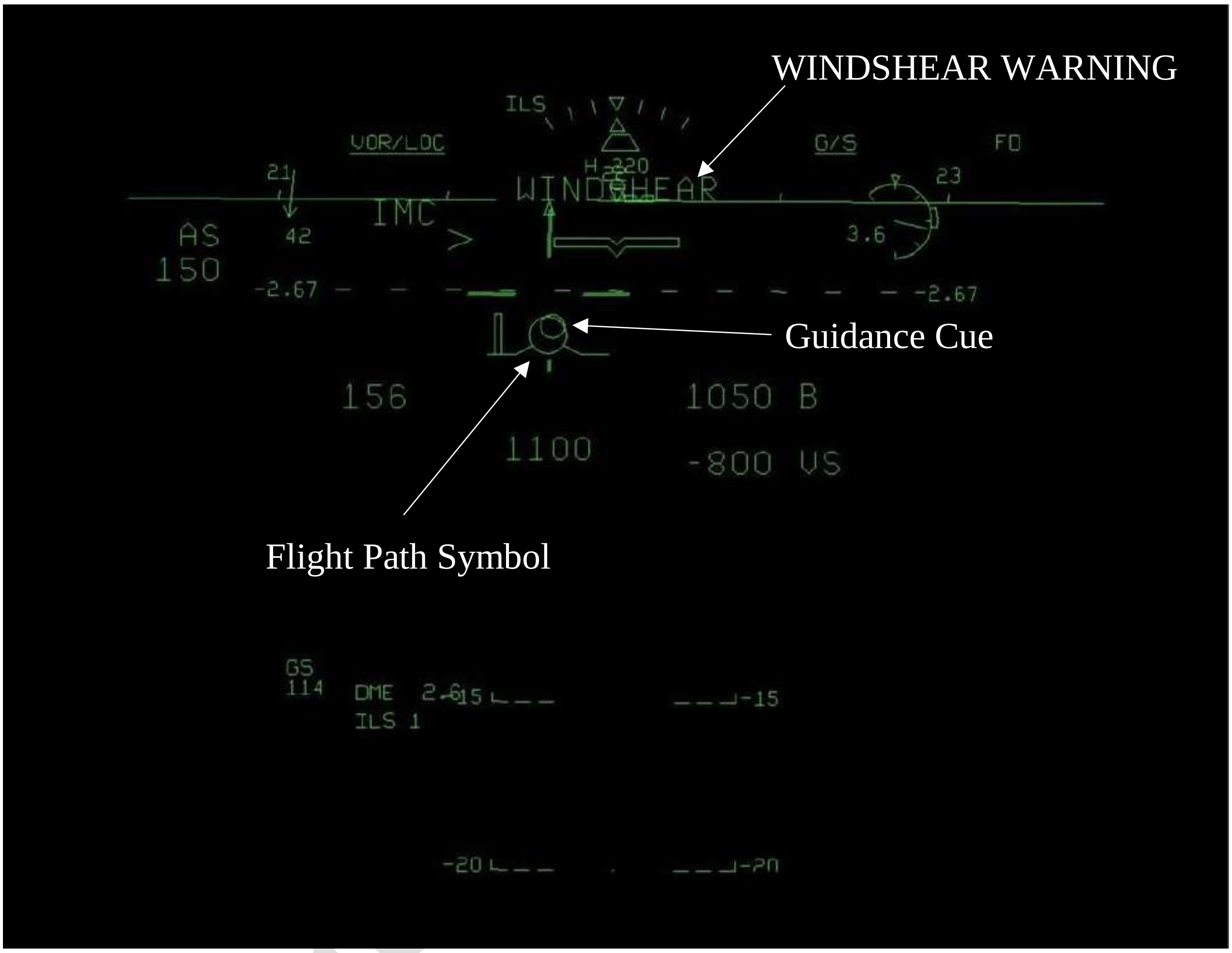

Fig. 54. The HUD reconstructed image at the point of time of 22:42:02 (the windshear warning trigger)[26]

It should be noted that the airline OM encourages the autopilot use on all stages of flight, besides takeoff, go-around (accordingly, as per the OM in progress of the approach the use of two autopilots is prohibited) and the low visibility approach. There were no conditions to follow the low visibility procedure. Thus the A/P disengage on this very flight stage was only due to the respective decision by the PIC.

The PIC performed further approach controlling the aircraft manually with the use of HUD with good accuracy of the flight path hold on localizer and glideslope. The F/O was monitoring the flight with the use of conventional instruments. The investigation team notes that the use of HUD on this very segment of the flight, probably, had a positive effect as for the quality of the manual control, as the HUD supplies information on the deviation off the ILS beams in a larger

[26] Hereinafter the pictures with the HUD reconstructed images represent only the parameters, the reconstruction of which had been possible with a sufficient degree of accuracy based on the FDR record.

scale against PFD and ND. For instance, the scale of the signal of the localizer beam deviation is increased by 6 times against the conventional indication.

At 22:41:50 on the altitude of ≈ 1240 ft (380 m), the PIC told that he could see the runway. The aircraft was then at the distance of 7 km off the runway. According to the ATIS information at that point of time: *cloud scattered at 480 m*.

At 22:42:02 on the altitude of 1100 ft (335 m) the aural «GO-AROUND, WINDSHEAR AHEAD» warning was triggered. There are two windshear detection systems on the airplane: Predictive Windshear (it is a predictive alarm that resides in the Weather Radar system and informs the pilot when the radar has detected a windshear event ahead of the airplane, ≈ 10-60 seconds ahead typically) and Reactive Windshear (this very alarm resides in the EGPWS and informs the pilots when they actually are in a windshear event). The analysis revealed that the warning was triggered by the predictive alarm. Concurrently, the respective information was displayed on HUD (Fig. 54), PFD and ND. It should be noted that the Reactive Windshear warning had never been triggered either on this very segment of flight, or in the progress of the subsequent flight.

It was an almost instant response by the crew, about 1 s from the aural message trigger! This is the evidence of the crew having been prepared for such kind of events and well trained on the simulator as for the practice of actions in windshear. Most likely, the HUD had a positive effect at that, too, as the windshear warning is very vividly noticeable.

22:42:02,1[27]	22:42:04,3	AV	Go around windshear ahead.
22:42:03,2	22:42:03,7	F/O	Windshear.
22:42:03,6	22:42:04,9	CPT	Windshear. Go around.

The PIC made the decision to initiate Windshear Escape Maneuver, that is to perform go-around with the aircraft configuration unchanged (without the retraction of landing gear and flaps) at the maximum thrust (the maneuver is described in QRH D6-27370-8KN-JXB, page MAN.1.10).

Note: ***QRH D6-27370-8KN-JXB p. MAN.1.9:***

Predictive windshear warning during approach (“GO–AROUND, WINDSHEAR AHEAD” aural) perform the Windshear Escape Maneuver, or, at pilot’s discretion, perform a normal go–around.

It should be noted that the operational documentation (for example, OM and FCOM) does not determine the criteria, which the pilot could follow when making a decision to choose between the standard go-around and the Windshear Escape Maneuver. Upon that if in actual windshear, it is no alternative but for the pilot to perform the Windshear Escape Maneuver.

[27] Hereinafter, as for the tables that contain the CVR transcript, in the first column the time of the sentence beginning is given, in the second – the time of the sentence end.

At 22:42:04 the TO/GA mode was activated and the maximum thrust was established as prescribed by QRH («Aggressively apply maximum thrust»). The actual N1 was 101-102% and was considerably higher than N1, required for GA that could have been set at the A/T engaged.

Note: *On this airplane, the function was incorporated of the reduced go around thrust. The concept of the function is that at the go-around with no need of maximum thrust of the engines, at the first press of the TO/GA button the A/T (if engaged) sets some estimated (based on the actual flight conditions) thrust that is sufficient for climb with the target gradient (the estimated RPM value is not recorded by FDR but the pilots may refer to N1 Limit Page or CDS). Another press of the TO/GA button sets the relevant thrust value, indicated by the green bug on the Thrust Mode Display (as for the accident flight – 97 % of maximum thrust). The pilots can set the maximum available thrust only manually by advancing the thrust levers full forward, which had been actually done by the PF.*

After the TO/GA mode activation the HUD automatically switched from IMC to PRI mode (Fig. 55), at the same time the Guidance Cue had become "filled" that is took the form of Windshear Guidance Cue, which is a signal of the Windshear Escape Maneuver carry out.

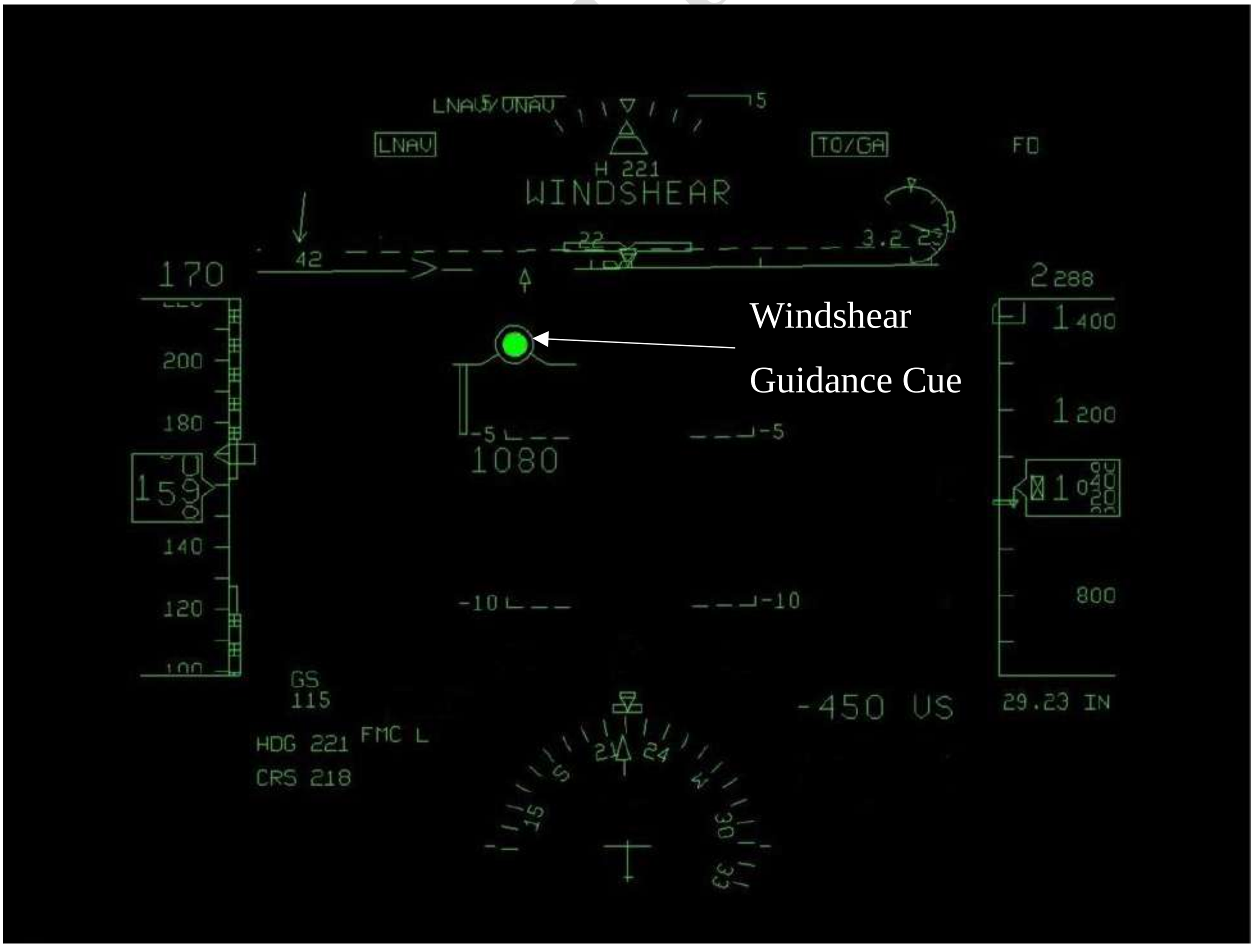

Fig. 55. The HUD reconstructed image at the point of time of 22:42:04 (after the TO/GA mode activation)

In the PRI mode, the HUD “director” indication duplicates the PFD command bars readings that are computed by FCC. Fig. 56 presents the HUD reconstructed image at the point of time of 22:42:08.5, when the position of the pitch command bar was maximum to nose-up. To maintain the target climb path the pilot needs to adjust the aircraft symbol to the TO/GA pitch target line. Alternatively, the pilot may proceed the aircraft control by overlaying the Guidance Cue and Flight Path Symbol.

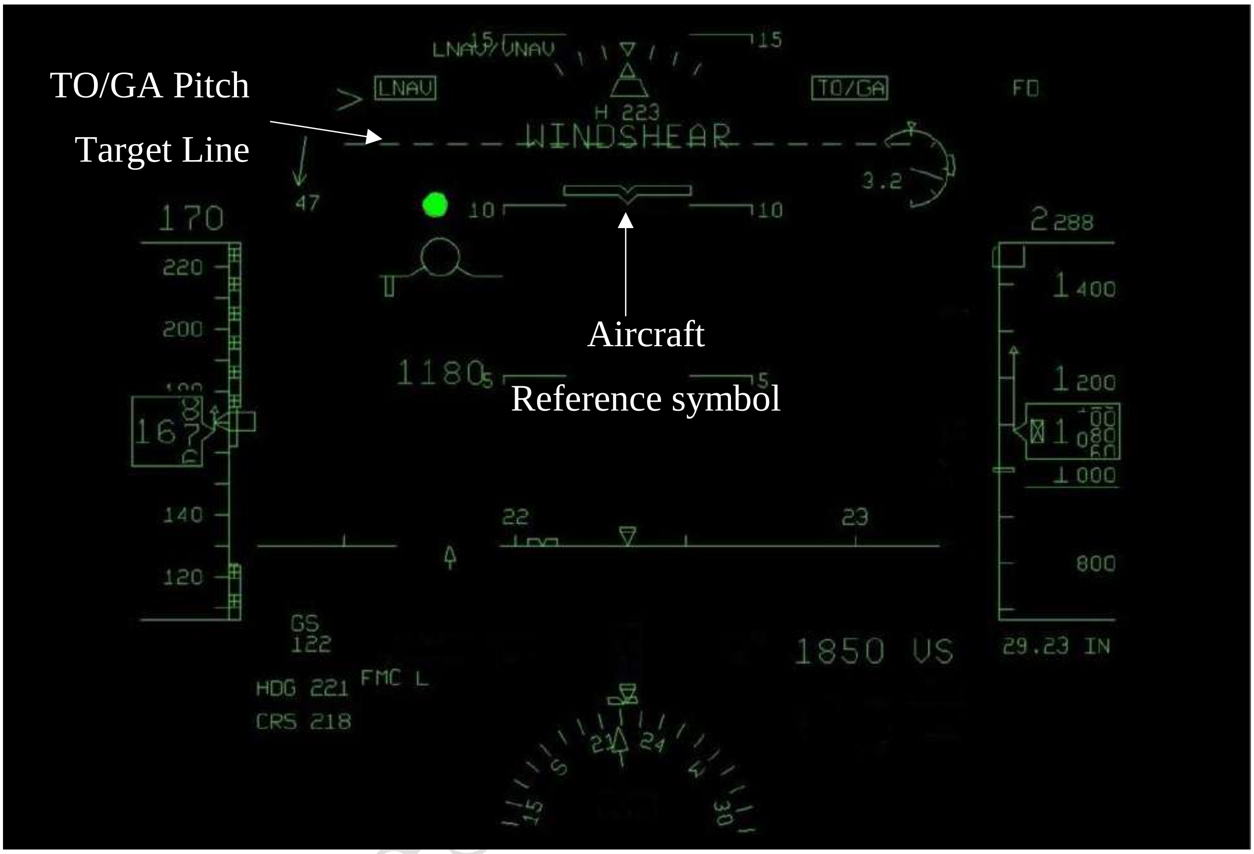

Fig. 56. The HUD reconstructed image at the point of time of 22:42:08.5

Initially in 10 sec, the PIC reached the pitch of 14…15º, following the HUD commands (Fig. 57) and the FCOM and QRH guidance. To counteract the excessive pitch-up moment, generated at the engine thrust increase to maximum, the PIC was forced to move the control column significantly forward.

Fig. 57. The HUD reconstructed image at the point of time of 22:42:11

At 22:42:08, the F/O on the PIC's command reported go-around. The Rostov Tower controller acknowledged the information and instructed the crew that they contacted Rostov Radar 121.2.

The go-around altitude, set on MCP, was 2300 ft, at 1000 ft below that altitude (at 22:42:13), as per the AFDS logic, the ALT ACQUIRE mode was activated (Fig. 58).

Fig. 58. The HUD reconstructed image at the point of time of 22:42:13 (the ALT ACQ mode activation)

The crewmembers did not speak out the activation of this mode, maybe because the F/O was then occupied with the communication with ATC. According to the airline within the flight personnel training the attention is drawn to the need to follow the AVIATE-NAVIGATE-COMMUNICATE principle. Probably such an early report on go-around “to the detriment” of the flight parameters monitoring was related to the necessity to request further climb (higher of the target go-around altitude) as the windshear warning was still displaying.

Indeed, to reach the target go-around altitude the aircraft should have climbed 1200 ft (365 m) only. Taking into account high thrust-to-weight ratio of the aircraft (especially with the maximum thrust of the engines) and high rate of climb it had been difficult to be established on the target altitude without significant reduction of thrust. The Low Altitude Level Off - Low Gross Weight of FCT 737 NG (TM) incorporates the recommendation as follows: *if full go-around thrust is used, reduce to climb thrust earlier than normal*. The operational documentation does not contain information that is more specific: at what stage, up to what value, based on what flight parameters should the thrust be reduced. In case of ALT ACQ activation and active windshear warning the recommended actions are not specified either. According to the information, provided by the airline, as for the flight personnel training, the above-indicated aircraft manufacturer documentation is used. The OM does not contain any “strict” quantitative instructions. In the progress of the simulator training, the flight instructors assess the quality of the exercises performance in a subjective manner, and, if required, another exercise is arranged.

After the activation of the ALT ACQUIRE mode, without being cleared for further climb, the PIC started to reduce pitch with the additional deflection of the control column to “nose-down” (up to 8.5° with the maximum deflection available of 13.75°) and, consequently, with the associated application of additional “pushing” forces. The actions in question with the engines on maximum thrust resulted in the increase of airspeed. The F/O drew the PIC’s attention to the need of monitoring the speed.

22:42:28,9	22:42:31,1	F/O	(Rostov Ra...) check the speed.
22:42:32,7	22:42:33,7	CPT	Speed checked.

At the moment the Flight Path Symbol on HUD was higher than Guidance Cue (Fig. 59 and Fig. 60), that is to maintain the target flight path the additional control inputs to “nose-down” were required. With the control column position unchanged the PIC, in addition, pressed the trim switches on the control wheel for about 4 s to nose-down (the angle of deflection of the stabilizer was changed for 1.8º) that resulted in the pitch reduction up to 3-4° and additional acceleration.

