INTERSTATE AVIATION COMMITTEE

AIR ACCIDENT INVESTIGATION COMMISSION

FINAL REPORT

Type of occurrence	Accident
Type of aircraft	Airplane, Boeing 737-500 (53A)
Registration	VQ-BBN (Bermuda)
Registered Charterer (according to the registration certificate)	AWAS (BERMUDA) LIMITED, Clarendon House, 2 Church Street, Hamilton HM 11, Bermuda
Operator	Tatarstan Airlines, JSC, Russia
Aviation Administration	Tatar ITO, FATA
Place of occurrence	Russian Federation, Kazan International Airdrome, coordinates: N 55º 36,5291' E 49º16,6111'
Date and Time	November 17, 2013, 15:24 UTC, 19:24 local time, night time

In accordance with ICAO Standards and Recommended Practices this Final Report has been published with the sole objective of aircraft accident prevention.

It is not the aim of this investigation to apportion blame or liability.

The criminal aspects of this accident are described within a separate criminal investigation.

Abbreviations and Definitions

AAIB UK	Aircraft Accident Investigation Board, UK
A/P	Autopilot
A/T	Autothrottle
AAISTSC	Air Accident Investigation Scientific and Technical Support Commission
AAL	Above Airdrome Level
AC	Advisory Circular
AD	Airworthiness Directive
Agreement, the	The Agreement on Civil Aviation and the Use of Airspace (Minsk, 1991)
AFDS	Autopilot Flight Director System
AFM	Aircraft Flight Manual
AFM	Aerodrome Flights Manager
AIBN	Accident Investigation Board of Norway
ALT ACQ	Altitude Acquire
ALT HOLD	Altitude Hold
ANEO	Autonomous Non-Commercial Educational Organization
AON	Aerodrome Operation Norms
APSC	Aviation Parachuting Sports Club
APTC	Aviation Personnel Training Center
APU	Auxiliary Power Unit
ASAGA	Aeroplane State Awareness During Go-Around
ASR	Aerospace Search and Rescue
ATB	Aviation Technical Base
ATC	Air Traffic Control
ATM	Air Traffic Management
ATPL	Airline Transport Pilot License
ATS	Air Traffic Service
BEA	Aircraft Accident Investigation Bureau of France (Bureau d'Enquêtes et d'Analyse pour la sécurité de l'aviation civile)
B-RNAV	Basic Area Navigation
CA	Civil Aviation
CAA	Civil Aviation Authority

CAT	Category
CCTV	Close Circuit Television
CRM	Crew Resource Management
CS 25	Certification Specification 25
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
DCA	Department of Civil Aviation
DME	Distance Measuring Equipment
EADI	Electronic Attitude Director Indicator
EASA	European Aviation Safety Agency
EGPWS	Enhanced Ground Positioning Warning System
ELP	English Language Proficiency
FAA	Federal Aviation Administration, USA
FAR	Federal Aviation Rules of the Russian Federation
FAR ATM	FAR “Air Traffic Management”
FAR MA CA	FAR for Medical Assurance in Civil Aviation
FAR-11	FAR “Certification Requirements for Physical and Legal Bodies Conducting Commercial Air Transportation. Certification Procedures”, approved by Order №11 of Ministry of Transport of RF as of February 4, 2009.
FAR-128	FAR “Preparation and Conduct of Flight in Civil Aviation of the Russian Federation”, approved by Order №128 of Ministry of Transport of RF as of July 31, 2009.
FAR-147	FAR “Requirements for Aircraft Crews, Maintenance Personnel and Flight Operation Assistants of Civil Aviation”, approved by Order №147 of Ministry of Transport of RF as of September 12, 2008.
FAR-148	FAR “Requirements for Flight Crews to Undergo Type Rating for Other (New) Civil Aircraft Types”, approved by Order №148 of Ministry of Transport of RF as of December 11, 2006.
FAR-23	FAR «Certification of Aviation Training Centers», approved by Order №23 of Federal Aviation Service of the Russian Federation as of January 23, 1999.
FATA	Federal Air Transport Agency
FCOM	Flight Crew Operations Manual

FCTM	Flight Crew Training Manual (the Airline's document unless otherwise stated)
FCTP	Flight Crew Training Program
FCU	Flight Control Unit
FD	Flight Director
FDR	Flight Data Recorder
FFS	Full Flight Simulator
FL	Flight Level
FMA	Flight Mode Annunciator
FMC	Flight Management Computer
FMS	Flight Management System
FO	First Officer
FOD	Foreign Object Damage
FOM	Flight Operations Manual
FR	Final Report
FSA	Flight Service Administration
FSFO	Federal State-Financed Organization
FSST	Federal Service for Supervision of Transport
FSUE	Federal State Unitary Enterprise
FTD	Flight Training Device
GCP	Ground Control Point
GPS	Global Positioning System
HAC	Higher Aviation College
HDG SEL	Heading Select
HPS	Higher Pilot School
HQB	Higher Qualification Board
IAC	Interstate Aviation Committee
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IRS	Inertial Reference System
ITO	Interregional Territorial Office
LCP	Local Control Point
LH	Left Hand
LLC	Limited Liability Company

LNAV	Lateral Navigation
LOFT	Line-Oriented Flight Training
LVL CHG	Level Change
MAC	Mean Aerodynamic Chord
MAMC	Main Aviation Meteorological Center
MASI	Mach Airspeed Indicator
MCC	Multi Crew Cooperation
MCP	Mode Control Panel
MEL	Minimum Equipment List
MPA	Multi Pilot Aircraft
MSD	Meteorological Support Directions
MSN	Manufacturer Serial Number
MT	Ministry of Transport
MTO	Maintenance Training Organization
MTOW	Maximum Takeoff Weight
N1	Low Pressure Rotor Speed
NDB	Non-directional Beacon
NEI	Nonprofit Educational Institution
NP	Nonprofit Partnership
NTSB	National Transportation Safety Board, USA
OAT	Outside Air Temperature
PAE	Public Address Equipment
PAPI	Precision Approach Path Indicator
PCU	Power Control Unit
PF	Pilot Flying
PIC	Pilot-in-Command
PIO	Pilot induced oscillations
PM	Pilot Monitoring
PNF	Pilot Non Flying
PTC	Personnel Training Course
QFE	Atmospheric Pressure At Aerodrome Elevation
QNH	Barometric Pressure Adjusted to Sea Level
QRH	Quick Reference Handbook
RCP	Radar Control Point
RF	Russian Federation

RFM	Regional Flights Manager
RG	Regional Group
RH	Right Hand
RNAV	Area Navigation
RNAV	Area Navigation
RQB	Regional Qualification Board
RWY	Runway
SACA	State Aviation Control Administration
SAIF	Safety Investigation Authority of Finland
SARPs	Standards and Recommended Practices
SMM	Safety Management Manual
SMS	Safety Management System
SOP	Standard Operating Procedures
SR	Safety Recommendation
SSP	State Safety Program
SSR	Secondary Surveillance Radar
STAR	Standard Terminal Arrival Route
TAF	Terminal Aerodrome Forecast
TC	Type Certificate
TCP	Tower Control Point
TGCP	Tower and Ground Control Point
TO/GA	Takeoff/Go-around
TQB	Territorial Qualification Board
TSO	Time Since Overhaul
TTSN	Total Time Since New
USSR	Union of Soviet Socialist Republics
UTC	Universal Time Coordinated
V/S	Vertical Speed
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Range
VOR/LOC	VOR/Localizer Capture Mode
VSI	Vertical Speed Indicator
WAFS	World Area Forecast System

Synopsis

On November 17, 2013 at 15:24 UTC (hereinafter, if not specified otherwise, UTC time is used; local time being 4 hours ahead of UTC time), at night time, a Boeing 737-500 (53A) aircraft (hereinafter referred to as Boeing 737-500) registered VQ-BBN operated by Tatarstan Airlines JSC (hereinafter referred to as Tatarstan Airlines, or the Airline) crashed while conducting a go-around after the terminated approach to RWY29 of Kazan International Aerodrome. The airplane had been conducting a domestic scheduled passenger flight TAK 363 from Moscow (Domodedovo, UUDD) to Kazan (UWKD).

The Air Accident Investigation Commission of the Interstate Aviation Committee was notified on the accident at 15:46, November 17, 2013.

The investigation team was appointed by the Order of IAC First Vice-Chairman № 41/655-P of November 17, 2013 as well as the Order of the Acting Chairman of the IAC № 41/655a-p of April 01, 2014.

In compliance with Annex 13 to Convention on International Civil Aviation, notifications on the accident were sent to the NTSB, USA as the State of Aircraft Design and Manufacturer; to BEA, France as the State of Engine Design and Manufacturer; to AAIB, UK as the State of Registry (the aircraft being registered in Bermuda, the overseas territory of the UK).