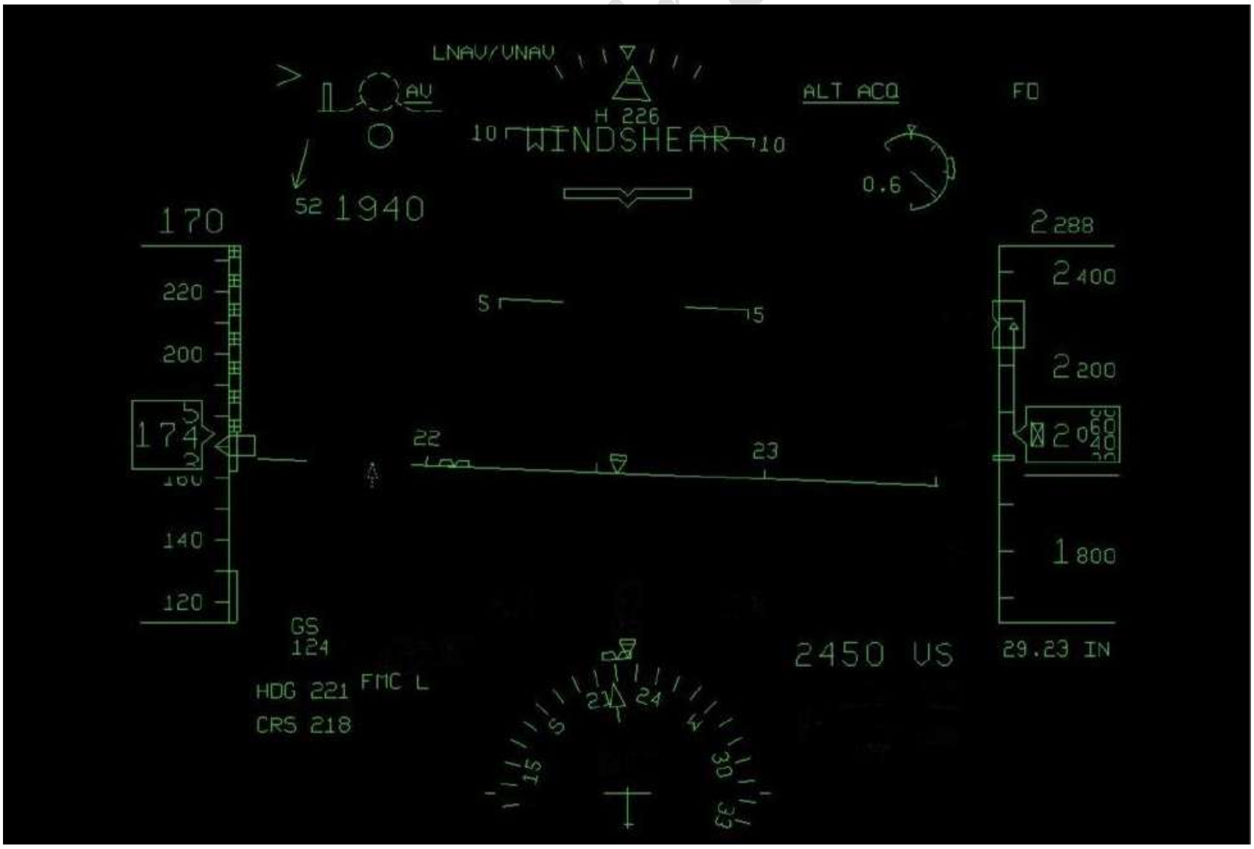

Fig. 59. The HUD reconstructed image at the point of time of 22:42:27.5 (the first press on the stabilizer trim switches)

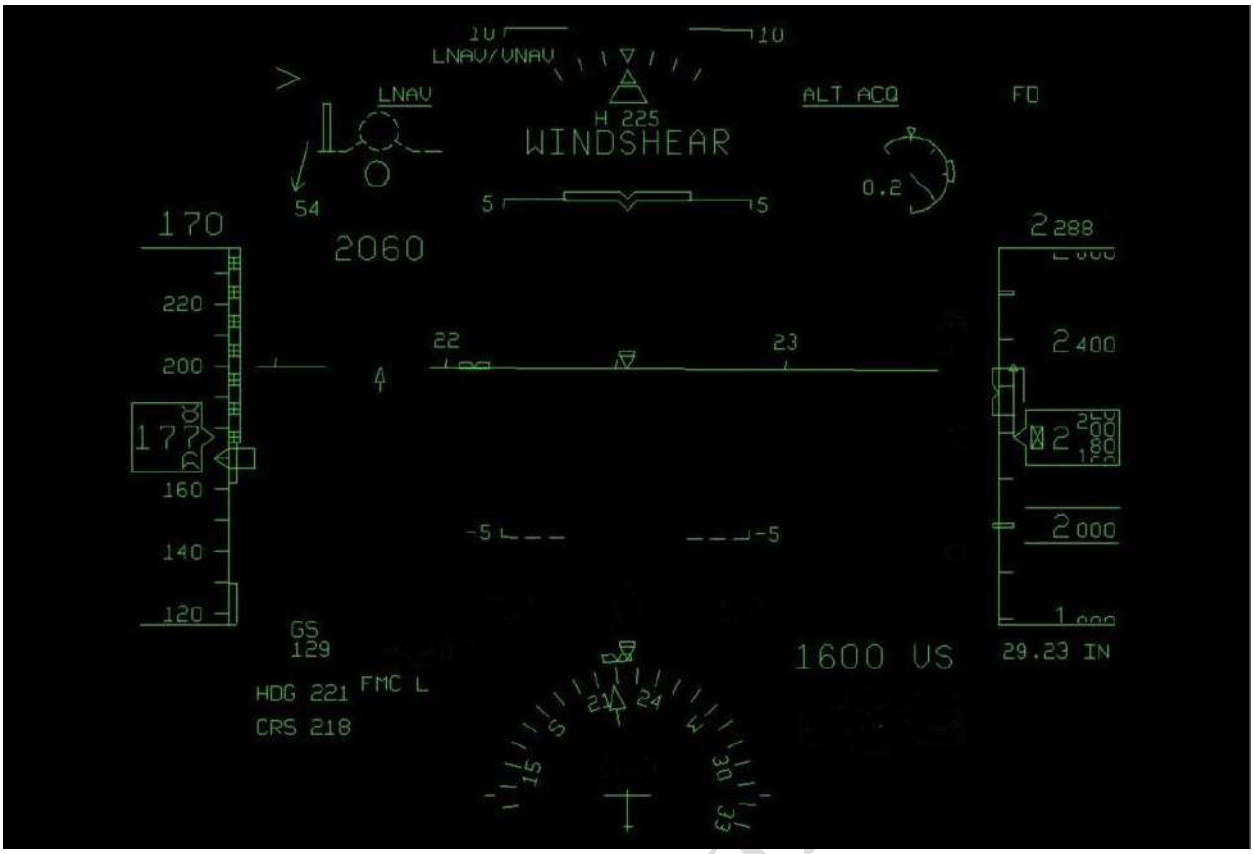

Fig. 60. The HUD reconstructed image at the point of time of 22:42:31.5 (the last press on the stabilizer trim switches)

As the result the IAS exceeded the limit value (with flaps, extended on 30°, Vfe is 175 kt) and TE Flap Load Relief was activated. The flaps automatically retracted to 25° (the flap handle remained at the 30° detent). It should be noted that at the initiation of go-around IAS was equal to 160 kt that is the margin to the limit (with no “flap load relief”) at the performance of Windshear Escape Maneuver amounted to 15 kt.

At 22:42:34, the aircraft reached the target altitude of 2300 ft and, despite all the actions by the crew, continued to climb. The PIC, without being cleared for further climb, reduced the thrust (down to 83 % N1), although the windshear warning was still displayed. The reduction of the engines thrust led to the reduction of the pitch-up moment. The control column was returned to an almost neutral position.

The IAS had continued to increase for a while (the maximum reached value was 182 kt), what the F/O drew the PIC’s attention to again.

22:42:47,7	22:42:48,2	F/O	Check the speed.
22:42:48,9	22:42:49,3	CPT	Checked.

Actually, due to the activation of Flap Load Relief, the speed exceedance with the extended flaps was low and short in time (as per FCOM D6-273 70-8KN-JXB page 9.20.19, with the flaps set to 30° the function is activated at the speed of 176 kt, i.e. 1 kt more than Vfe). However, the exceedance itself and the further climb with the TE FLAP LOAD RELIEF activated within about a minute (up to the moment of flaps resetting to 15° at 22:43:33) cannot be ignored. In the progress of flight in the holding area, the pilots discussed the occurrence of the overspeed (23:25:22…23:26:32).

23:25:22,4	23:25:24,6	CPT	How was the go around, was it a mess or was ok?
23:25:24,8	23:25:25,3	F/O	That's ok.
23:25:25,6	23:25:32,5	F/O	The only thing is that the ... the speed went to Barberpole but it's normal, because we have this wind shear.
23:25:27,6	23:25:28,2	CPT	The speed.
23:25:32,9	23:25:33,3	CPT	Yea.
23:25:33,8	23:25:35,0	CPT	What do you mean on the go around?
23:25:35,6	23:25:36,8	F/O	No, after the go around.
23:25:36,9	23:25:39,8	F/O	We were climbing did you note that the speed going up?
23:25:37,0	23:25:37,4	CPT	Yea.
23:25:40,5	23:25:40,9	CPT	Ok.
23:25:40,7	23:25:42,0	F/O	To the… to the up.
23:25:42,5	23:25:43,5	F/O	We call it bad *(illeg)*.
23:25:43,9	23:25:44,8	F/O	Very good, very good.
23:25:45,5	23:25:46,8	F/O	Did you notice anything?
23:25:46,9	23:25:48,0	CPT	So, *(illeg)* went into the reds?
23:25:48,6	23:25:50,3	F/O	Went almost into the red.
23:25:50,4	23:25:51,4	CPT	Almost *(illeg)*.
23:25:50,9	23:25:56,2	F/O	Maybe... maybe one or two knots but it's nothing. You have a fif… fifteen knots to get into red.

23:25:56,9	23:25:57,6	F/O	So, it was ok.
23:25:58,4	23:26:01,6	F/O	At placard speed, we were with flaps thirty.
23:26:02,0	23:26:03,1	F/O	That moment.
23:26:03,2	23:26:06,2	CPT	Or was it flaps thirty, one seventy five?
23:26:06,2	23:26:06,5	F/O	Yea.
23:26:06,5	23:26:08,1	CPT	Did we do one seventy five or no?
23:26:08,4	23:26:14,1	F/O	Eh, I don't think so, maybe... Maybe a few seconds unable hold altitude.
23:26:14,5	23:26:15,0	CPT	Ok.
23:26:28,1	23:26:30,2	F/O	I think it was ok... the go around was ok.
23:26:30,6	23:26:30,9	CPT	Yea.
23:26:31,9	23:26:32,5	F/O	Was ok.

The pilots do not mention the TE FLAP LOAD RELIEF activation. It is not clear out of the conversation, if either of the pilots even notice the activation of the function.

The PIC, apart of the above-given dialogue with the F/O, discussed the overspeed even with the cabin attendant (at about 00:09). Among other things, he told that because of the overspeed that would be a need for maintenance inspection.

Note: *1. The discussion of the issue with the cabin attendant and the context of the concerned conversation show that, most probably the PIC, after landing, was going to report the overspeed on extended flaps, this is in favor of the confidential reporting system efficiency in the airline.*

2. According to the airline, in his flying experience, the PIC, back when having performed the flights as a F/O, had one overspeed occurrence. The F/O did not have such occurrences before.

At 22:42:34, the crew contacted Rostov Radar controller and reported go-around, with that requested further climb: *«Rostov Ra... A… approach. Eh… This is SkyDubai niner eight one in go around runway two two. Request to climb higher»,* as the respective windshear warning was kept displayed (up to 22:42:47). Initially, the crew requested clearance for further climb without specifying the altitude value. The controller cleared to reach the altitude of 900 m (2950 ft). After the clarification of the altitude, up to which the controller cleared the climb, the crew requested to reach the altitude of 5000 ft (1525 m), however was cleared on the second attempt, after informing the controller about windshear.

In the progress of climb, at 22:43:14, with the actual setting of flaps to 25º, at the altitude of 3750 ft (1150 m) and speed of 176 kt, the PIC engaged A/P and A/T.

At 22:43:32, the crew initiated landing gear and flaps retraction to 15°. Within about a minute, the flaps were fully retracted. The go-around was complete.

Thus, the crew actions in response to the activation of the Predictive Windshear Warning and in the progress of go-around, in general, had not created any significant risks to the flight safety. At the same time, the crew run into one of the most unfavorable scenarios: the necessity of the go-around due to the possible windshear encounter from quite a high altitude (with a little margin as far as the target go-around altitude) on a low weight aircraft. The investigation team is of the opinion that the scenario in question as for the manufacturer and operator documentation needs the further elaboration in terms of recommended detailed procedures.

At 22:44:30, the Rostov Radar controller instructed the crew that they maintained FL50 with a heading to *«Bravo - Alpha»*[28]. In 15 sec, he relayed to the crew that they were number two for landing: «*SkyDubai niner eight one, for your information, you are number two to land. And report reason for go around»*. In response to the controller request on the reason for go-around the crew reported: *«Wind shear was the reason of our go around, SkyDubai niner eight one».*

At 22:45:15, the crew set the standard pressure of 1013 hPa. The aircraft flight path after the go-around is given on Fig. 61. On the figure the only crew-ATC communication is stated, which is referred to in the further text.

[28] The BA (Bagayevskiy) NDB (Fig. 30).

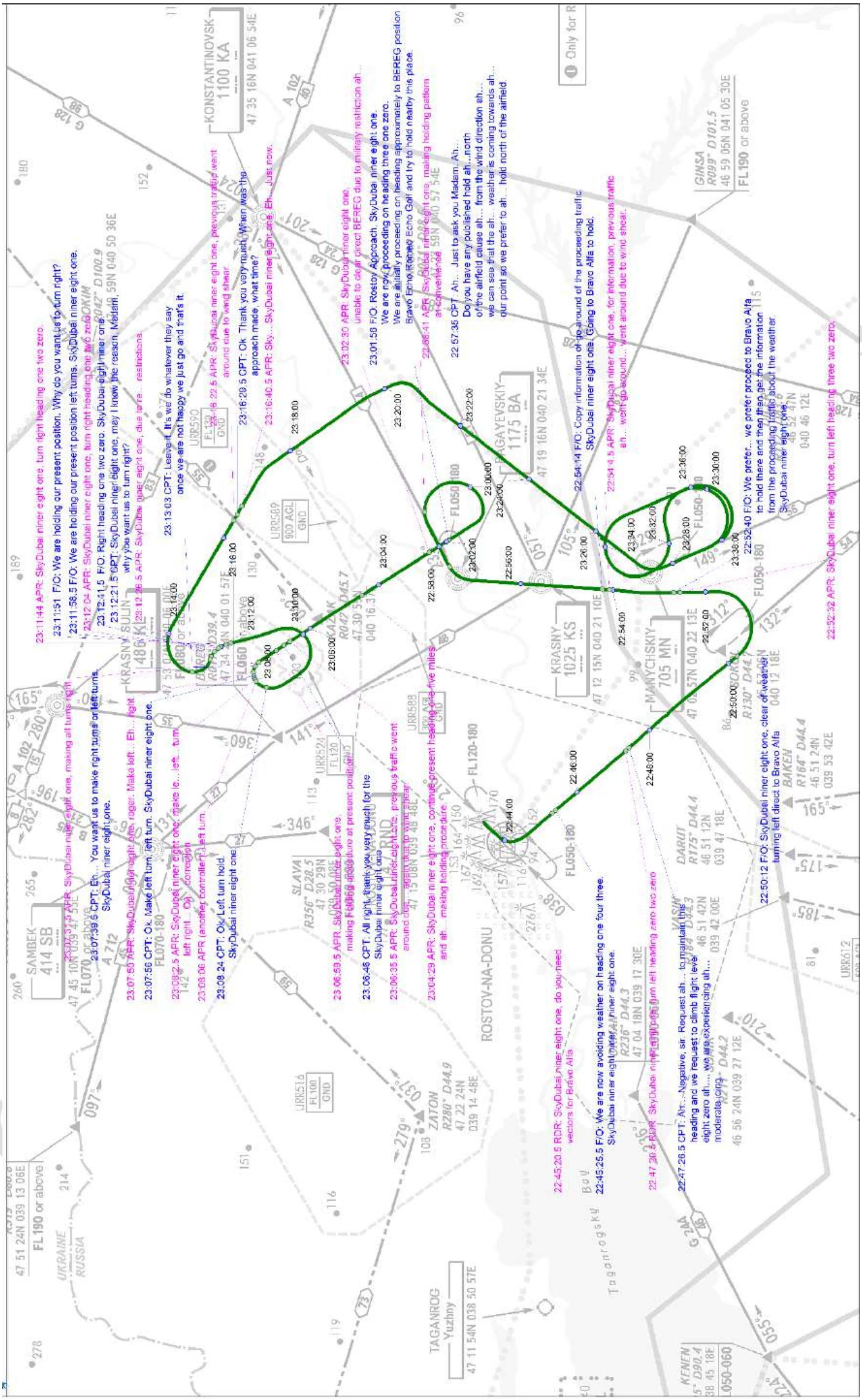

Fig. 61. The flight path after the first go-around and in the holding area

On the Rostov Radar controller question at 22:45:20 if they need vectors for *«Bravo - «Alpha»* the crew responded: «*We are now avoiding weather on heading one four three. SkyDubai niner eight niner... niner eight one».*

The crew had not immediately performed the turn, prescribed by the go-around procedure, but first proceeded with the landing heading up to reaching the altitude of 5000 ft and then with heading ≈ 145° in attempt to avoid the area with "bad weather", having reported it to the Radar controller. In parallel, with the use of the available instruments the crew was analyzing the speed and direction of the moving of the "bad weather" area. At 22:47:26, the crew requested climb to FL080 in order to leave the moderate icing area.

22:47:26,7	22:47:35,7	CPT	Ah… Negative, sir. Request ah… to maintain this heading and we request to climb flight level eight zero ah…, we are experiencing ah… moderate icing.

The Radar controller cleared the climb to FL080 and instructed the crew that they contacted the Approach controller.

FL080 was reached at 22:49:34.

After weather avoidance was completed, at 22:50, the PIC performed the left turn directly towards the BA NDB. Apparently, the PIC had not made the decision yet by the moment, whether to perform another approach immediately or to proceed to holding area. Concurrently, the Aeroflot SSJ-100 (AFL 1166) aircraft had been approaching. The PIC intended to wait until the information on the result of the AFL 1166 flight approach would be available.

22:52:22,6	22:52:24,3	CPT	I want to see what this guy will do.
22:52:31,9	22:52:36,0	APR	SkyDubai niner eight one, turn left heading three two zero.
22:52:36,1	22:52:40,9	CPT	Negative we want to find information the previous aircraft if it landed or go around.

22:52:40,0	22:52:50,5	F/O	We prefer... we prefer proceed to Bravo Alfa to hold there and then then get the information from the preceeding traffic about the weather. SkyDubai niner eight one.

In this way, the crew actions on this stage of the flight and the decisions made by the PIC were logical and reasoned.

At 22:53:31, the approaching AFL 1166 flight reported go-around and the presence of windshear at the altitude of 600 m (1970 ft) to the Rostov Radar controller.

Proceeding heading BA, the crew was relayed by the controller that AFL 1166 performed go-around due to windshear.

22:54:04,3	22:54:13,6	APR	SkyDubai niner eight one, for information, previous traffic ah… went go around... went around due to wind shear.
22:54:14,0	22:54:20,2	F/O	Copy information of go around of the preceeding traffic, SkyDubai niner eight one. Going to Bravo Alfa to hold.

This information was important for the further decision making and was the evidence that the conditions of windshear on final had been preserved. The PIC decided to proceed the flight in the holding area for indefinite time and further on, depending on circumstances, make the decision to undertake another approach or divert to an alternate aerodrome. The fuel on board (nine tons approximately) was quite sufficient to proceed in a holding pattern for more than two hours.