The investigation was participated by representatives of the NTSB, FAA, Boeing, Parker Aerospace, AAIB UK, Bermuda DCA, BEA France; experts from Rosaviatsiya, Rostransnadzor, Rosgidromet, FSUE "State ATM Corporation", Kazan International Airport JSC, State Center for Flight Safety, Scientific Production Enterprise “Rodina”; test pilots from Gromov Flight Research Institute, Tupolev JSC, as well as flight operations managers, instructors and line pilots of Tatarstan Airlines, Aeroflot, Transaero, UTair and other airlines.

In order to render assistance to the persons involved in the accident as well as families of the deceased, as well as cooperation in the rectification of the accident consequences, a Governmental Commission was formed by Resolution № 2135-r of the Chairman of the Russian Government as of November 18, 2013 chaired by the Russian Minister of Transport.

Investigation initiated on November 17, 2013.

Investigation completed on December 23, 2015.

Preliminary judicial inquiry was conducted by the Main Inquiry Office of the Inquiry Board of the Russian Federation.

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1. Factual Information

1.1. History of Flight

On November 17, 2013 the flight crew of "Tatarstan" Airlines" including a Pilot-in-Command (PIC) and a First Officer (FO) conducted a scheduled domestic passenger flight TAK 364/363 Kazan (UWKD) – Moscow (Domodedovo, UUDD) – Kazan (UWKD) on the Boeing 737-500 VQ-BBN aircraft.

At 10:10 all the crew members passed medical examination at Kazan airport medical post and the record was made in the flight task. There were no comments concerning their health status. After the medical control the crew members commenced performing their duties in accordance with the working procedure.

At 10:26 the PIC had a consultation on weather conditions and got the necessary documentation on the flight route, the airport of destination (Domodedovo) and the alternate airport (Pulkovo, Saint Petersburg). The weather conditions were in compliance with the requirements and did not interfere with making a decision to fly.

At 11:22 the aircraft performed takeoff from Kazan airport (Flight TAK 364). The flight from Kazan airport to Domodedovo airport was passing in a normal mode, without any comments by Air Traffic Management (ATM).

From 6000 ft the descent was performed in turbulence conditions. At the time of the aircraft final approach and landing in Domodedovo airport, complicated wind conditions in the ground air layer were observed. The actual weather at Domodedovo airport at 12:44 (the aircraft landed at 12:43) was as follows: surface wind 240° - 7 m/sec, gusting up to 11 m/sec, wind at 100 m 240° - 13 m/sec, at circuit height 280° - 25 m/sec. At 60 m a wind shear was observed, in the ground air layer there was moderate turbulence.

The final approach was performed in an automatic mode, the autopilot was disengaged by the crew at the height of approximately 80 m. The landing was performed without deviations. There had been no aircraft equipment failures or faults registered during the flight from Kazan to Moscow, the crew did not have any complaints about aircraft equipment operation.

After landing and passenger disembarkation, the crew proceeded to preparation for flight TAK 363. The preparation was performed as preflight briefing. The weather conditions in the airports of departure and destination and the alternate airports (Samara, Ufa) did not interfere with making a decision to fly.

The weather forecast en route at FL290 predicted wind 310° at 200 km/h, and at FL270 to FL370 - moderate to strong turbulence.

The departure of flight from Moscow to Kazan was performed at 14:25, on schedule.

Besides 2 flight crew members, there were 4 cabin crew members and 44 passengers on board; 50 people in all, including 48 citizens of the Russian Federation, 1 citizen of United Kingdom, 1 citizen of Ukraine.

In accordance with the documentation provided, the commercial load of the aircraft was 4047 kg, there was no cargo prohibited for air transportation on board. Takeoff fuel weight was 7800 kg, which was enough for performing the flight according to the planned route considering the standby airport chosen. Estimated takeoff weight was approximately 45000 kg (maximum takeoff weight is 59193 kg), estimated CG was approximately 21% of MAC, which did not go beyond the acceptable limits.

In accordance with the flight plan filed by the crew, the flight route passed through: KARTINO – GEKLA – DAKLO – CHERUSTI – BT P480 – SHUMERLYA – BT P301 – MISMI, estimated flight time was 01:15. ATM control transfer threshold between Moscow and Kazan area control center was SHUMERLYA NDB.