Note: *The UAE aviation legislation stipulates that it is the PIC, who always makes the decision on the quantity of fuel aboard the aircraft. The only exception to this rule is when the airline requests additional refuel based on its cost at the destination aerodrome. In the accident flight, the aircraft had been additionally fueled due to the higher fuel cost at the Rostov-on-Don airport compared to the Dubai airport. The Sabre FPM that is used by the airline computes when the* *additional refueling is cost-effective. This information is available to the flight crewmember and the Dispatch. However, even when the additional refueling is being requested, the PIC has the right to cancel it, depending on the specific operating conditions (for instance if the increased landing weight affects the landing performance of the aircraft).*

At the same time it should be noted that within 00:11– 00:11:30, when the PIC had got out of the cockpit, the F/O in talking to the cabin attendant, had expressed concern about the extended flight at the holding area. The following utterances had been recorded, in particular:[29]

00:11:08,4	00:11:12,5	F/O	Todos los aviones se han marchado. Solamente quedamos nosotros aquí haciendo el tonto.	All the aircraft have left. We are the only one left here doing nonsense.
00:11:12,4	00:11:13,4	C/A	¿Y a dónde se fueron?	Where did they go?
00:11:14,0	00:11:23,3	F/O	Pues no sé… porque era un Aeroflot y el otro no sé qué era… y se fueron por ahí. Se han ido a sus otros destinos. Nosotros tenemos suficiente combustible.	I do not know… because there was an Aeroflot and… I do not know about the other…..they left. They went to their other destinations. We have fuel enough.
00:11:24,2	00:11:28,8	F/O	Pero no creo que … con el tiempo como sigue, si sigue así de tocho no merece la pena.	But I do not think that… with such a weather, if it keeps being bad it is not worthy.

And then later:

00:13:14,5	00:13:22,5	F/O	La verdad es que no entiendo cómo pueden poner este tipo de vuelos a este sitio de Rusia por la noche, cuando saben que el tiempo es una mierda ya por el día ¿lo ponen por la noche?	Actually I don't understand why they plan this type of flights to this Russian place at night, when they already know during the daytime that there is a shit of weather, they plan it at night?

[29] The conversation was conducted in Spanish. In the text the translation into English is given, undertaken by CIAIAC.

At 22:55, the PIC transferred the controls to the F/O, then spoke out the reason for the delay of landing due to safety reasons and offered apologies to passengers.

At 22:57, the crew initiated right turn at FL80 in order to enter holding area over Bravo Alpha, of which they communicated the ATC at 22:57:24.

Further on, to avoid hold into "bad weather" in the BA area, the PIC tried to coordinate with the Approach controller the clearance to proceed a holding pattern to the north of the aerodrome, for which first was cleared to make holding pattern "at convenience".

22:57:35,1	22:57:53,6	CPT	Ah… Just to ask you Madam. Ah… Do you have any published hold ah…north of the airfield cause ah… from the wind direction ah… we can see that the ah… weather is coming towards ah… our point so we prefer to ah… hold north of the airfield.
22:58:40,8	22:58:46,1	APR	SkyDubai niner eight one, making holding pattern at convenience.
22:58:47,0	22:58:58,2	CPT	Ok. Thank you very much. ah… We're gonna start heading north and we will do a present position hold ah… when we find a place where is no icing. SkyDubai niner eight one. We let you know. Thank you.

At proceeding the flight with heading 310° in order to find the suitable weather conditions for holding, the crew at 23:06:35 was relayed new information that the AFL 1166 flight in the progress of another approach, performed go-around again due to windshear.

23:06:35,5	23:06:44,3	APR	SkyDubai niner eight one, previous traffic went around due… again due to wind shear.
23:06:44,2	23:06:45,2	CPT	Yea. Thank you very much.
23:06:45,9	23:06:49,0	CPT	All right, thank you very much for the information, SkyDubai niner eight one.
23:06:49,2	23:06:50,2	CPT	So they went around again.
23:06:50,3	23:06:51,2	F/O	Again. So we...
23:06:51,3	23:06:55,6	CPT	It's no, it's no way we can go in now, man. We've got plenty of fuel nine tons
23:06:55,9	23:06:56,2	F/O	Yea.
23:06:56,3	23:06:59,6	CPT	Ok now it's how to manage to go out of this icing conditions.

The stated dialogue between the PIC and the F/O is the evidence that the PIC was not eager to make decision to perform another approach or to divert to an alternate aerodrome. Still, the crew requested and was relayed the weather at the Volgograd aerodrome (URWW). It indicates that the diversion to an alternate aerodrome was not excluded by the crew and they prepared in advance for it.

Subsequently the crew contacted the Rostov Approach controller on the possibility to hold on Sierra Bravo (SAMBEK) NDB or over the BEREG fix, but the Approach controller refused it due to restrictions. The controller proposed to hold over the KAZAK fix (it is located eastwards of the aerodrome), but the crew rejected it.

It should be noted that the English language proficiency of the Approach controller (see Section 1.16.6) did not meet ICAO Level 4 requirements. It posed difficulties for the crew. The crew was forced to explain their intentions to the controller several times, whereas the responses by the controller were unclear, once it even required the intervention of another controller to clarify the content of the ATC instruction. At some point the crew decided to stop trying to explain their intention to hold to the north of the aerodrome (the PIC to the F/O at 23:13:03: *«Leave it. It's we do whatever they say once we are not happy we just go and that's it.»*.

Finally following the Approach controller guidance the aircraft was brought to holding area over the MN/Manychskiy NDB to the south-east of the aerodrome. To leave the icing area the crew requested and was cleared to climb to FL150 (at 23:16:10).

Meanwhile, the AFL 1166 flight performed the third go-around due to windshear with the speed increment at the altitude of 400 to 300 m. The respective information was relayed by the controller to the crew.

23:16:22,6	23:16:28,5	APR	SkyDubai niner eight one, previous traffic went around due to wind shear.
23:16:29,3	23:16:34,0	CPT	Ok. Thank you very much. When was the approach made, what time?
23:16:40,4	23:16:46,2	APR	Sky... SkyDubai niner eight one. Eh... Just now.
23:16:46,5	23:16:47,8	CPT	All right thank you very much.
23:16:46,6	23:16:46,9	F/O	Just now…
23:16:48,4	23:16:49,1	CPT	Still there…

Thus, within 22:00 – 23:16 the crews of different aircraft repeatedly reported moderate-to-strong windshear. The crew of the AFL 1166 flight performed go-around three times, and diverted to the alternate aerodrome of Krasnodar afterwards.

Under the current circumstances with the windshear conditions that continued to prevail for quite a long time, the PIC made the decisions as follows:

– wait for the improvement of weather in the holding area. Particularly given that, there had been the trend towards its improvement, whereas the quantity of fuel aboard allowed performing a long-time flight in the holding area;

– under the anticipated conditions of the improved weather (no windshear or the reduction of its intensity to acceptable values) to perform another approach;

– if it does not work out again, to divert to an alternate aerodrome immediately after go-around.

Such decisions seem to be logical and correct. In taking them the PIC, most probably, was driven by the considerations as follows:

1) The improvement of weather conditions that had been monitored by the crew as far back as the point of go-around allowed hoping for a successful approach after a certain time.

23:24:09,1	23:24:13,1	CPT	The weather looks better here it’s not the same as before.
23:24:10,7	23:24:13,4	F/O	Much better *(illeg)*. Yea.

2) The sufficient quantity of fuel allowed to proceed the holding pattern not less than 2 hours and did not constitute the time pressure.

23:30:52,9	23:30:55,7	CPT	(illeg) they diverted, they didn't have the fuel.
23:30:56,4	23:30:56,6	F/O	Yeah.
23:31:04,5	23:31:06,5	CPT	And for us now, you know what I'm doing?
23:31:07,1	23:31:07,3	F/O	What?
23:31:07,9	23:31:08,8	CPT	We are holding.
23:31:09,7	23:31:10,6	CPT	We are burning time.
23:31:11,0	23:31:14,1	F/O	Yeah, we are burning a lot of time. Yeah, oh, thank you. For me?
23:31:14,3	23:31:23,6	APR	SkyDubai niner eight one, for your information, previous traffic went to alternate aerodrome.
23:31:15,8	23:31:18,8	CPT	Oh (no) to divert you mean? It’s no need.
23:31:21,0	23:31:22,5	CPT	Eh… I want to fly.
23:31:24,5	23:31:27,1	F/O	Sorry, say again for the SkyDubai niner eight one, please.

3) The actual weather and the forecast weather at the alternate aerodromes (Volgograd and Mineralnye Vody) were favorable, which did not involve hasty actions either.

4) The aircraft was in immediate proximity to the Rostov-on-Don destination aerodrome, with radio and navigation aids set and ready for approach.

Taking the decision to perform another approach the PIC, most probably, took into account that in case of landing at the Rostov-on-Don airport the loss of time in the holding area (about 2 hrs) would not be crucial. The passengers will be delivered to destination; it will still be possible to perform the return flight, as the duty time will not exceed the allowed value. The potential diversion to the alternate aerodrome would entail many problems: the overnight stop and the associated significant delay of the flight, the passengers' accommodation, the breach of the operational schedule of the aircraft, the other expenses both for the airline and for the crew. These circumstances could have enhanced the motivation of the PIC to perform landing right at the destination airport (Rostov-on-Don). The PIC undertook every possible step to complete the main task, that is to deliver passengers to destination.

It was unreasonable, from the point of view of the PIC, not to take the chance to perform another approach. Particularly given that to his mind he could have completed even the first approach if «GO-AROUND, WINDSHEAR AHEAD» warning were not activated and brought him to make the decision to perform go-around. He mentioned it three times. The first was immediately after go-around in the conversation with the F/O.

22:46:32,7	22:46:35,1	CPT	It was ok, man, but it call "wind shear".
22:46:33,8	22:46:34,7	F/O	[Sigh].
22:46:35,3	22:46:35,7	F/O	Yea.
22:46:36,1	22:46:37,4	CPT	It was ok to be honest.
22:46:37,5	22:46:39,6	F/O	That for me was ok, but they call "wind shear".

The second and the third time was in the holding area in a conversation with a cabin attendant.

23:01:29,1	23:01:30,9	CPT	Eh, we got a fucking wind shear warning.
23:01:31,0	23:01:34,7	CPT	Man I could see the airfield, and we could go in, but nevertheless...
23:01:35,1	23:01:36,7	C/A	No problem *(illeg)*.
23:01:35,6	23:01:44,5	CPT	Wind shear warning we went around, aa.. we are ah.. in the hold now. We gonna move from this direction the weather is coming this side.

23:01:45,6	23:01:51,5	CPT	So, ah… I expect I don't know, maybe twenty minutes and then we shoot another approach.

00:07:45,7	00:07:47,2	C/A	So, do you think we will get in or not?
00:07:47,6	00:07:48,6	CPT	I think we will do.
00:07:48,8	00:07:49,8	C/A	We will do?
00:07:50,3	00:07:50,8	CPT	Yea.
00:07:51,4	00:07:54,6	CPT	I think… Before I could see the runway, but...
00:07:55,9	00:07:59,6	CPT	The machine called wind shear, I could control the aeroplane very well.
00:08:00,5	00:08:04,6	CPT	But it says: go around, wind shear, that's it, I couldn't do the approach, you know.
00:08:05,5	00:08:08,9	CPT	And it was correct, because the other aeroplane they go around as well.

Truly, at the point of activation of the warning «GO-AROUND, WIND SHEAR AHEAD» the PIC from the altitude of about 1100 ft (335 m) had positive visual contact with the RWY and with the required accuracy proceeded the flight on the glide path. The current airspeed (160 kt) exceeded the approach speed, selected by the crew, for 10 knots and actually met the recommended one as per operational documentation for these conditions. These circumstances (the RWY in sight and the stabilized position of the aircraft) could have reassured the PIC that if the warning had not activated he would successfully have completed the landing under the prevailing conditions at that moment. This fact could have had an important psychological effect as far as the subsequent development of the situation is concerned.

Note: *The investigation team notes that the long discussion by the PIC with the cabin attendant of the "purely flying matters" (on the windshear warning activation* *and the exceedance of IAS with the extended flaps), can be the evidence that the PIC was affected by them and needed to speak them out.*

When approaching the holding area the crew set the speed of 210 kt that is consistent with the maximum endurance (minimum fuel consumption) for the actual conditions (the weight and the altitude of flight of the aircraft) and maintained it until flown out the holding area for another approach.

In the holding area over the MN NDB, the aircraft was flown for about an hour. The analysis of the crew communication and the actions allows making the conclusions as follows:

– the crew was constantly monitoring the Rostov-on-Don aerodrome actual weather in attempt to choose the best time for another approach;

– the PIC contacted the airline representative via the SATCOM satellite communication system and was proceeding the long discussion. In the progress of the discussion the airline supported the decision of the PIC, recommended the Mineralnye Vody aerodrome (URMM) as the alternate with more stable weather and even filed and sent the flight plan for an alternate aerodrome aboard (the estimated distance 270 nm, the flight time 44 min and the required fuel 1728 kg). With that, the airline recommended that the PIC attempted to land in Rostov that could have been a stronger motivation for the PIC to perform the task in question:

23:38:30,9	23:38:52,1	CPT	If we divert you know that we are divert... diverting to Minerale Vody. I'm gonna try this approach if I can not get in I will not try another one, because they tried many people the next air... the next airplane coming in is about one hour from now. So I will go once if I don't manage I will go around and I will go to Minerale Vody, ok?

23:38:54,0	23:39:04,5	FD	Ok, captain that is understood. We would like to recommend you to hold max as possible but if you don't want to approach take one more approach that is understood.
23:39:12,1	23:39:38,1	FD	Yes hopefully if the weather passes, because we have the fuel we would like to at least try to land into Rostov instead of diverting so that would be our recommendation. Eh... depends on you directing weather situation out there what you see fit. And then, you can try another approach if the weather improves. But ac... According to the fuel that we have we will recommend you to hold as max as possible.
23:39:38,4	23:39:53,4	CPT	Ok, perfect, I agree with you, we will hold then. If you see the weather that is forecasting to be bad in Minerale, just give us a call again, ok?
23:39:44,6	23:39:45,1	FD	Ok.

– the crew was thoroughly preparing for a possible diversion to an alternate aerodrome. Two aerodromes were considered as the alternate - those of Volgograd and Mineralnye Vody. The crew, having studied the actual weather and the forecast for the immediate future and, as well, followed the recommendations by airline, selected the Mineralnye Vody aerodrome as the first option, calculated the remaining fuel, at which the diversion to the alternate should have been performed, entered the route to the alternate aerodrome into FMS, studied the approach charts and the other necessary data on the alternate aerodrome;

– the crew calculated Vref and discussed the go-around sequence if windshear warning were activated again:

23:54:39,0	23:54:49,1	CPT	So one three four, autobrake three, flaps thirty, wind shear warning go around do not change flap or gear configuration.
23:54:49,3	23:54:50,0	F/O	Aha.

In case of go-around due to windshear, the PIC, as he did the first time, was going to perform Windshear Escape Maneuver, that is to go around with the aircraft configuration unchanged, of which he informed the F/O;

– for quite a long time the crew reviewed the possible options of the subsequent actions in case of landing at the alternate aerodrome and estimated the amount of duty time:

23:59:21,4	23:59:27,7	CPT	I don't know, man if we divert there… we are gonna be out of hours, we are late for five hours, man.
23:59:26,3	23:59:26,6	F/O	Yea.
23:59:28,2	23:59:28,4	F/O	Yea.
23:59:33,8	23:59:36,1	F/O	I see my future is sleeping in the aircraft.
23:59:36,9	23:59:37,2	CPT	Oie.
23:59:37,3	23:59:41,8	F/O	[laugh] And, and... If this is it, this place, having the night there.

00:02:30,5	00:02:30,9	F/O	Tired?
00:02:33,3	00:02:33,6	CPT	No.
00:02:35,4	00:02:36,5	CPT	What are you looking?

00:02:36,5	00:02:44,6	F/O	For the *(illeg)* limitations is on the... for report time duty time or whatever.
00:02:45,1	00:02:45,5	CPT	Ah…
00:02:45,8	00:02:48,6	F/O	We eleven hours or something *(illeg)*.
00:02:48,6	00:02:50,3	CPT	Just put there FDP.
00:02:50,7	00:02:51,7	F/O	Yea. I put it that.
00:02:53,3	00:02:55,1	F/O	Put FDP.
00:02:55,4	00:02:56,0	CPT	Yea.
00:02:58,7	00:03:00,9	CPT	Then go OMA chapter seven.
00:03:01,3	00:03:03,7	F/O	Yea, it's here *(illeg)*.
00:03:02,6	00:03:06,0	CPT	Calculation of the flying duty periods for flight crew.
00:03:04,9	00:03:05,1	F/O	Yea.
00:03:06,1	00:03:07,0	CPT	Acclimatised.
00:03:09,6	00:03:11,9	F/O	So, we reported around…
00:03:13,6	00:03:16,0	F/O	Hm… This time nine forty, yea.
00:03:13,8	00:03:15,5	CPT	Nine... nine forty five.
00:03:18,2	00:03:20,4	F/O	Eleven and fifteen minutes.
00:03:40,5	00:03:46,2	F/O	I lost the number, the count number of how many holds, we have done already *(illeg)*.
00:03:48,1	00:03:49,7	CPT	We’ll count it later.
00:03:56,0	00:04:03,2	CPT	When we enter this hold we had two hours and twenty minutes holding time, so we are almost one hour holding.

00:04:00,1	00:04:00,4	F/O	Yea.

00:08:12,2	00:08:15,3	C/A	So how long, before out of hours so that you are not looking into that again?
00:08:15,8	00:08:18,1	CPT	Yea, of course, we are out of hours, don't worry.
00:08:19,5	00:08:20,9	C/A	So what? Nightstop?
00:08:21,4	00:08:23,3	CPT	Yea. Most probably, yea.
00:08:27,4	00:08:29,6	CPT	We are flying now for five and half hours, man.
00:08:29,9	00:08:31,8	C/A	We know we've been holding for like an hour and a half, right?
00:08:31,8	00:08:32,1	CPT	Yea.
00:08:34,3	00:08:36,1	C/A	So, we gonna stay in Minerale Vody?
00:08:36,6	00:08:38,2	C/A	Or, I mean in Rostov?
00:08:38,3	00:08:44,5	CPT	If we manage to land we'll see what the plan it is and I smell Kuwait.

In this context, the PIC's decision to proceed a holding pattern for another approach under the actual circumstances had been the best possible and reasoned decision. This very decision was coordinated with the airline. Taking into consideration the sufficient quantity of fuel to hold and divert to an alternate aerodrome, actual weather and favorable forecast as for the alternate aerodrome, this solution did not pose risks and did not threaten the successful outcome of the flight. The crew undertook all the necessary steps both for the successful landing at the destination aerodrome and the diversion to an alternate aerodrome.

However, it should be noted that the landing at the destination aerodrome was the primary (dominant) goal for the PIC. In talking to the F/O at 00:18:40 the PIC expressed concern that even in case of diversion to the alternate aerodrome the crew might be commanded to "*refuel the aircraft and fly back to Rostov*" (*«… they will tell us: fill up the airplane and fly back to a … Rostov»*).

At 00:20, having evaluated the weather (its shift) once again as per the available instruments, the PIC decided to perform another approach.

00:19:52,4	00:20:01,4	CPT	Sixty five knots, a-a-a, I think it will clear by the time we do this approach now, even now if we start the approach. I think it will be good.
00:20:01,7	00:20:02,0	F/O	Will be good.
00:20:02,4	00:20:03,6	CPT	I think… I would like try now.
00:20:02,9	00:20:04,1	F/O	Let's try, let's try.

In addition, the PIC requested the weather from the ATC. The Tower controller at 00:20 relayed the weather as follows: «*SkyDubai niner eight one, weather at zero zero two zero: visibility five kilometers, ceiling six three zero meters, surface wind two three zero degrees one three maximum one eight meters per second, light shower rain, mist, on final severe turbulence and moderate wind shear*».

From 00:22:17 to 00:22:36 the crew accomplished the DESCENT section of the Checklist. Another before-landing briefing had been previously accomplished.

At 00:23, having got an update on weather at Rostov, the crew requested descent.

00:22:43,6	00:23:15,8	APR	SkyDubai niner eight one, at two two: wind two three zero degrees, one four meters per second, maximum one eight meters per second, visibility six kilometers, scattered four eight zero, correction, six three zero meters. Meteorological office is not reported about wind shear on the runway.
00:23:16,5	00:23:17,6	CPT	Request descent.

00:23:18,4	00:23:25,6	F/O	Ok, copied, SkyDubai niner eight one. Request descent for another approach, SkyDubai niner eight one.

It should be noted that the latest weather information, relayed to the crew, incorporated the sentence *"Meteorological office is not reported about wind shear on the runway"*, which, to certain extent, contradicted the information on moderate windshear, relayed to the crew two minutes before. As per item 5.3.16 of Doc 9817 Manual on Low-Level Wind Shear, ATS units should continue to transmit information on wind shear conditions until it is confirmed, either by subsequent aircraft reports or by advice from the associated MET office, that conditions are no longer significant for operations at the aerodrome. In the previous period, the flight crews had not reported on the windshear presence or absence. Accordingly, the ATC officers had not informed the meteorological office on the windshear situation. With that, there were no automated means of windshear detection at the aerodrome. According to the data, present at that moment on the ATC MeteoDisplay, there had been no information on the actual windshear, as there had been no reports by the flight crews for more than 30 minutes, confirming the windshear presence. However, at the same MeteoDisplay the information (warning) had been kept displayed: *moderate windshear is forecasted.* The flight crew had not requested the windshear information clarification/update.

At 00:23:35, the crew set the target altitude of 8000 ft and started the descent.

At 00:27, the pilots once again discussed the Vref value and the correction that should have been introduced, considering the actual wind. The Vref was determined by the crew as 133 kt, which was consistent with the actual landing weight of 54 t. The fact that the crew introduced the one knot correction against Vref, that had been determined by them earlier (see the text above for the communication at 23:54:39), indicates that the crew had been in a normal working condition and monitored the situation.

The PIC decided that the "wind" correction of Vref should have been equal to +20 kt, whereas the approach speed Vapp = 153 kt. The latest data on the wind that the crew had been relayed: *wind 230 degrees, 14 m/s, max. 18 m/s.* The value of the stable headwind component amounted to: $14*1.94*\cos(230°-218°) \approx 26$ *kt*, the exceedance of the gusts value against the headwind component: $(18-14)*1.94 \approx 8$ *kt*. Thus, the correction, recommended by the operational documentation was equal to: $26/2+8 = 21$ *kt.* With the consideration of the recommended maximum value of the correction of 20 kt, the crew had appropriately identified the approach speed. The crew had "reviewed" the Vfe that had been exceeded during the first go-around, too.

00:26:54,5	00:26:57,5	CPT	Ah… fifteen meters to this like thirty knots.
00:26:56,4	00:26:59,4	F/O	*(illeg)*. A thirty knots of a head wind.
00:26:59,8	00:27:00,4	F/O	A lot.
00:27:00,6	00:27:01,9	CPT	Plus twenty we need.
00:27:01,9	00:27:02,3	F/O	Yea.
00:27:03,8	00:27:05,6	F/O	I just update here, one three three.
00:27:06,0	00:27:08,3	CPT	One three three plus twenty.
00:27:06,3	00:27:07,2	F/O	*(illeg)*.
00:27:14,0	00:27:15,8	CPT	We will give us one five three.
00:27:15,8	00:27:16,8	F/O	One five three, yea.
00:27:16,7	00:27:18,9	CPT	And the flaps thirty it's one seventy five.
00:27:18,8	00:27:20,8	F/O	Yea, we have a lot of margin with that.

At the same time the crew, having in mind the difficulties during the first go-around, coordinated with the controller that in case of go-around they would immediately climb FL080.

00:27:22,4	00:27:26,9	F/O	But I will let them know in case of go around at least coming flight level eight zero.
00:27:27,2	00:27:27,7	CPT	Yea-yea.
00:27:31,2	00:27:32,7	F/O	I will inform them, already.
00:27:37,2	00:27:39,4	F/O	Rostov Approach, SkyDubai niner eight one.
00:27:40,9	00:27:43,3	APR	SkyDubai niner eight one, go ahead.

00:27:44,3	00:27:53,9	F/O	Just for your information, in case of next approach and in a go around, we are going to request climb flight level eight zero, during the go around.
00:27:56,2	00:28:05,3	APR	SkyDubai niner eight one, roger, after go around climb to flight level eight zero.

At 00:28:23, the controller issued clearance for descent to FL060. The crew set 6000 ft as the target altitude.

At 00:29, the HUD switched to an IMC mode.

At 00:30:30 the aircraft was transferred under control of the Rostov Radar controller, to whom the Co-pilot, at 00:30:41, reported the descent to FL060 with heading 310°. The controller instructed for the further descent to the altitude of 600 m QFE 988 hPa (2250 ft QNH) and requested by the crew, relayed QNH of 998 hPa.

This time the crew set QNH correctly. With that the PIC drew attention on the QNH value: *«Before we did the approach with niner niner zero»*. The F/O agreed to that noting the significant difference. The fact that the crew noted the difference of pressures (although they did not catch that as for the first time they were wrong in the setting) indicates the normal working condition and the monitoring of the situation.

The approach was carried out under weather conditions, similar to those of the first approach (as per ATIS as of the moment of the accident: moderate turbulence, visibility 7000 m, scattered cloud 4 octants, cloud base 420 m).

The descent was proceeded with the A/P and A/T engaged. At 00:33:01 at the speed of 210 kt the flap handle was set to 1°.

From the altitude of about 3800 ft QNH (1075 m QFE), the aircraft entered the area of turbulence (the vertical G was alternating within 0.75 – 1.4 g).

At 00:33:41 at the speed of 190 kt the flap handle was set to 5°.

At 00:33:48 the controller instructed the crew to change the heading from 310° to 290° and asked to copy the actual weather, transmitted by the crew of the SVR 2757 aircraft that had just departed: *«… wind on six hundred meters two six zero degrees five three knots and there is also light icing».*

Note: *The engineering simulation (section 1.16.7) did not reveal any signs that the aircraft performance had been affected by the potential icing.*

At 00:34:49 the crew introduced correction of QNH following the controller information on a QNH change of 1 hPa. Concurrently the controller instructed to turn to heading 270°.

At 00:35:29, the Rostov Radar controller issued clearance for an ILS approach to RWY 22 and instructed the crew that they reported established. The crew acknowledged the information and relayed that in case of go-around they would immediately climb to FL080.

Fig. 62 presents the flight parameters at the second approach. On the plot the parameter "relative altitude (adjusted for baro correction)" stands for QNH altitude.

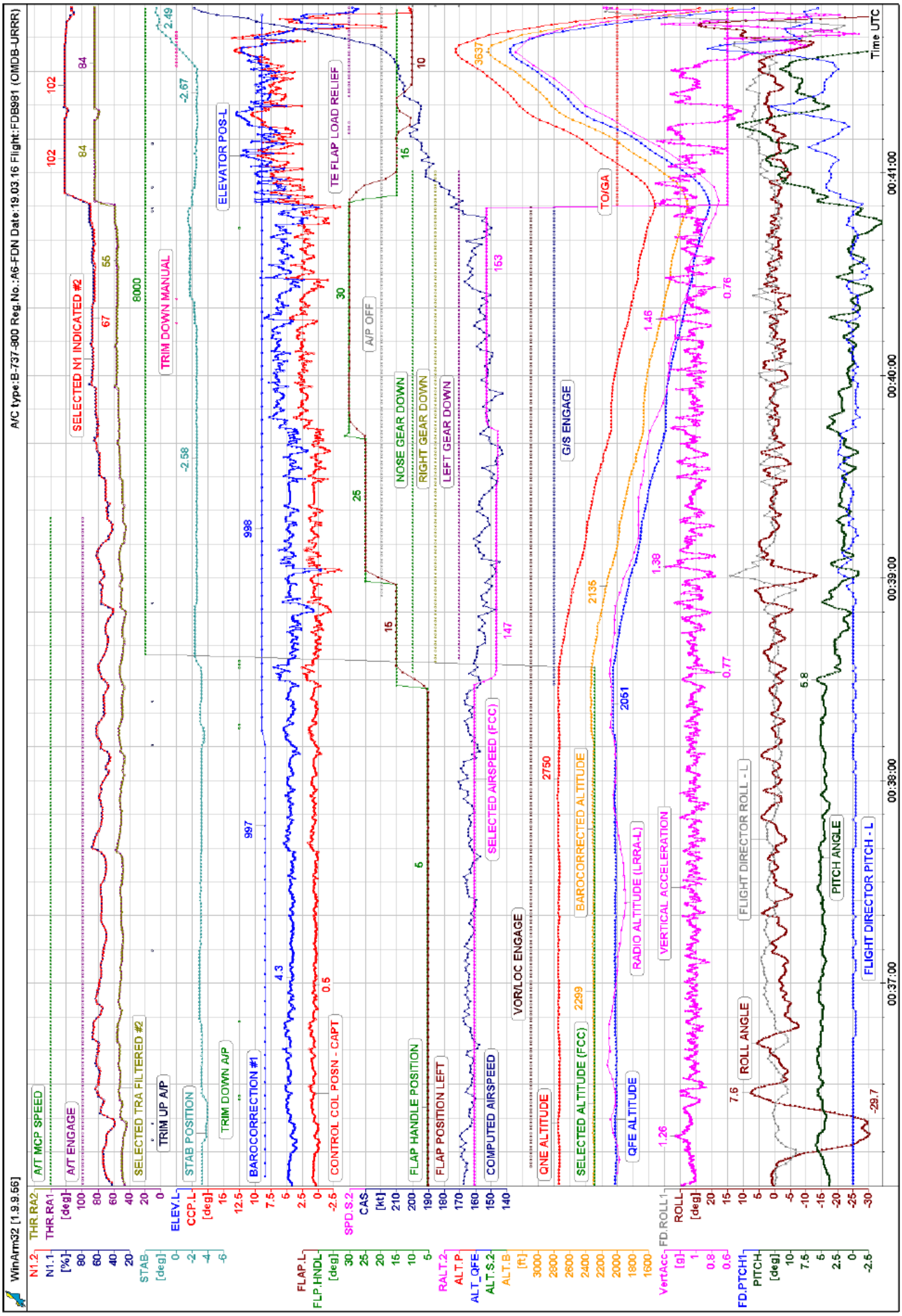

Fig. 62. The flight parameters at the second approach

At 00:36:05, the localizer capture is recorded and the aircraft automatic tracking out initiation on final. At the moment the aircraft was flown in a level flight at the distance of 11.5 nm (21.3 km) off the runway at the altitude of 2250 ft QNH (it corresponds to the altitude of glide path interception) (600 m QFE), IAS – 166 kt.

At 00:37:03, the crew requested the wind information from the Rostov Radar controller. The controller relayed *«230 degrees, 12 m/s, gusts 18 m/s»*. The crew acknowledged the receipt of information and reported established on localizer. After this communication, the Rostov Radar controller transferred the crew to the Rostov Tower controller.

At 00:37:25, the F/O contacted the Rostov Tower controller and reported established on localizer. The controller relayed the actual weather to the crew: *«wind two three zero degrees one two maximum one eight meters per second»* and issued clearance to land on RWY 22. The PIC affirmed cleared to land.

At 00:38:14, the crew had once again corrected QNH in relation to the controller information of the pressure change by 1 hPa. The capture of the glideslope occurred at 00:38:29 in a level flight at the distance of 7 nm (13 km) off the RWY. At the point of the glideslope capture, the crew extended landing gear and flaps on 15°. The target go-around altitude was reset to 8000 ft.

The aircraft started descent on glide path. At 00:38:55 at the altitude of 2165 ft QNH (575 m QFE), the PIC disengaged autopilot and continued to control the aircraft with the use of HUD. The PIC did not explain the reason for A/P disengage to F/O.

Note: *The airline SOP, based on the aircraft manufacturer documentation, do not require such explanations.*

After autopilot disengage, the flaps were extended to 25°.

At 00:39:17 at the altitude of 1960 ft QNH (510 m QFE) the AT was disengaged. The flaps were extended to the landing position of 30°. The LANDING section of the Checklist was carried out afterwards.

At the point of One thousand advisory callout activation (00:40:37) the aircraft was nearly stabilized for the approach (the flaps at a landing position 30°, landing gear down, the deviations off the beam on localizer and glideslope within tolerance), with that the PIC uttered: *«Stabilizing now»*, most probably, speaking about speed that was equal to 163 kt (and trended to reduce), which was 10 kt higher than the approach speed, determined by the crew.

The aircraft was flown a little bit higher of glideslope (0.3…0.2 dots), and the PIC was applying the corrective “pushing” movements on the control column to maintain the glide path descent more precisely, along with that the thrust (N1) was increased from 65% to 70%. Over the same moment the aircraft encountered wind gust. The combination of these three factors resulted in the IAS, after decreasing to the target value of 153 kt, increase within a second for 15 kt (from

153 to 168 kt), in 2 next seconds it additionally increased up to 176 kt. In such a way the actual speed exceeded the target one (153 kt) for more than 20 kt. This overspeed was responded by the F/O at 00:40:49: *«Check the speed»*. It is the overspeed for a considerable value that, most probably, was the reason for the PIC to make decision on go-around. The PIC took the decision right away, called it out to the F/O and similarly was responded immediately:

00:40:49,7	00:40:50,4	CPT	(Ok), go around.
00:40:50,5	00:40:51,1	F/O	Go around.

At 00:40:50 the TO/GA mode was activated with the power levers advanced to full thrust. The flight parameters at the go-around are given on Fig. 63.

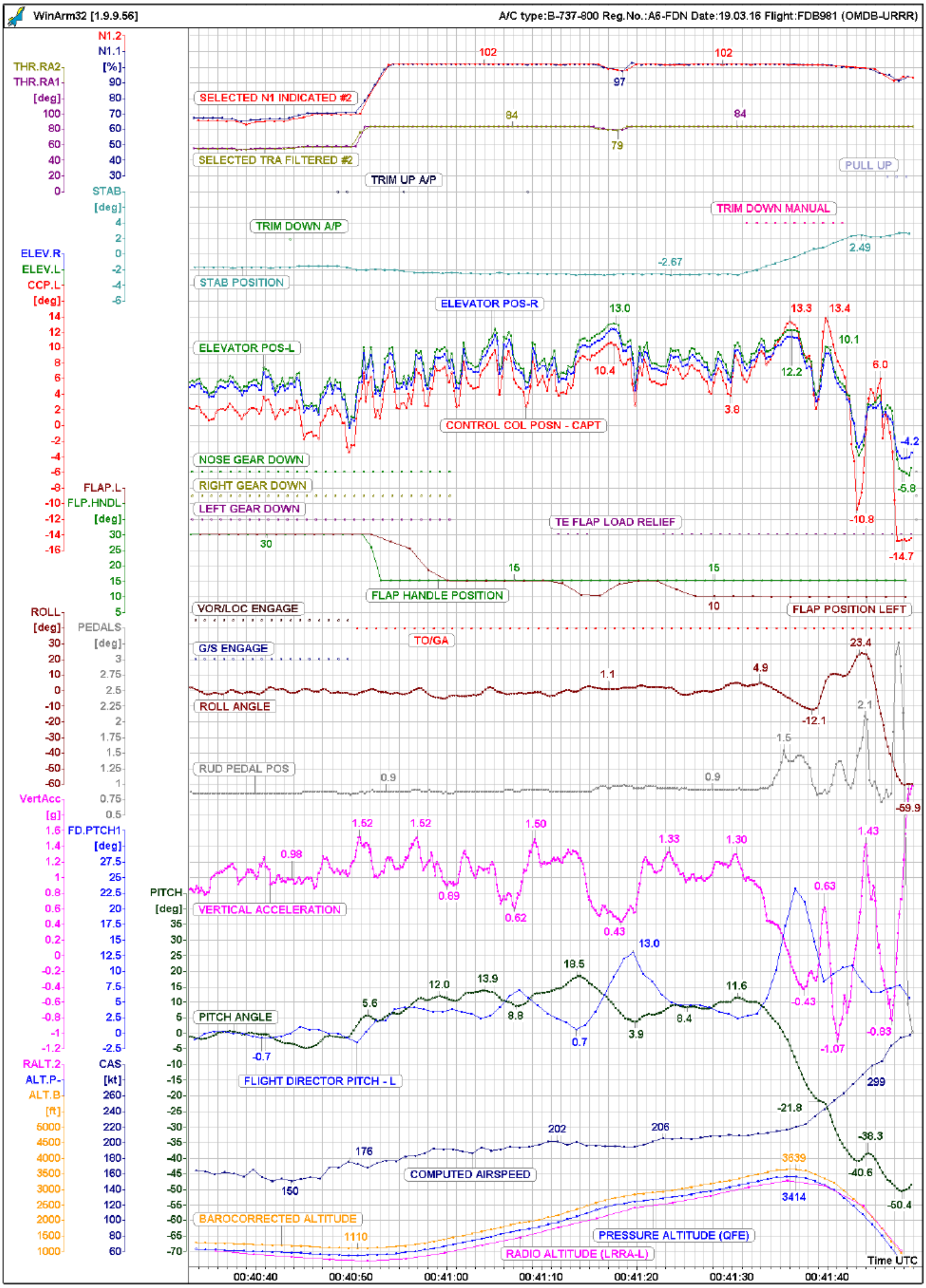

Fig. 63. The flight parameters at the second go-around

Fig. 64 presents the HUD reconstructed image at the point of TO/GA mode activation.

Fig. 64. The HUD reconstructed image at the point of time of 00:40:50 (the TO/GA mode activation)

At the point of go-around initiation the altitude was equal to 1100 ft QNH (250 m QFE) with the speed of 173…175 kt, that is it was consistent with Vfe for flaps 30°. As per the information available, it cannot be clearly established if the PIC perceived the abrupt increase of speed readings as one of the signs of the windshear encounter (according to QRH D6-27370-8KN-JXB page MAN.1.9, the IAS alteration for 15 kt at the altitude of less than 1000 ft is applicable to “unacceptable flight path deviations’, which in their turn are one of the signs of the windshear encounter), or as the ordinary sign of an unstabilized approach. It may be assumed that in advancing thrust levers to full thrust the PIC (“in his mind”) initiated, similar to the first go-around, the Windshear Escape Maneuver. Particularly given that, if the PIC perceived the speed leap in question as associated with the windshear encounter, this very maneuver is directly (without an alternative) prescribed by QRH.

The SOP of some airlines, prior to initiate a range of maneuvers (TCAS, Windshear escape, Terrain avoidance etc.) recommend that the type of the performed maneuver be spoken out explicitly (for example, GO-AROUND, Windshear Escape Maneuver), for the other crew member unambiguously understand what it is going to happen. Particularly if, as in the case in question, both standard go-around and the specific maneuver were possible. Prior to the first go-around the windshear was called out with the activation of the respective warning, that is why, most probably, the Windshear Escape Maneuver was carried out coherently by the crew even without any additional information.

Before the second go-around there was no windshear warning activation, as well as there was no explicit callout by the PIC on the type of maneuver (the airline OM did not stipulate such a specification of commands), that is why the F/O could have perceived the maneuver to come as the standard go-around – particularly given that he had just drawn the PIC's attention to the deviation (on speed) of the stabilized approach criteria. It is the F/O who offered to PIC to retract flaps to 15°, as it is prescribed at the standard go-around. The PIC immediately agreed with the F/O, although according to SOP (item 12.1.1), the decision-making and the respective callout to retract flaps should come from the PIC himself with a simultaneous GO-AROUND callout.