At 14:30:24 the crew reported the air traffic controller of “Moscow - Approach 7” sector about climb to FL130 at CHERUSTI NDB, and was commanded to climb to FL290. On controller’s request: “... What flight level is assigned?”, the crew reported that it was FL310 and was informed that FL310 was occupied by a transit aircraft. The crew reported that they would fly on FL290 (approximately 8850 m). FL290 was reached at 14:37:30.

At 15:00:46 the controller commanded the aircraft crew to contact the controller of “Kazan - Control” sector at frequency 133.1 MHz. At the moment, the aircraft was leaving Moscow area control center (20 km to SHUMERLYA NDB). The flight was passing in a normal mode, in accordance with the flight plan filed by the crew.

At 15:01:30, after receiving the controller’s permission, the crew started descending to FL70 (approximately 2130 m).

At 15:07:10 the controller reported: “Tatarstan 363, Kazan, for your information, according to my data, you are going 4 km left of the track”, to which the aircraft crew responded: “Copied, thank you, Tatarstan 363”.

At 15:12:11 the controller commanded the aircraft crew to contact the adjacent sector controller: “Tatarstan 363, Kazan, contact Radar 119.4”, to which the aircraft crew responded: “Radar 119.4, Tatarstan 363, good bye”.

At 15:12:35 the aircraft crew was commanded by the Kazan - Radar controller: “Tatarstan 363, Kazan - Radar, good evening, cleared for ILS, RWY29, QFE 980, descend to 500 m”. The crew acknowledged the information.

At 15:18:00 the aircraft crew reported: “Tatarstan 3-6-3, turning base, 500”, to which they were commanded: “Tatarstan 363, make base-to-final (turn)”. The actual point where the turn was started deviated significantly from the turning point assigned by the approach pattern (the aircraft was “inside” the assigned circuit).

At 15:19:02, going approximately 3.5 km right of the extended runway centerline (according to the data from “Galaktika” ATC automation aids complex), the aircraft crew was released to the Tower controller: “Tatarstan 363, contact Tower, 120.3”, which was copied and acknowledged by the crew.

At 15:19:13 the crew contacted the ATC Tower controller and reported: “Kazan Tower, Tatarstan 3-6-3, good evening, at handover 500.”, to which the controller responded at 15:19:18: “Tatarstan 3-6-3, Kazan Tower good evening, distance 14 kilometers, right of heading”. At 15:19:24 the crew acknowledged the received information: “Copied, right of heading, Tatarstan 363”.

At 15:21:24 the controller requested the crew: “... Tatarstan 363, ready?”. At the moment, the aircraft radial distance, according to the data from “Galaktika” ATC automation aids complex, was approximately 5 km, the height was 500 m (above the aerodrome level) without descending, the aircraft was significantly to the right heading to join the final approach path. At 15:21:29 the controller received the aircraft crew report: “... on glide path, gear down, ready to land”. At 15:21:34 the controller advised: “Tatarstan 363, wind 220 degrees at 9 meters per second gusting 12, RWY29, cleared to land”. At 15:21:41 the crew acknowledged: “Cleared to land, Tatarstan 363”.

Estimated landing weight was approximately 42000 kg (maximum landing weight was 49895 kg), CG (according to simulation match results, section 1.16.1) was approximately 19.23% of MAC, which did not go beyond the acceptable limits.

At 15:22:41 the crew reported going around due to non-landing position: “Tatarstan 363, going around, non-landing position”. At that moment, the aircraft was at a distance of approximately 1 km from the runway threshold, almost on the final approach path, at the constant height of approximately 270 m (approximately 900 ft) above the aerodrome level.

While going around, after climbing approximately 700 m (approximately 2300 ft) above the aerodrome level, the aircraft pitched nose down and impacted the ground at a great speed (approximately 450 km/h) and a big negative pitch angle (approximately 75°). From the start of go-around and till the end of the recording, approximately 43 sec passed.

As a result of impacting the ground, the passengers and crew members who were on board died, the aircraft was completely destroyed and was partially burned in the postcrash fire.

The air accident occurred at 15:23:28, at the territory of Kazan airport, between the runway, main taxiway, taxiway C and taxiway B. The elevation of the accident site is 115 m above sea level.

1.2. Injuries to Persons

Injuries to Persons	Crew	Passengers	Others
Fatal	6	44	-
Serious	-	-	-
Minor/None	-/-	-/-	-/-

1.3. Damage to Aircraft

The layout of the remained fragments of the aircraft is shown in Figure 1.