00:40:51,1	00:40:51,6	F/O	Flaps fifteen?
00:40:51,6	00:40:52,2	CPT	Flaps fifteen.

Thus, with the consideration of the subsequent landing gear retraction following the F/O's report on positive rate of climb, actually the crew was performing a standard go-around procedure at the low weight aircraft with the maximum thrust of the engines (N1=101%), as it is prescribed by the Windshear Escape Maneuver. Taking into account that in preparation for the second approach it is this procedure that had been talked over by the crew, the indicated factor may have played a certain role, as later the whole range of the erroneous and inappropriate actions by the PIC resulted in a loss of control of the aircraft. This very moment, most probably, had been a turning point in the chain of the events.

At 00:40:54, the F/O reported go-around to the Rostov Tower controller and was instructed to contact the Rostov Radar controller. The crew did not contact the Radar controller.

The increase of the engines thrust combined with the retraction of flaps and landing gear led to the significant increase of pitch-up moment (more than at the first go-around); to counteract it the substantial push of the control column was required with the application of pushing forces on the control column of up to 50 lb (23 kg), that had been preserved for quite a long time (more than 40 sec). The piloting - especially the precise piloting - of an out of trim aircraft (unbalanced on forces), is always complicated and implies the increase of the pilot's workload, including the psychoemotional component. Indeed, the nature of the control wheel motion on pitch after the initiation of go-around is loose (the longer movements) and abrupt (reactive) with the noticeable delay. This very nature of the piloting is always the evidence of the flight mental mode disruption and the absence of forecast on the further behavior of the aircraft (the pilot "is behind" the aircraft, the aircraft flies "ahead" of the pilot).

Note: *1. It should also be taken into account that the stated forces on the control column PIC, most probably, had maintained by one (left) hand. The other hand was on power levers (the confirmation to this is stated here below).*

2. Hereinafter the integral "flight mental mode" means not only the pilot's reflection of the flight process, that is matching of real aircraft attitude and mode to the perceived ones, but also the ability of the pilot to fly "ahead of the aircraft", including to predict the aircraft behavior in response to the control inputs.

3. As per the information, submitted by the airline, the PIC was well experienced in performing go-arounds in real flights (6 go-arounds not counting the first go-around at the day of the accident, of which 3 as a PF and 3 as a PM). The airline could not provide the information on the reasons for go-arounds. However, based on the data that all go-arounds having been performed at N1 less than 100 %, it could be supposed that the windshear escape maneuvers had not been applied.

As the result all the further actions in the rapidly changing environment, that was evolving into non-standard (non-trained) situation, were of a belated character. The analysis of the angle of climb (pitch) value shows evidently that the PF (the PIC) had been never able to create the initial pitch of 15º, recommended by FCOM. The actual pitch was changing in steps (6º, 12º, 14º, 9º, 14º, 18.5º, 4º). As oppose to the first go-around, the PIC failed to maintain the climb path, set on by the pitch command bar, the position of which on PFD at the same points of time was equal to[30] (4º, 3.5º, 2.5º, 7º, 3º, 1º, 13º). The HUD reconstructed image as per the points of time 00:41:03 (the pitch local maximum 14°), 00:41:07 (the pitch command bar local maximum 7°), 00:41:13 (the maximum reached pitch 18.5°), 00:41:19 (the pitch command bar local maximum 13°) is given on the below figures (Fig. 65., Fig. 66, Fig. 67, Fig. 68).

[30] These values are measured from the present pitch of the aircraft.

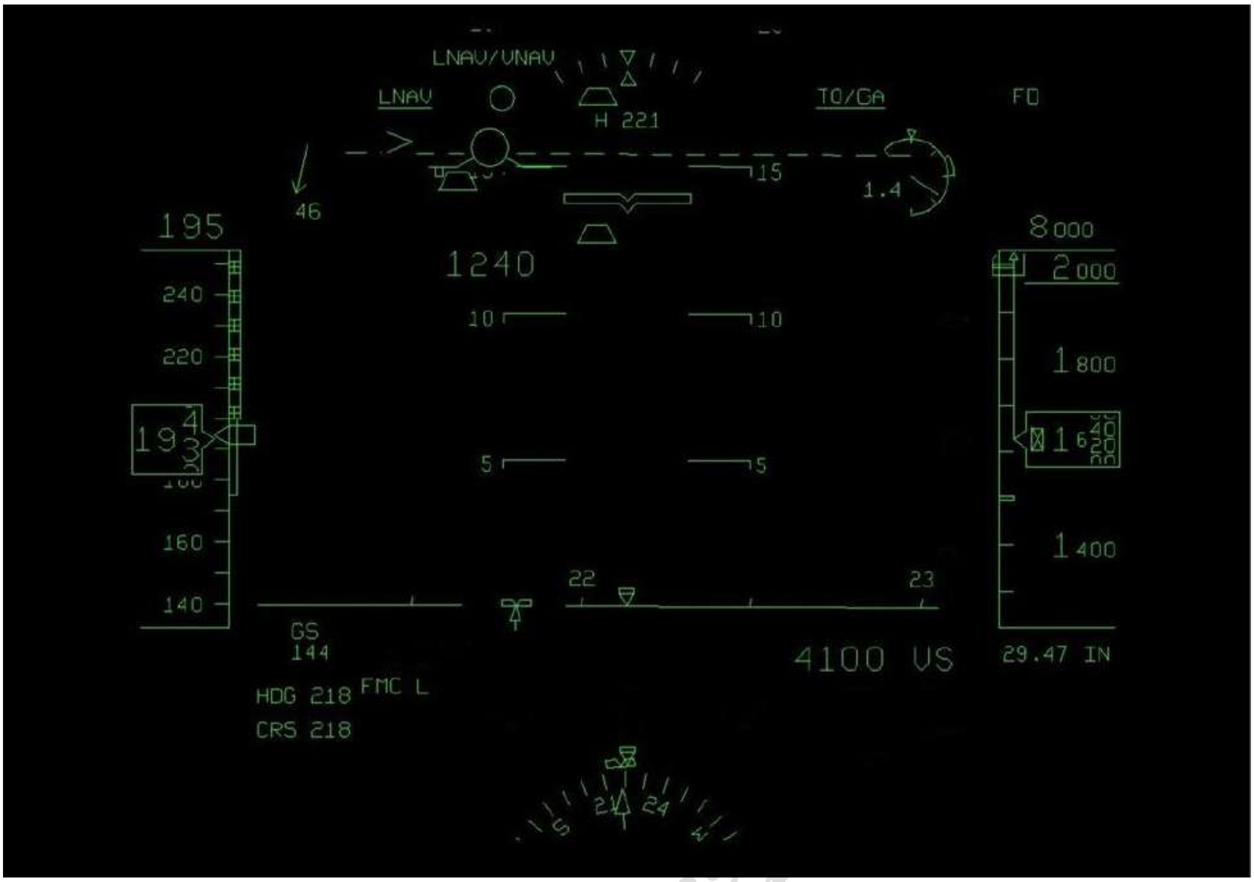

Fig. 65. The HUD reconstructed image at the point of time of 00:41:03 (the pitch local maximum ≈14°)

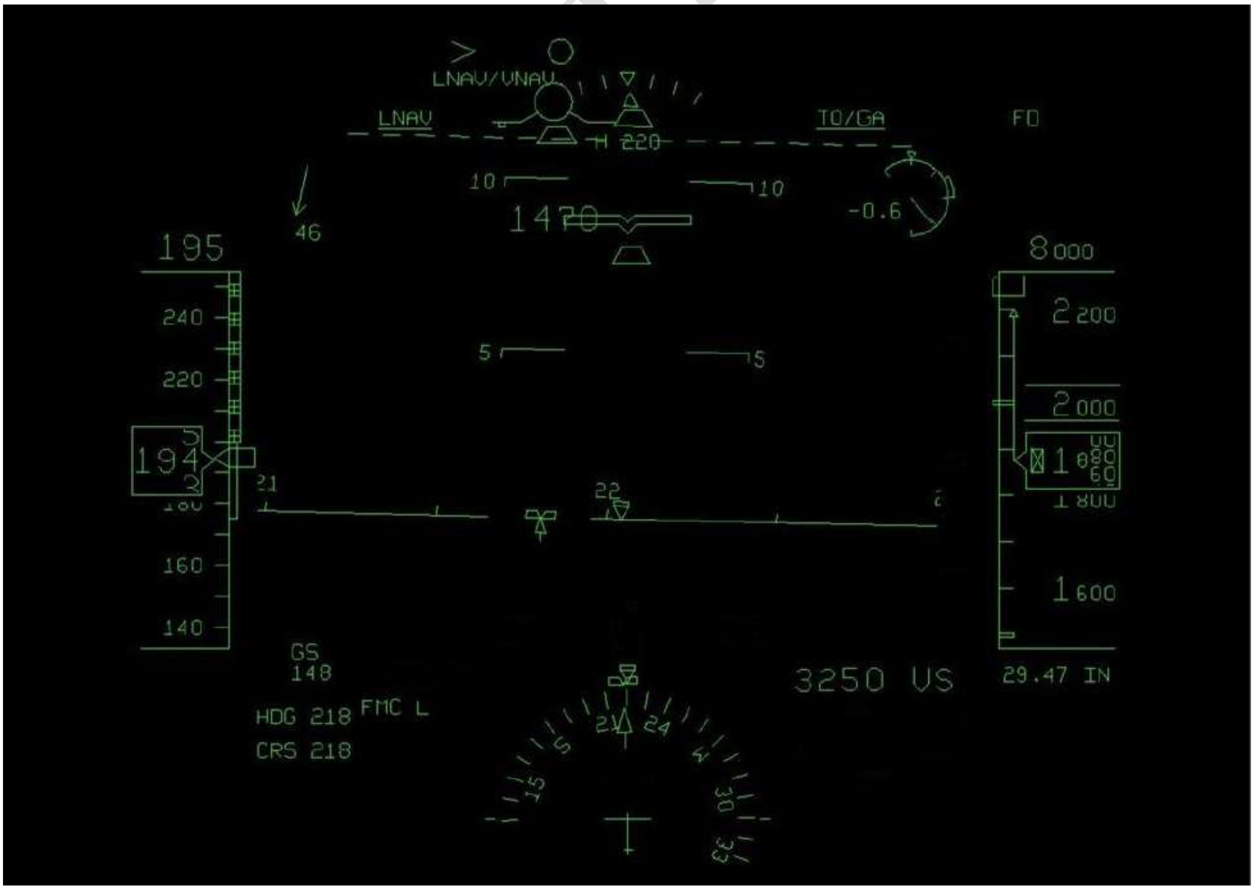

Fig. 66. The HUD reconstructed image at the point of time of 00:41:07 (the pitch command bar local maximum ≈7°)

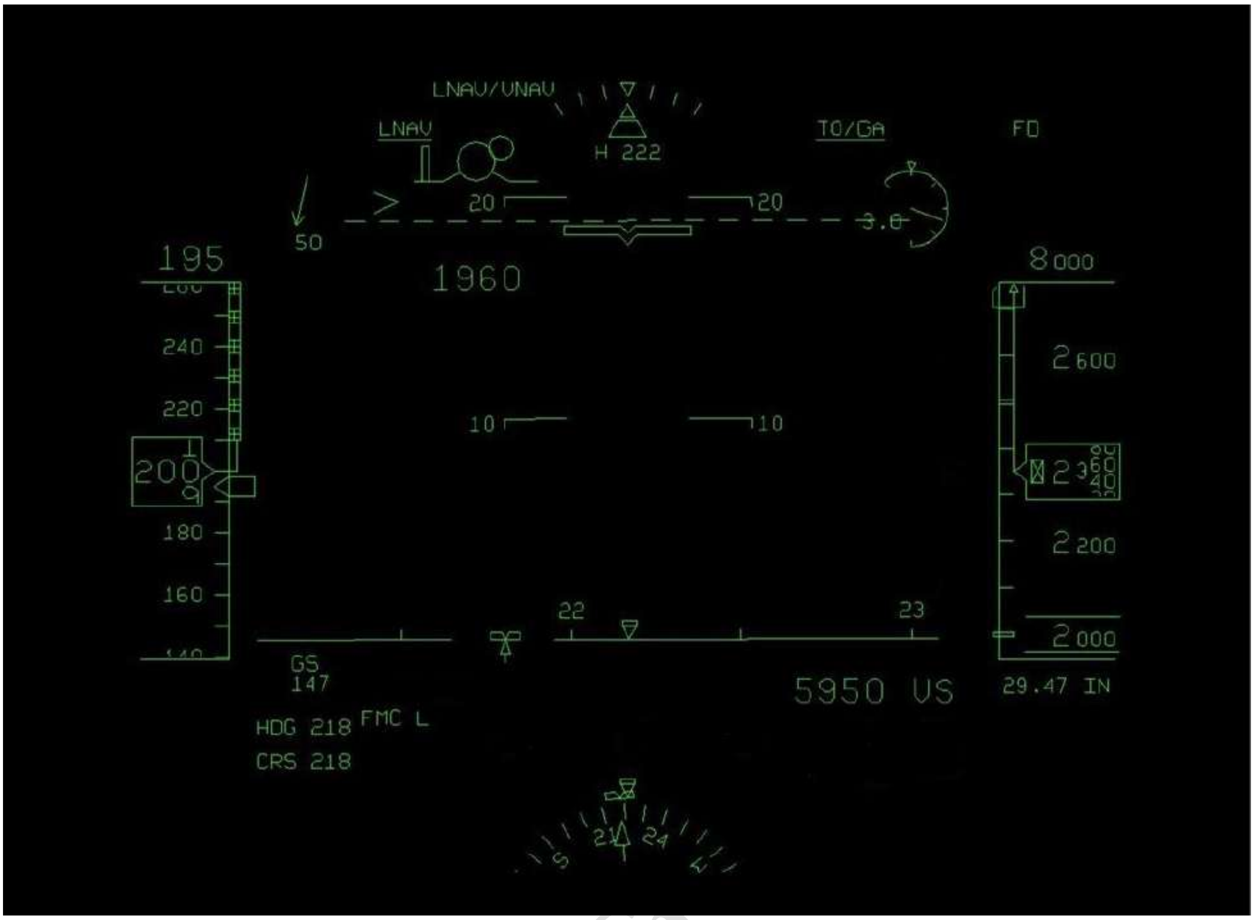

Fig. 67. The HUD reconstructed image at the point of time of 00:41:13 (the pitch local maximum ≈18.5°)

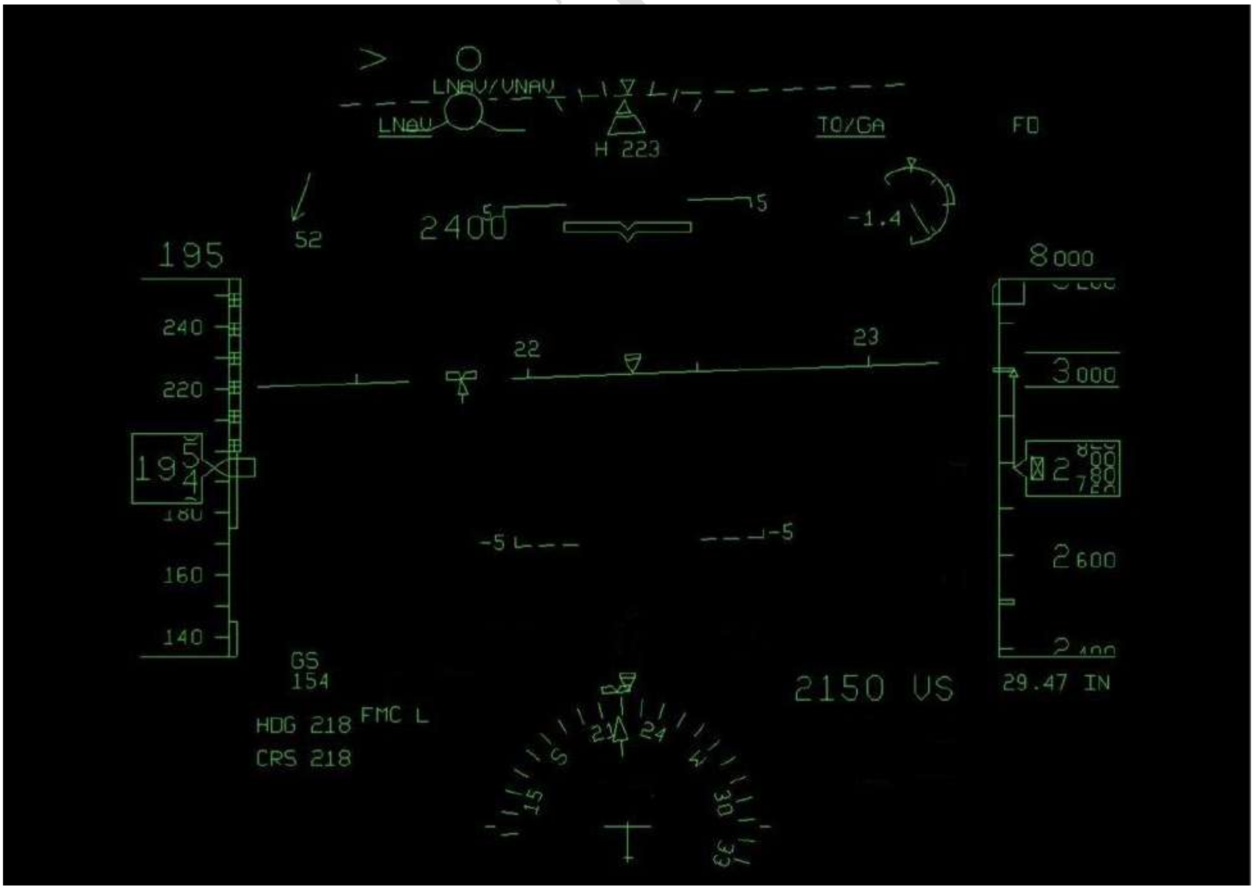

Fig. 68. The HUD reconstructed image at the point of time of 00:41:19 (the pitch command bar local maximum ≈13°)

The average pitch in climb was equal to about 10º, which was obviously insufficient for the given conditions, taking into account that:

– the thrust-to-weight ratio of the aircraft was high (the aircraft was of a relatively low weight of 54 t. and the engines were delivering the maximum possible thrust);

– the drag of the aircraft was significantly less against the first go-around (landing gear up, flaps 15º).

The PIC, apparently, failed to consider all these factors. At the same time the F/O, observing the PIC, having difficulties in piloting the aircraft drew his attention to the necessity to maintain the required pitch.

00:41:09,7	00:41:12,0	F/O	Keep it to fifteen degrees, nose up.

The PIC briefly (for a second) increased pitch up to 18.5º, then reduced it again to 4º...5º, having applied the disproportionately significant pushing movements on the control column (more than ½ of travel from the neutral position to fully forward) and generated the vertical G of 0.43 g. In reaction to such actions by the PIC, the F/O prompted once again:

00:41:18,0	00:41:19,4	F/O	Now keep it, keep it to fifteen, keep it…

Note: *At this moment, there was a minor (down to 97 % N1) decrease in engines power with the subsequent restoration of the maximum thrust. The investigation team is of the opinion that this very decrease was incidental and is associated with the PIC's hand on power levers at the above-indicated significant change of the vertical G.*

Having focused the attention on maintaining pitch, both pilots had completely lost the awareness of on the airspeed, that was gradually increasing and at 00:41:10 reached the limit Vfe (200 kt) for flaps 15º, after which the T.E. FLAP LOAD RELIEF was activated. The flaps were set to 10º. In such a way, it was a repetition of the situation that occurred during first go-around. With that, the F/O, as opposed to the first go-around, did not draw the PIC's attention on the speed exceedance. The engines kept on running at the maximum thrust up to the impact with ground; the flaps handle remained at the 15º detent.

The situation when the attention of the crew was excessively concentrated on the pitch control of the aircraft led to the substantial narrowing of perception of the other information ("the tunnel effect"). The number of parameters, having been monitored and analyzed at a time, had decreased sharply, down to about one or two.

The onset of the critical situation started at 00:41:30.5. In proceeding the piloting of the out of trim aircraft (unbalanced on forces), and obviously enduring inconvenience; at the present parameters of flight: H ≈ 3350 ft QNH (935 m QFE), IAS – 210 kt, pitch – 10º to nose-up, the stabilizer setting – 2.7º to nose-up, flaps 10º, the power mode of the engines – the maximum thrust, the PIC pressed the stabilizer trim switches to nose-down. Fig. 69 presents the HUD reconstructed image at that point of time.

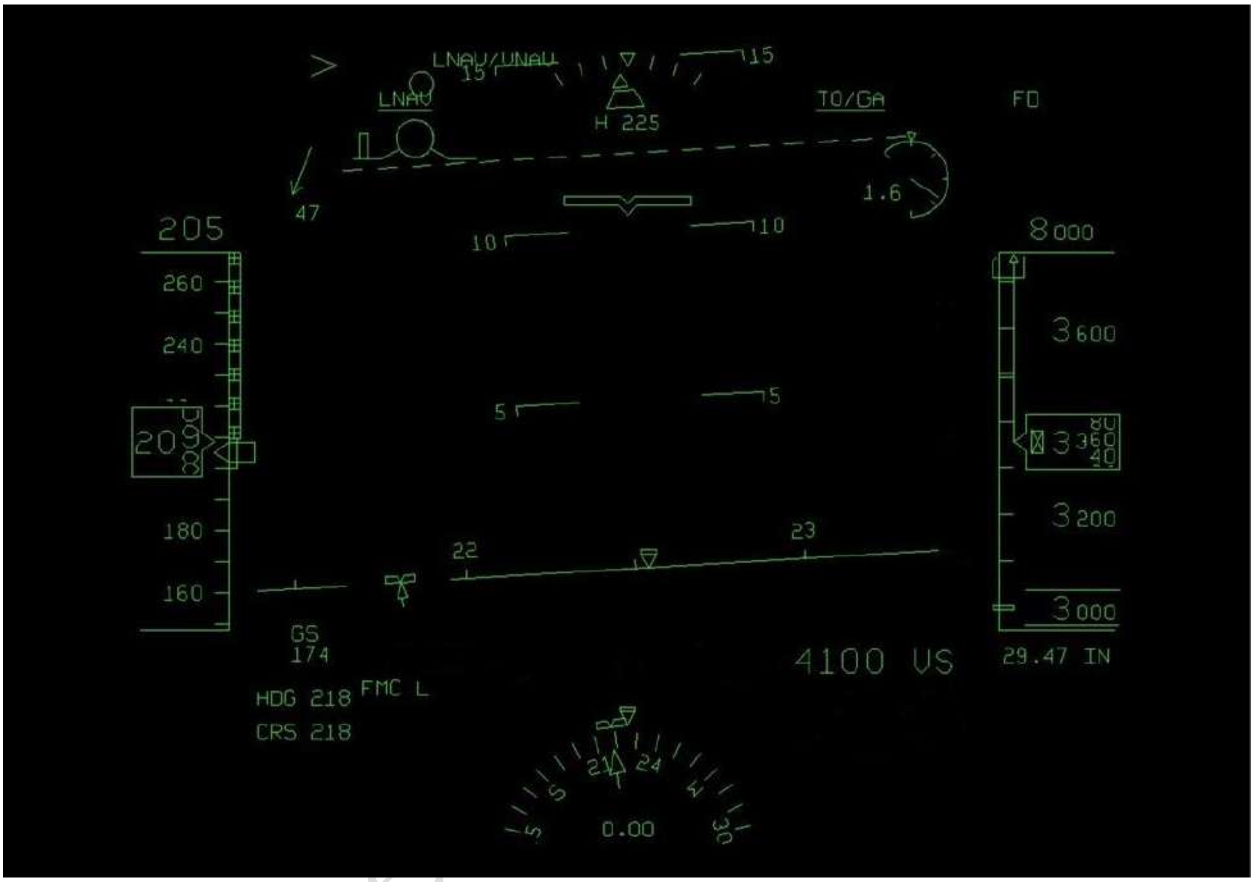

Fig. 69. The HUD reconstructed image at the point of time of 00:41:30.5 (the initiation of the stabilizer trim to nose-down)

The figure is the evidence that the system "commanded" the pitch increase (the dashed line – TO/GA pitch target line – is higher than the aircraft reference symbol). In other words, most probably the PIC, having acted in such a manner, tried "to relieve" the pushing forces on the control column, rather than to transition the aircraft to nose down. However, along the stabilizer trim, the pilot did not return the control column to neutral position, with that the stabilizer trim switch remained pressed for an abnormally long time (12 s!!!).

Note: *1. The investigation team did not identify any signs of failure or the uncommanded movement of the stabilizer. The direction and duration of the stabilizer trim are consistent with the respective discrete signals registration (the FDR records the discrete signals, associated with the commands to the nose-down and nose-up stabilizer trim in a manual or automatic mode). The short-*

time pull of the control column (at 00:41:39) beyond neutral resulted in the stabilizer trim stop that is consistent with the inherent logic of the control system function.

2. Most likely, by this moment of time the flight mental mode at the PIC had been completely disrupted, whereas his emotional condition may be characterized as "distress/a very strong stress". It is confirmed by the fact that from 00:41:33 and up to the end of the flight the quite dynamic pedal inputs are recorded, with that they had not been anyhow justified by the flight situation. It is known from the practice of the air accident investigation that when the pilots encounter complete spatial disorientation and lose the ability to appropriately evaluate the situation, often they start to do the involuntary (reflex) control inputs. In this sense, as for the modern transport aircraft, the deflection of pedals that, usually, are not used in flight, is the most indicative symptom. After the forward deflection of the left pedal within a time of 00:41:33 – 00:41:39, the aircraft bank was changing with a constant angular rate from 5° to the right to 12° to the left with the practically neutral position of the control wheel that again demonstrates the crew failure to monitor all the necessary parameters.

The actions in question (the substantial stabilizer trim to nose-down along with the keeping and even some increase of the average deflection of the control column to nose-down) led to the rapid decrease of pitch (the average pitch rate about 6°/sec) and the aircraft transition from the climb to descent with the significant negative G (initially minus 0.3…minus 0.4 g, then – up to minus 1.07 g), at that the near-zero and negative G (<+0.2 g) were present for a long time.

Note: ***FCT 737 NG (TM), page 7.22:***

It may be difficult to know how much stabilizer trim to use, and care must be taken to avoid using too much trim. Pilots should not fly the airplane using stabilizer trim, and should stop trimming nose down when they feel the g force on the airplane lessen or the required elevator force lessen.

The F/O, operating as PM, realized that the hazardous situation was emerging. Desperately, with the increasing anxiety in voice, he tried "to return" the PIC to a control loop and rectify the situation. From the point of time of 00:41:34 the F/O prompted the appropriate actions to the PF (the control column pull) to prevent the situation transition to the accident. Nevertheless, most likely, the PIC had no longer heard the F/O and had not reacted to his words – he had fully lost the control of the situation, as well as the capability to control the aircraft.

00:41:33,8	00:41:35,4	F/O	Yea. Be careful now.
00:41:35,4	00:41:36,4	CPT	Oh, shit!
00:41:35,6	00:41:36,6	F/O	Be careful. Be careful!
00:41:36,2	00:41:45,9		***Sound effect of rising or falling items sound in flight deck.***
00:41:36,8	00:41:37,3	F/O	Be careful!
00:41:37,5	00:41:38,2	F/O	No, no, no, no, no, no!
00:41:38,3	00:41:38,5	F/O	No!
00:41:38,5	00:41:39,2	F/O	Don't! Don't do do that.
00:41:39,9	00:41:40,4	F/O	Don't do that.
00:41:40,7	00:41:41,6	F/O	No! Pull it! Pull it!
00:41:42,1	00:41:42,5	F/O	Pull it!
00:41:42,7	00:41:43,5	F/O	My God!

The inappropriate actions by the PIC within 12 sec, when the stabilizer trim switches were kept pressed, the aircraft entered into nose-down upset (negative pitch of about 40º, IAS – 280 kt with the flaps 10º, the altitude of 2800 ft QNH (770 m QFE), the engines power at maximum thrust, the stabilizer setting of 2.4º to nose-down).

Within the time interval of 00:41:42-43 it had been a momentary aft control column deflection by ≈11° (more than 2/3 travel off neutral) with the subsequent return beyond neutral in the forward direction. The calculations were the evidence (see Section 1.16.7), that if at that point of time the control column were repositioned to a full pull and was kept at that position, the aircraft could have been recovered from descent with a sufficient margin of height. Only aircraft aerodynamic performance and capabilities are analyzed here. The crew members' state and actions are analyzed below and have not been taken into consideration in the engineering simulation.

Similar results were obtained as a result of the experiment at the B737-800 aircraft simulator. The appropriate actions by the crew (the pull of the control column creating vertical G of 2.2…2.4 with the simultaneous reduction of the thrust to idle) allowed recovering the aircraft safely.

From the point of time of 00:41:44, the F/O attempted to pull the control column (see also Section 1.16.8).

The last seconds of the FDR record explicitly confirms the complete spatial disorientation of the PIC and indicate the critical disruption of the flight mental mode integrity. Apart the lack of appropriate actions on the aircraft recovery from descent (even after the EGPWS PULL UP warning activation) the control wheel was repositioned to practically full left in roll that led to the intensive development of the left roll. The aircraft impacted ground with the significant speed (≈ 340 kt), high negative pitch (≈ 50º) and the left bank ≈ 60º.

Note: *The analysis showed that, most probably, even with the appropriate actions by the pilot at the EGPWS PULL UP warning activation at that point it had not been possible to prevent the catastrophic situation (to recover the aircraft out of descent).*

Honeywell, being the EGPWS manufacturer, upon the investigation team request commented that the accident flight actual parameters (rate of descent 18000 ft/min (91 m/s)) had been far beyond than the maximum values (7000 ft/min (36 m/s)), determined by the TSO C151b and DO-161A documents, in accordance to which the system had been designed.

At the same time at that phase of flight the pilots could not have known that it had been already impossible to recover the aircraft out of descent, for this reason no appropriate actions in response to this warning demonstrates indeed the critical disruption of the flight mental mode.

In the progress of the analysis of the crew proficiency and their in-flight actions the question arises – quite naturally – how the experienced and disciplined crew, having been in a normal working condition and monitored the flight, all of a sudden had lost control and let the situation occur that resulted in the fatal accident?

All the actions and taken decisions (besides the setting of QFE instead of QNH during first approach) up to the moment of initiation of the second go-around testify to a high level of training and proficiency of the crew, and the PIC had been an indisputable leader. The point of initiation of go-around during the second approach can be considered as the onset of the abnormal situation. From that moment, the PIC started to make errors, take inappropriate actions and was no longer a leader. After the Gear Up callout (00:41:00) and up to the end of the record the PIC did not give a single command. Within this time interval, he uttered the total of four remarks:

00:41:12,2	00:41:13,5	CPT	Checked [Exertion breath]
00:41:16,4	00:41:17,6	CPT	Aaak [Exertion breath]
00:41:22,4	00:41:23,1	CPT	Don't worry. Don't worry.
00:41:35,4	00:41:36,4	CPT	Oh, shit!

These remarks were not commands. They are just another proof of the non-optimal psychoemotional state of the PIC.

Why in a short time (several seconds) after taking the decision to go-around did the PIC get into such a condition? As it was already stated above, in case of an unsuccessful second approach due to windshear, the crew were prepared to perform Windshear Escape Maneuver and immediately divert to an alternate aerodrome. However, the landing at the destination aerodrome had been the predominant goal for the PIC. Just to achieve the goal two hours were spent in the holding area. The PIC had been certain that he would manage landing under actual circumstances, if the windshear warning did not activate. Most probably, it was the activation of the warning in question that should have been that internal trigger for the PIC, which would have altered the action plan – to perform go-around instead of landing. Instead of the activation of the windshear warning the speed leap caused the decision to go around which under the conditions of turbulence and gusty wind had not been as much clear sign from the PIC's point of view comparing to the warning activation (taking into account the PIC confidence in his capability to perform landing).

Most probably, psychologically, the PIC had never got over the impossibility to perform landing at the destination aerodrome and accepted the need to divert to an alternate aerodrome. Particularly given that after the first go-around he had been sure in mind that he would have managed landing. The confidence in question at certain time kept haunting his mind and he spoke it out even in conversation with the cabin attendant.

As the result, probably, the PIC had been stuck in "a clinch" of two opposite goals (motives): to proceed approach for landing or initiate go-around. Even though the PIC, in compliance with SOP, took the immediate decision to perform go-around, "the clinch" resulted in the disruption of the previous flight mental mode (the approach with landing), whereas the new one (the go-around) had not been formed yet. The failure to follow the Windshear Escape Maneuver, that had been supposed to be carried out, and the loss of the initiative (the consent to the F/O's offer to retract flaps to 15º, that is to perform standard go-around) is the confirmation to this. As a result, the PIC, whose actions did not allow him achieving the goal, had been in "a mixed- up" condition and lost the ability to predict the further behavior of the aircraft (he was "behind" the aircraft). This led to the loss of the situational awareness and psychological incapacitation.

Thus, the erroneous actions by the PIC, when he had not been able to maintain the required climb path for a long time with the application of the significant "pushing" forces (though to get to the "correct" path he needed to relieve some forces on the control column), first of all are related to his mindset as the result of the simultaneous manifest of two opposite motives at the point of taking decision to perform go-around. Similar casual factors were revealed at the investigations of the other fatal accidents that occurred in the progress of go-around, among them the air accident to the B737-500 VQ-BBN aircraft, operated by Tatarstan airline, on 17.11.2013 at the Kazan airport and to the A320 EK-32009 aircraft, operated by the Armavia airline on 03.05.2006 at the area of the Sochi airport.

The F/O, for the most part, appropriately assessed the attitude of the aircraft and prompted the correct actions to the PIC. The Flydubai airline OM, as the OM of the majority of other airlines, states the actions of the PM in case of the physical incapacitation of the PF. The actions in question are recurrently practiced on simulators. As a criterion of incapacitation (in addition to the obvious symptoms) for the altitudes of more than 1000 ft) the airline OM states the following:

– no verbal reply to two communications by the PF addressed by the PM;

– no verbal reply to the PM's remarks on the significant deviations of the intended flight path;

– no reaction to the system malfunction warning.

In the case under review, the PIC verbally (though in a one word) responded to the prompts by the F/O and there were no system failures occurred.

The events of the psychological incapacitation, when the PF verbally responds to the communication and physically exercises the control inputs, but these are obviously inconsistent with the current flight environment, as a rule, are not incorporated into the airlines OM. The Flydubai airline OM did not state such occurrences either. Consequently, the PM for more than 30 s had been prompting the correct actions to PF and at a certain point even tried to intervene in the control with prompting the correct direction of the control column deflection "by the action". Still, because of the continued inappropriate actions by the PIC and the specific features of the pitch control system (Sections 1.16.7 and 1.16.8), the actions by the F/O had been unsuccessful.

Note: *On the results of one of the simulator sessions, the flight instructor wrote down a comment to the F/O "Needs to be quite a bit more assertive in what is needed from the Captain. Tell him/her what you want done and do not wait for the Captain to enquire with you or direct you in this regard. Need to be more decisive in taking actions when needed." Maybe more decisive actions by the F/O in intervention on the control of the aircraft could have prevented the accident, still he started to act in a formal way (as fixed by the OM provisions) no sooner than against the inappropriate actions by the PIC at the EGPWS Pull Up alert activation.*

A major factor that led to the PIC's spatial disorientation and his inability to take appropriate actions was, probably, the G-force that, as the result of his control inputs, reached the near-zero and negative values. The practice of flights with the near-zero and negative G is the evidence that the pilots, who encounter zero G for the first time (even if fastened by the seat belts) during the first seconds are not just incapacitated, but spatially disoriented as well. In addition at the near-zero and negative Gs together with the unsecured objects the mud and dust, always present in the cockpit, float up in the air. This occurs, generally, all of a sudden, with a startle effect to the crew. Likewise, the mud and dust, as a rule, penetrate into the eyes and nose, degrading the vision and breath. The investigation team has no data available that either of the crewmembers up until that time had the practical knowledge of the zero-gravity condition, not to mention the respective exercise.

The findings on the crew's actions at the final phase of the flight

In progress of the second approach up to the point of go-around, the crew's actions were appropriate and complied with SOP.

The onset of the abnormal situation was at the point of initiation of go-around and, most probably, had resulted from the inherent lack of psychological readiness of the PIC to perform go-around that led to the loss of his leadership in the crew, the disruption of the flight mental mode and piloting errors, which within a short time were transformed into the inappropriate actions, resulted in the loss of control of the aircraft. The key point for the transition of abnormal situation into the accident (emergency) one was the fact that for a long time (12 sec) the PIC kept holding the trim switches (the stabilizer control) to nose down. With that, the stabilizer trim rate with the extended flaps is about twice the trim rate with the retracted flaps. This resulted in the significant pitch imbalance and, combined with the keeping of the forward deflection of the control column, inconsistent with the actual situation, the aircraft encounter near-zero and negative Gs with the associated spatial disorientation of the PIC. The situation itself was consistent with the psychological inability of the PIC to control the aircraft (the pilot incapacitation); however, the actions of the PM under the circumstances in question are not described in the airline OM.

The F/O, for the most part, was appropriately assessing the attitude of the aircraft, prompted the correct actions to the PIC and even attempted to intervene in the control of the aircraft. Still, the essentially correct attempts of the F/O to prompt the PIC from the hazardous situation had been unsuccessful.

The "operational" tiredness can be attributed to the factors that could have had the negative impact on the PIC's condition and actions – by the moment of the accident the crew had been proceeding the flight for 6 hours, out of which 2 hours under intense workload, related to the performance of go-around and the necessity to take non-standard decisions; in this context the fatal accident occurred at 04:42 as per the departure airport (Dubai) time zone – the worst possible time from the point of view of the circadian rhythms, when the human performance is severely degraded and is at its lower level along with the increase of the risk of errors.

2.2. On the peculiarities of the trim (relief) of forces

As it was mentioned above, the long-time press of the trim switches (the stabilizer control) to nose down by the PIC had been a factor that contributed to the transition of the abnormal situation into the accident (emergency) one. Probably, by this action the PIC tried to relieve the "pushing" forces on the control column that had been preserved by him for a long time.

The presence of forces on flight controls (for example on the control column), which, in general, increase along with the increase of their deflection, is required by the modern airworthiness standards. With that the systems that trim (relieve) these forces are introduced into design. There exist two fundamentally different concepts of the forces generation and relief on the flight controls.

The first concept is nowadays integrated, mainly, to the light and ultralight aircraft, on which the control column feel is achieved with the direct forces from the aerodynamic control surfaces (for example from the elevator). In this case at the deflection of the elevator (the control column) the pilot feels a feedback on changing forces (due to the change of the hinge moment on the control surface), which is caused by the change of the pattern of the elevator flow by the relative wind. To trim (relieve) the forces (to reduce the hinge moment) for the case the specific auxiliary aerodynamic surfaces (trim tabs) are provided, mounted on the trailing edge of the aerodynamic control surfaces. In deflection to the opposite direction against the deflection of the control surface with the larger arm they relieve forces on the control surface and, consequently, on the flight control. As for this concept, if a pilot moved the control surface to a certain position to create the control moment and wants to preserve this moment, but to relieve forces, he should, with no change of the flight control (control surface) position, deflect the aerodynamic trim tab to the corresponding (opposite) direction. As the result the forces on the flight control will be relieved, whereas the flight control itself and the control surface will remain in a required position. The aircraft with that type of pitch control usually have fixed or adjustable (repositioned on a particular setting) stabilizers. That means, generally speaking, that the pitch balance and control of the aircraft are ensured by the elevator.

As for the modern commercial airliners, on which the PCUs are integrated to deflect the control surfaces, it is not the case of the direct transfer of forces to the flight controls. The aircraft of the type can still integrate the trim tabs, but these relieve the forces on the PCUs and are controlled automatically, not by the pilot. With that, the control wheel loading is achieved synthetically with the specific feel and centering unit. Generally, as for these aircraft types, the trimmable stabilizers are mounted that may be deflected to any position (within the range of travel), both commanded by pilot and automatically. It is this concept that was implemented on the Boeing 737-8KN A6-FDN aircraft (and on all the aircraft of the Boeing 737-800 type). At the same time, the aircraft has no function of trim (relief) of the forces directly on the control column. To relieve forces on the control column it should be returned to neutral position, with that the elevator deflection with the associated control moment is changed in proportion.

As for this very concept if a pilot created a certain control moment with the elevator and wants to preserve it with the simultaneous relief of the forces on the control column, he should initiate the stabilizer movement in direction along the deflection of the elevator. With the stabilizer deflection, a pilot returns the control column to neutral, relieving the forces. Concurrently the deflection of the elevator is reduced. At the end of the cycle the required control moment is created by the stabilizer, whereas the control column is in neutral position. The concept implies the pitch balance of the aircraft, ensured with the stabilizer, the control is achieved with the elevator. As stated above, FCT 737 NG (TM) page 7.22 reads that the pilots should not fly the airplane using stabilizer trim.

The vast majority of pilots start their career on the airplanes of the first type. At the transition training to the aircraft of the second type the specific features in question should be explained to them.

Upon the request of the investigation team the aircraft manufacturer, the Boeing Company, responded that the Boeing 737 aircraft documentation does not contain the specific guidance on the general principles of the forces trim[31]. Boeing is of the opinion that the indicated skills are integral of the basic airmanship to perform flights on large transport aircraft. At the same time the manufacturer notes that this documentation is designed based on the assumption that the customers have had the previous flying experience on the jet multi-engine aircraft and are familiar with the basic systems of the jet aircraft and basic flight maneuvers, common for the aircraft of the type. In relation to this FCTM does not incorporate the background information, of which the awareness is considered as prerequisite to familiarize with the concerned document.

Note: *At the same time, at the movable stabilizer introduction into service Boeing has issued the detailed guidance, explaining the general principles of the use of such systems through the Boeing 707 and 720 aircraft. These materials can be found in the Boeing Airliner magazines of April, 1959 and May, 1961 on the myboeingfleet.com website.*

As it is indicated in Section 1.5.1, the Boeing 737 type was, most probably, the first jet multi-engine aircraft in the PIC's career. Prior to that, the PIC had operated light aircraft. The investigation did not manage to find the data on these airplane types. It had not been possible to determine, whether the PIC had been ever informed of the peculiarities of the forces trim at the transition training.

[31] In this case, the general principles of forces trimming on large transport airplanes with movable stabilizer are discussed, and not the operation of the system mounted on the specific aircraft type (Boeing 737-800).

The investigation team notes that throughout standard operation the Boeing 737 pilots rarely run into the necessity to trim the stabilizer manually by a large amount as the aircraft balance is exercised by the automatic systems of the aircraft.

As for the accident flight, both in progress of the first and the second go-around the PIC, when pressing the trim switches, did not return the control column to neutral, thereby increasing the pitch-down moment. In the course of the meetings with the representatives of the command, flight crew and instructor personnel of the airline the view has been expressed by them that the PIC could not have possessed the sufficient level of knowledge on the peculiarities of the forces trim on the aircraft of the Boeing 737 type.

The investigation team also notes that in case of long-time press on the stabilizer trim switches there is a danger of “loss” of the feedback on forces. Due to the small amount of forces the pilot’s finger gets used to them quickly, which may lead to the “prolongation” of the earlier started action, that is to the “holding” of the trim switches. The non-optimal working condition of the pilot or the situation, when the pilot does not achieve the required goal (the forces relief on the control column) with the mentioned action, can be contributive in the case.

IAC had come across the alike phenomenon in the previous investigations (see for example the results of the investigation of the fatal accident to the Ilyushin Il-86 RA-86060 on 28.07.2002 at the Sheremetyevo airport, Section 1.18.1). To prevent such occurrences some aircraft types integrate the discrete control of the stabilizer – one press implies the stabilizer trim to certain amount. To trim further the trim switch is to be released, and then pressed again.

The potential risk of such a situation is also in the fact that the signs, indicative of the stabilizer moving (resetting), (in the case of Boeing 737 it is the rotating trim wheel, enabling the back-up control of the stabilizer), themselves (without the analysis of their duration and monitoring of the stabilizer actual position) are not perceived by the pilots as alarming, as they are constantly manifested throughout normal operation. According to SOP no pilot is obliged to monitor the in-flight stabilizer setting on the indicator (it is located beneath on the central console next to the back-up control wheel and is out of the line of sight of the pilots), with that the event of pressing the trim switches by the finger may not be noticed by PM.

The PM has the opportunity to stop the stabilizer trim by pressing the trim switches in the opposite direction (as for the situation of the accident flight with the control column, for a long time had been kept by the PF at the nose-down deflection, for the PM to use “his own” stabilizer trim switches it had been necessary to use the stabilizer override switch (see also Section 1.18.2).

2.3. On the use of HUD in progress of go-around

As it was stated above, according to the airline SOP (Supplement D, Section D.1.2) the use of HUD, if it is operative, is mandatory throughout the entire flight.

FCT 737 NG (TM), page 1.42 reads that no restrictions are imposed to the use of HUD. At the same time, the document does not contain the description of any additional actions by the crewmembers as for the use of HUD in progress of go-around.

The airline SOP incorporates the information on the HUD automatic switch to the PRI mode following the press of TO/GA button. The crew is also prescribed to adjust the Aircraft Reference Symbol to the dashed Target Pitch Line, upon which follow the Guidance Cue.

Both FCTM and SOP encourage the use of HUD at any time (on any leg of the flight), since it facilitates the monitoring of the aircraft flight parameters with the concurrent out-of-the-window view. Actually, it is one of the main advantages of the use of HUD in the observation of the outside environment with the preservation of monitoring of the primary flight parameters.

At the same time, at certain flight legs, for example, at the go-around or at the aircraft upset recovery, especially if it is the occurrence in IMC and at nighttime, the advantage in question is not relevant.

Indeed, under certain circumstances, such as inappropriate adjustment of the unit brightness against specific lighting environment, the excessive focus of the pilot on the outside environment at the potential different visual effect in cloud or fog, may contribute to the degraded situational awareness and/or spatial orientation.

One more specific feature of the use of HUD is that the pilot only at his certain relative head posture against HUD can observe the “complete” picture. At the considerable change of the pilot’s head posture against HUD, for example, at the extreme maneuvers, severe turbulence, upset encounter (notably with the reach of near-zero and negative Gs) the portion of the HUD picture may be lost out of the pilot’s vision field. Following the investigation team request the HUD manufacturer responded that at its certification there were no flight assessment of the unit carried out into the entire range of the operational G (up to -1 g) for the Boeing 737 aircraft (since it is not stipulated by the certification requirements) and the respective test pilot evaluation does not exist either.

Should the aircraft encounter irregular attitude or upset the HUD indication changes. The figures below (Fig. 70, Fig. 71, Fig. 72) represent the HUD reconstructed image at approximately the time of 00:41:36, 00:41:40 and 00:41:43.

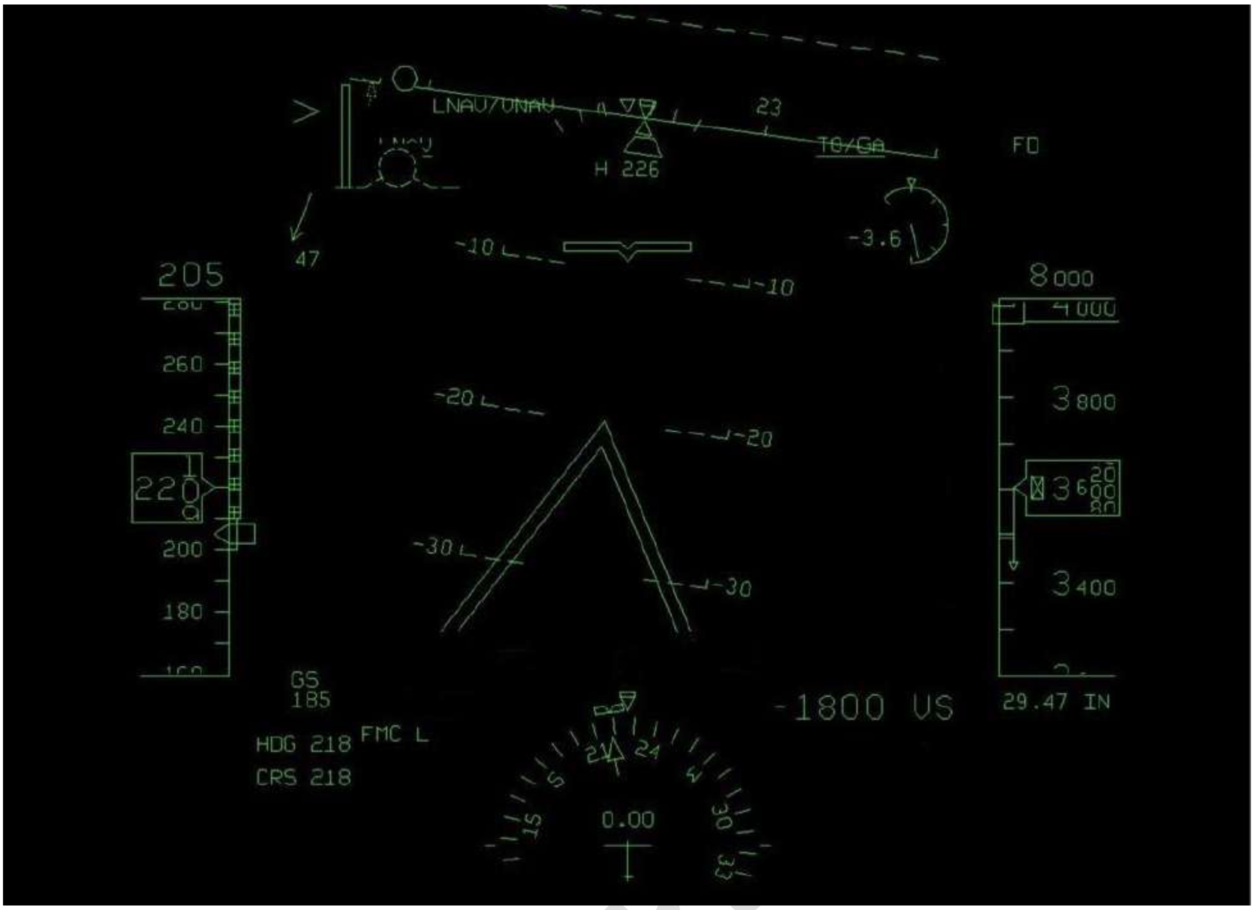

Fig. 70. The HUD reconstructed image at the point of time of 00:41:36

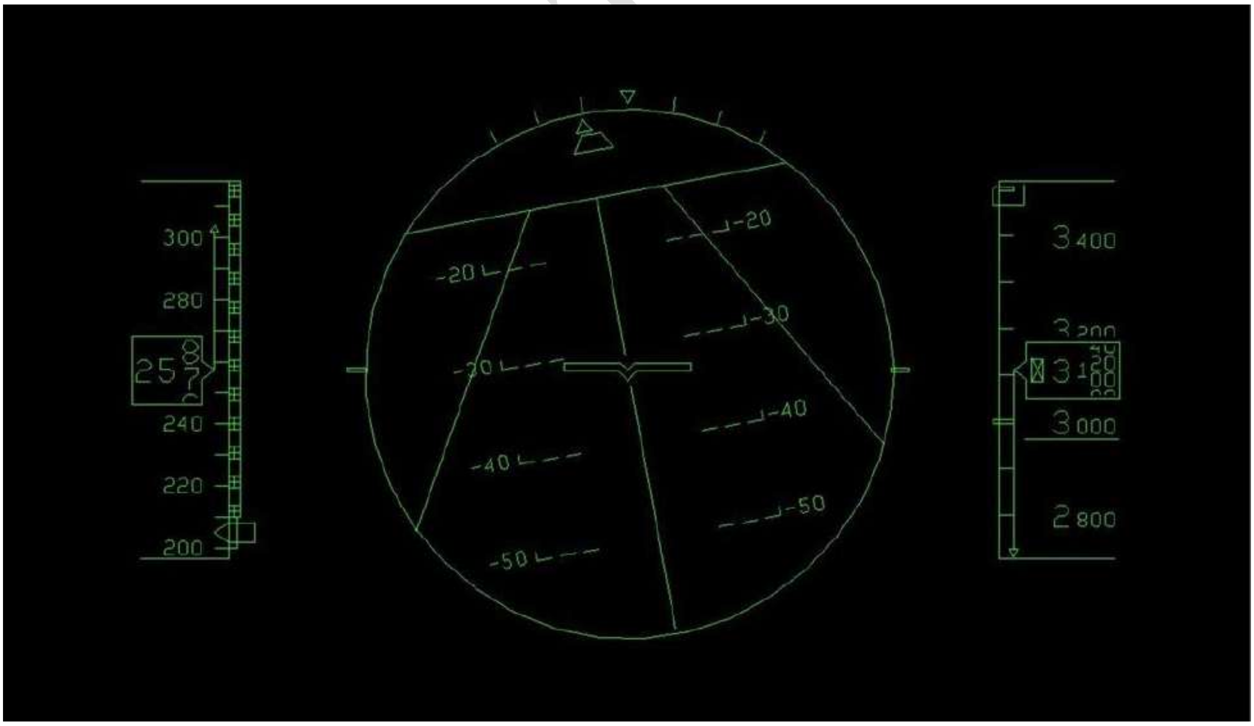

Fig. 71. The HUD reconstructed image at the point of time of 00:41:40

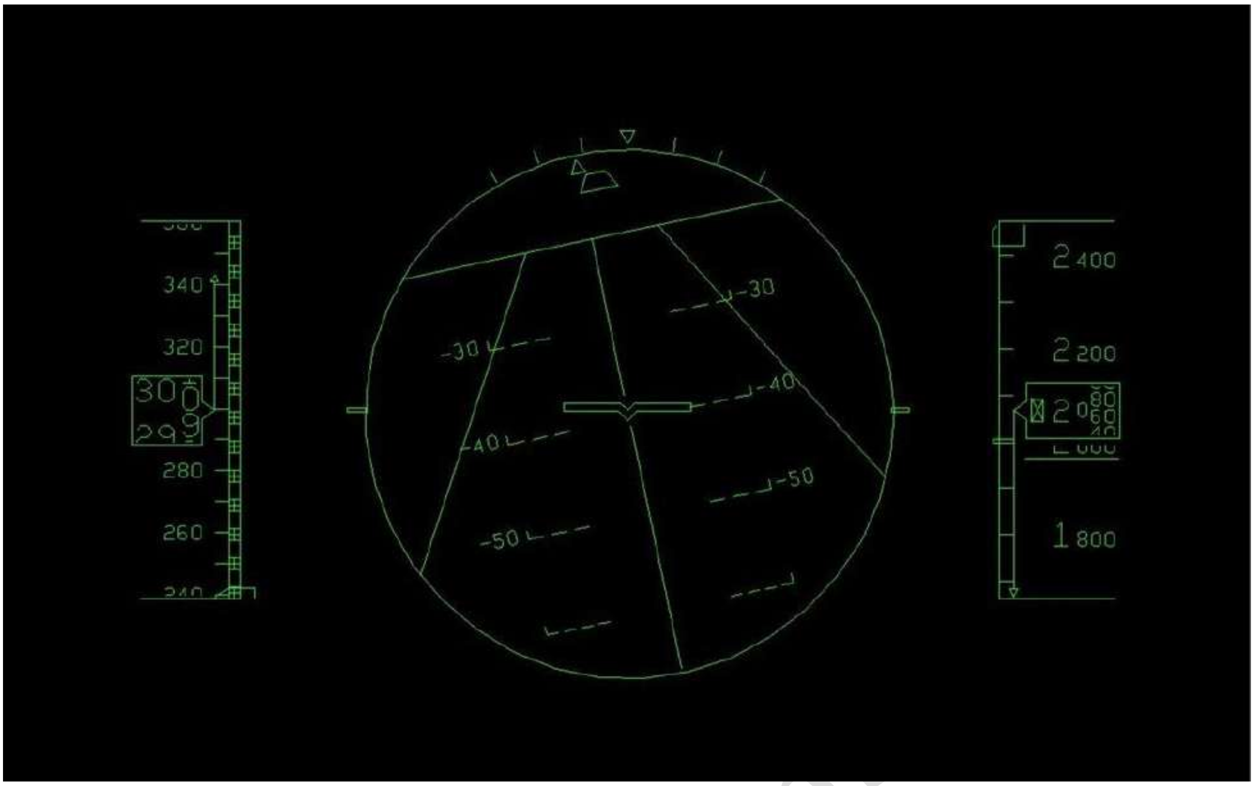

Fig. 72. The HUD reconstructed image at the point of time of 00:41:43

At Fig. 70, at the actual nose-down pitch of about 10°, the upward pointing Pitch Chevron is displayed on HUD (the direction of the aircraft recovery to the “regular” flight) with the top point at the pitch value of 20° nose-down, at the same time the HUD is still operated at the PRI mode. The Pitch Chevron appears when the HUD is switched to the compressed mode. The Pitch Scale is compressed, when the aircraft attitude is such that the Horizon Line or the Flight Path Symbol cannot be displayed conformably. In the compressed mode, the increment of the pitch scale is doubled, from 5° to 10°. The figure is the evidence that in this mode the proportion between the position of Guidance Cue and Flight Path Symbol, the target and actual pitch symbols is no longer respected. At that the Flight Path Symbol is displayed in dashed line – becomes “ghosted” (the term, used in the HUD Pilot Guide) – this means it is no longer conformal with the real world, though being in a qualitatively correct position against the Guidance Cue.

The respective information is stated in the HGS Pilot Guide. All the while, it is doubtful that the PIC in the progress of the simulator sessions, with the standard go-arounds performed, could have often observed the similar change of indication. In the case, the HUD picture becomes as if “cluttered”, which, taking into account the increased stress of the pilot, may lead to the wrong interpretation of readings.

One more specific feature of the display consists in the Pitch Scale Lines, which in the positive region (to nose-up) are displayed solid-line, whereas in the negative region (to nose-down) are dashed. The Pitch Target Line at the go-around is dashed as well. At the standard go-around, the dashed Pitch Target Line contrasts well with the solid lines of scale and Horizon. In the situation of the accident flight, the dashed Pitch Target Line was displayed next to the dashed lines of the scale. Although the lines of scale are visually different (they integrate additional side "notches", pointing the direction of recovery to the "zero pitch", and digital values, the dashed line is ruptured in the middle and is of a smaller length), as for the stress situation, the pilot with the trained skills to match aircraft reference symbol to "dashes" (see the SOP guidance above), may misinterpret the actual indication.

Fig. 71 and Fig. 72 represent the HUD reconstructed images at the points of time, coherent with the maximum reached negative G (-1.07) and the moment of the F/O's interference into the control. It is apparent that HUD switched to the display mode, corresponding to upset. The HUD is switched to this mode, when the nose-down pitch exceeds 20°. According to the HGS Pilot Guide, this mode enhances interpretation of an unusual attitude by the pilot. All the "redundant" information is retracted out from the HUD screen. These are only altitude and IAS scales, pitch and roll together with the slip indicator that are displayed.

In the progress of the investigation team activities team some pilots noted that in the stress environment the applied indication (two nonparallel lines) might be misinterpreted by the pilot, as the indication, similar in appearance, is used to display RWY at the HUD operation in the AIII mode.

Thus, taking into account the lack of the objective information on the HUD operation (there were no flight tests of the unit carried out in the entire range of the operational G; the impossibility to reproduce the real HUD readings in the progress of the accident flight, that is the image, the pilot was really watching with the consideration of his posture in the seat, through the stream video (see Section 1.16.9) or at the FFS) did not allow making unambiguous conclusion on its possible impact on the flight outcome.

At the same time the investigation team believes that the further elaboration of the methodological issues of the practicability and the use of the HUD at different segments of flight, as well as the carry out of the additional flight tests into the entire operational range and the works on the improvement of the data presentation (with the consideration of the opinion of the experts in ergonomics and aviation psychology) may mitigate the risks of the erroneous interpretation of readings in the stress situation.

2.4. On the possible impact of somatogravic illusions

Somatogravic illusions have been noted repeatedly as a contributing factor during investigations of aviation accidents and incidents which involved go-arounds[32].

[32] See the BEA Study on Aeroplane State Awareness during Go-Around /ASAGA for details (**http://www.bea.aero/etudes/asaga/asaga.php**).

Note: *Somatogravic illusion is the common form of vestibular illusion or "false sensation". Somatogravic illusion may lead to spatial disorientation. The significant positive longitudinal acceleration of the aircraft may contribute to the nose-up pitch illusion. If it is the case, the pilot in a horizontal flight may instinctively deflect the control column forward, tending to avoid the increase of the "perceived" pitch. The rapid deceleration of the aircraft results in the opposite effect: the pitch-down illusion is induced and the pilot may inappropriately pull the control column, thereby increasing pitch.*

The investigation team analyzed the possible impact of the somatogravic illusions on the outcome of the flight.

For the preliminary assessment of the possible occurrence of the somatogravic illusions the GIF (gravito-inertial force) action angle value is usually analyzed (the "illusory pitch").

Note: *The gravito-inertial force constitutes in the longitudinal and vertical G effect on the pilot. The angle of action of this force may be approximately assessed according to the following formula:*

$GIF \approx arctg\frac{Nx}{Ny}$, *where Nx, Ny – longitudinal and vertical G, recorded by FDR.*

The formula is estimative as it has a range of limitations and assumptions. For instance, it incorporates neither the angular rates of the aircraft motion, nor the dynamic processes, associated with the function of the human organs of perception (the otoliths and semicircular canals). It is also obvious that the formula is restricted on the near-zero values of the vertical G.

The results of the calculations by formula are given on Fig. 73. The plot is the evidence that within time intervals of 00:40:52 – 00:40:56, 00:41:05 – 00:41:09, 00:41:14 – 00:41:23 and from 00:41:33 up to the end of the flight there are substantial differences in the values of the recorded pitch and GIF angle, with that the GIF angle is greater, that means that there are prerequisites for the occurrence of the "pitch-up" illusion.

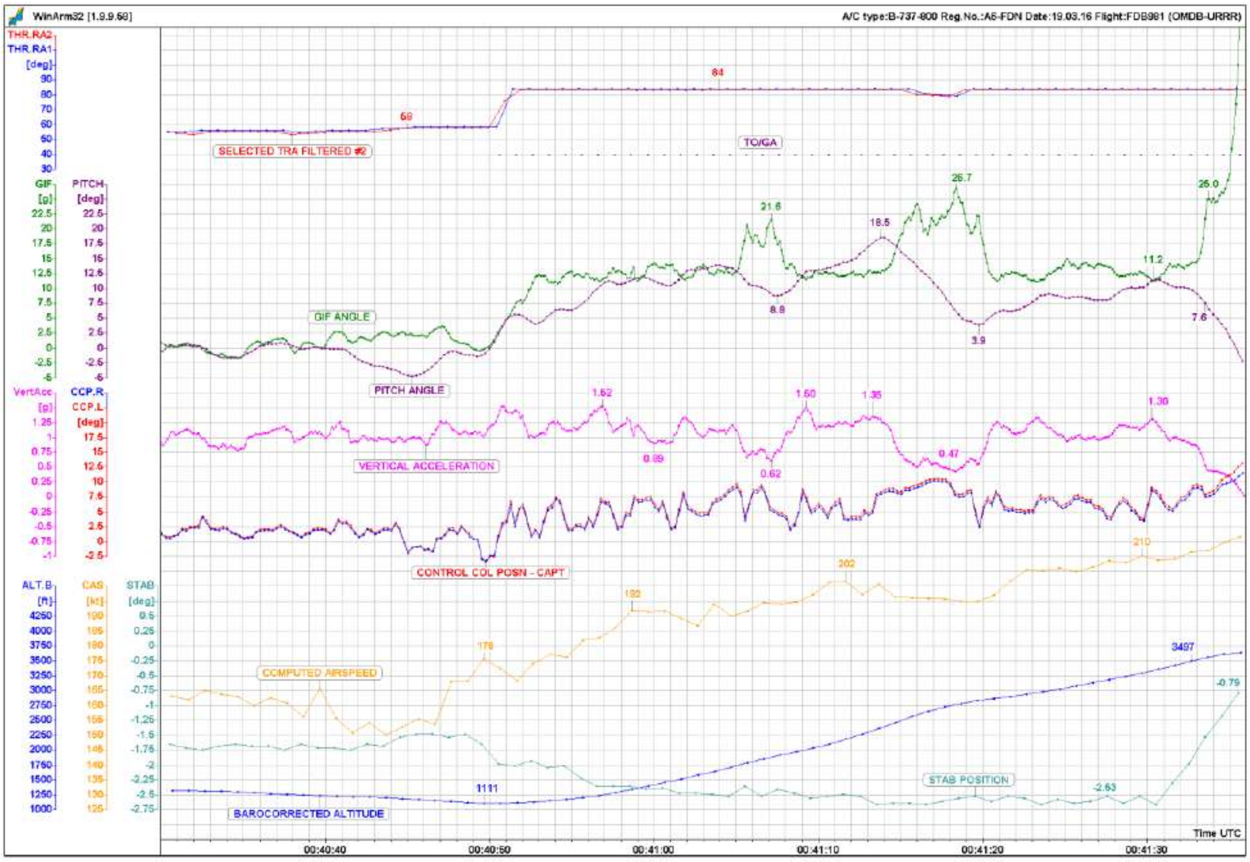

Fig. 73. The estimated GIF angle

In the progress of the discussion of the draft Final Report the State of the Operator expressed the viewpoint that ***in 2 or 3 seconds after the initiation of another go-around*** the PIC had been fallen under the influence of the pitch-up illusion and all his further actions, having led to the accident, had been carried out affected by that illusion.

The investigation team does not agree with this position. The investigation team notes that the presence of conditions for the somatogravic illusions (in this very case the mismatch of the actual pitch and GIF angle) is **a *necessary, but not sufficient condition*** for its actual effect on pilot. Actually, the illusion emerges (the pilot is affected by it) at the flight out of sight of the natural horizon and/or ground reference and at the deficient monitoring of the flight parameters on instruments.

At the initial phase of go-around (that is to say when on the opinion of the State of the Operator the PIC had fallen under the influence of the illusion) the flight had been actually proceeding in VMC. According to the KRAMS-4 weather information archive at the moment of the accident the cloud base of the scattered (4 octants) cloud had been equal to 420 m above the RWY level (1660 ft QNH), RVR at the touchdown and midpoint equal to 7000 m. This altitude had been passed at 00:41:04, that is in 14 seconds after the initiation of the go-around. It is highly unlikely that the PIC, having piloted by HUD, that is at ***that very phase of flight*** having watched both the instruments readings and the outside environment, had fallen under the influence of the somatogravic illusions ***in 2-3 seconds after the initiation of go-around.*** The cloud base of the broken (5-7 octants) cloud that had been equal to 1080 m above the RWY level (3820 ft QNH) had never been reached.

Thus, the complex analysis of all the information available, stated above, is the evidence that, most probably, both the intense forward repositions of the control column up to the initiation of the stabilizer trim to nose-down and the trim itself, had not been attributable to the PF (the PIC) having been affected by the “pitch-up” illusion.

At the last time interval being considered (after the start of the stabilizer trim to nose-down and the outbreak of the near zero and negative G) there had been the explicit conditions for the most intense “pitch-up illusion”. However at that phase of the flight the PIC was completely disoriented and it does not seem possible to assess the potential impact of one or another factor (the stress, negative G, somatogravic illusions) on it. The F/O up to the point of the aircraft impact with ground had not been subject to spatial disorientation.

Consequently, the investigation team is of the opinion that the potential occurrence of the somatogravic “pitch-up illusion” ***did not have crucial importance as far as the onset of the accident situation is concerned***. In the progress of the accident situation the pitch-up illusion might have had some impact on the long-time keeping the trim switches pressed to nose-down.

3. Conclusion

The fatal air accident to the Boeing 737-8KN A6-FDN aircraft occurred during the second go around, due to an incorrect aircraft configuration and crew piloting, the subsequent loss of PIC's situational awareness in nighttime in IMC. This resulted in a loss of control of the aircraft and its impact with the ground. The accident is classified as Loss of Control In-Flight (LOC-I) occurrence.

Most probably, the contributing factors[33] to the accident were:

– the presence of turbulence and gusty wind with the parameters, classified as a moderate-to-strong "windshear" that resulted in the need to perform two go-arounds;

– the lack of psychological readiness (not go-around minded) of the PIC to perform the second go-around as he had the dominant mindset on the landing performance exactly at the destination aerodrome, having formed out of the "emotional distress" after the first unsuccessful approach (despite the RWY had been in sight and the aircraft stabilized on the glide path, the PIC had been forced to initiate go-around due to the windshear warning activation), concern on the potential exceedance of the duty time to perform the return flight and the recommendation of the airline on the priority of landing at the destination aerodrome;

– the loss of the PIC's leadership in the crew after the initiation of go-around and his "confusion" that led to the impossibility of the on-time transition of the flight mental mode from "approach with landing" into "go-around";

– the absence of the instructions of the maneuver type specification at the go-around callout in the aircraft manufacturer documentation and the airline OM;

– the crew's uncoordinated actions during the second go-around: on the low weight aircraft the crew was performing the standard go-around procedure (with the retraction of landing gear and flaps), but with the maximum available thrust, consistent with the Windshear Escape Maneuver procedure that led to the generation of the substantial excessive nose-up moment and significant (up to 50 lb/23 kg) "pushing" forces on the control column to counteract it;

– the failure of the PIC within a long time to create the pitch, required to perform go-around and maintain the required climb profile while piloting aircraft unbalanced in forces;

– the PIC's insufficient knowledge and skills on the stabilizer manual trim operation, which led to the long-time (for 12 sec) continuous stabilizer nose-down trim with the subsequent substantial imbalance of the aircraft and its upset encounter with the generation of the negative G, which the crew had not been prepared to. The potential impact of the somatogravic "pitch-up

[33] In compliance with Manual of Aircraft Accident and Incident Investigation (ICAO Doc 9756) the factors are stated irrespective of their priority. The determination of the contributing factors does not presume the apportion of blame or liability.

illusion" on the PIC might have contributed to the long keeping the stabilizer trim switches pressed;

– the psychological incapacitation of the PIC that resulted in his total spatial disorientation, did not allow him to respond to the correct prompts of the F/O;

– the absence of the criteria of the psychological incapacitation in the airline OM, which prevented the F/O from the in-time recognition of the situation and undertaking more decisive actions;

– the possible «operational» tiredness of the crew: by the time of the accident the crew had been proceeding the flight for 6 hours, of which 2 hours under intense workload that implied the need to make non-standard decisions; in this context the fatal accident occurred at the worst possible time in terms of the circadian rhythms, when the human performance is severely degraded and is at its lower level along with the increase of the risk of errors.

The lack of the objective information on the HUD operation (there were no flight tests of the unit carried out into the entire range of the operational G, including the negative ones; the impossibility to reproduce the real HUD readings in the progress of the accident flight, that is the image the pilot was watching with the consideration of his posture in the seat trough the stream video or at the FFS) did not allow making conclusion on its possible impact on the flight outcome. At the same time the investigation team is of the opinion that the specific features of the HUD indication and display in conditions existed during final phase of the accident flight (severe turbulence, the aircraft upset encounter with the resulting negative G, the significant difference between the actual and the target flight path) that generally do not occur under conditions of the standard simulator sessions, could have affected the situational awareness of the PIC, having been in the highly stressed state.

4. The shortcomings, revealed in the investigation

The shortcomings are referred to in the text of the Report.

5. Safety Recommendations[34]

It is recommended that FATA[35]

5.1. Inform the flight personnel, the air training centers staff and the ATC officers on the results of the investigation in question at the subject-oriented debriefing meetings.

5.2. Consider the possibility of expediting of the Russian Federation transition to the flight operations on QNH.

5.3. Draw the attention of organizations, engaged in the aviation personnel testing for their compliance with the ICAO Language Proficiency Requirements, to the need for enhanced monitoring of the raters-examiners' activities, as well as further develop the measures to exclude the assignment of the ICAO language proficiency level to persons, whose level in question does not meet the subject requirements.

5.4. Draw the attention of the air navigation service providers to the need for enhanced monitoring and responsibility of the instructor personnel, engaged in the officers' simulator training, inter alia of the adherence to the R/T rules in English.

5.5. In association with Roshydromet and the State ATM Corporation, FSUE organize training with the ATC and meteorological services officers on the procedure of the information communication on windshear to the flight crews.

5.6. In view of the position of the aircraft manufacturer that the Boeing 737-800 operational documentation implies the presence of the pilots' previous experience of operating the jet multi-engine aircraft, familiarization with the basic systems and basic airmanship, assess the risks of the pilots' approval for the type in case it is the first jet multi-engine airplane in the pilot's career. If required, amend the current regulations. Assess the applicability of this safety recommendation as for the other aircraft types.

It is recommended that the Flydubai airline[36]

5.7. Conduct the flight personnel training on the specific aspects of the stabilizer trim manual operation (the forces trim).

5.8. Consider the practicability of the HUD Model 4000 changing to Model 6000 (STC ST02522SE) to equip both pilots' duty stations.

[34] In accordance of ICAO Annex 13 provisions, the safety recommendations are developed with the intention of preventing accidents or incidents and in no case have the purpose of creating a presumption of blame or liability for the specific air accident.

[35] It is recommended that the aviation authorities of the participant states of the Agreement consider the applicability of the Safety Recommendations based on the actual state of affairs as for them.

[36] The other airlines are recommended to consider the applicability of these Safety Recommendations with the account of the operated aircraft fleet.

5.9. In association with the aircraft and HGS manufacturers, consider the practicability of the development of the additional instructional guidelines on the HUD use at the different stages of flight.

5.10. Consider the practicability of the elaboration of the flight personnel training programs, allowing for the incorporation of the practical familiarization (training) of the pilots with the upset conditions, including zero and negative G state.

5.11. Consider the practicability to amend the airline OM with the criteria of the psychological incapacitation and the respective recommended actions.

5.12. Consider the practicability of the elaboration of SOP in terms of specifying the type of the next maneuver (for example Go-Around, Windshear Escape Maneuver) as far as the callout by the PF is concerned[37].

5.13. Consider the practicability to elaborate SOP in terms of monitoring of the trim duration and the current stabilizer position.

5.14. Evaluate the possible risks, associated with the partial blocking of the PFD at the significant forward deflection of the control column and take measures on the risks mitigation (if required).

It is recommended that FAA, Rockwell-Collins

5.15. Consider the practicability of the conduct of the additional flight tests of HGS into all the anticipated operating conditions and the entire range of G of the aircraft with these systems installed.

5.16. Taking into account the views of the experts in ergonomics and aviation psychology, consider the practicability of the improvement of the HUD information presentation in order to mitigate the risk of its erroneous interpretation.

5.17. In association with the designers and manufacturers of the aircraft, equipped with the HGS, consider the practicability of development of the additional guidance on the use of HUD at different stages of flight.

It is recommended that FAA, the other certification authorities (EASA, IAC Aviation Register, FATA etc.)

5.18. Consider the practicability of the amendment of the aviation regulations with the provisions on the mandatory flight assessment of the flight parameters indication systems to pilots into the entire operating range of the aircraft with such systems installed.

5.19. Consider the practicability of the amendment of the aviation regulations that determine the procedure of the STC issue for the indication systems to pilots, with the requirement to the manufacturer of the equipment in question to have the hardware/software package available to

[37] As per the information available, the Flydubai airline has implemented this safety recommendation. The safety recommendation has been retained in the section for its consideration by the other airlines.

reproduce the indication as per the FDR data in real time and in the scope, sufficient for the investigation of the aircraft accidents and incidents.

It is recommended that the Boeing Company

5.20. Consider the practicability of the amendment of the FCT 737 NG (TM) Low Altitude Level Off - Low Gross Weight section with more detailed information on the criteria that the pilots should follow to determine the point, when the maximum thrust should be reduced, including go-around performance in windshear.

5.21. Consider the practicability to implement the design changes of the stabilizer control system to reduce the risk for the pilot to set stabilizer in-flight into out of trim position[38].

5.22. Consider the practicability of the elaboration of SOP in terms of specifying the type of the Go-Around maneuver (for example Go-Around, Windshear Escape Maneuver) as far as the callout by the PF is concerned.

5.23. In association with FAA assess the possible risks, arising due to the partial blockage of PFD at considerable forward deflection of the control column and take measures on their mitigation (if necessary).

5.24. Taking into consideration the information, stated in Section 1.18.2, consider the practicability of introduction of additions and amendments to FCOM and/or FCTM, explaining the stabilizer control sequence on the Boeing 737 aircraft under different conditions. Consider the applicability of this safety recommendation for the other aircraft families.

5.25. Consider the practicability of the introduction of additions and amendments to FCOM and/or FCTM, explaining general principles of the stabilizer use and forces trim, as well as the monitoring of the current stabilizer setting.

It is recommended that ICAO

5.26. Consider the practicability of establishing a working group to study the issues of the psychological incapacitation of the flight crewmembers and elaboration of the relevant recommendations to provide guidance to the operators and States in the OM draw up and approval.

[38] In the Comments to the draft Final Report the aircraft manufacturer suggested to remove this recommendation, reasoning that the Boeing Company design philosophy implies the pilot can fully operate with the available deflection of flight controls, including the stabilizer control. This may be required in a variety of non-normal situations, for example at the total loss of hydraulic system/hydraulic circuits' pressure. At the same time according to the manufacturer, the aircraft design provides for reasonable amount of engineering concepts for the PM to stop the in-flight stabilizer setting into the out of trim position by the PF. The investigation team agrees that the aircraft design allows for it. But, the air accidents investigation practice shows that the PM, who monitors the flight management and aircraft control actions by the PF, is not always able to promptly identify the out-of-trim stabilizer position, as well as to detect the mere fact of the stabilizer prolonged motion. The investigation team notes that at the current level of technological development the combination of the mentioned engineering concepts is a possible solution: the limitation of the stabilizer deflection angles, when this could result in the adverse consequences, and the full travel/deflection when actually necessary.