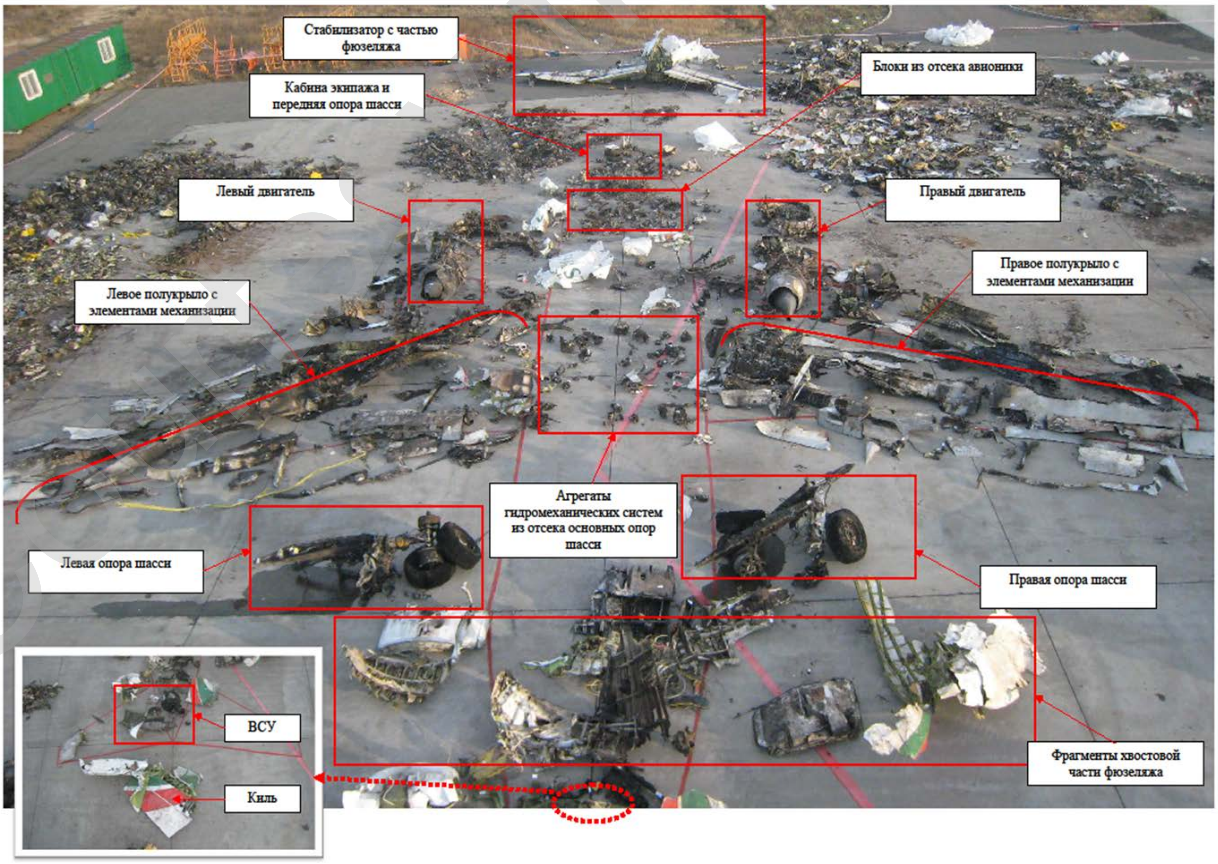


Figure 1 The layout of the remained fragments of the aircraft

As a result of the investigation of the remained fragments of the aircraft, the following was concluded[2].

The aircraft airframe was broken into a great number of fragmented parts. The biggest aircraft fragments, found at the accident site, are:

- the forward fuselage (with the cockpit);
- the center wing section, the left and right wings;
- the horizontal stabilizer with the fuselage tail section fragment;
- the vertical stabilizer with the rudder;
- the left-side fuselage fragment from frame 360 to frame 500;
- the left and right engines fragments.

On impacting the ground, the aircraft was destroyed and postcrash fire occurred. The seat of fire was located in the area, where the fragments of the cockpit, the center wing section (with the landing gear wheel wells), and also of the left and right wings were found. On the other fuselage fragments, e.g. on the section from frame 360 to frame 500 (left side), horizontal stabilizer and vertical stabilizer, there were no signs of fire found.

Judging by the condition of the landing gear retraction/extension hydraulic actuators, one can conclude that all the landing gears were in retracted position.

The found shafts and screw mechanisms of the flaps control system have mechanical damage and are partially broken off and deformed as a result of impacting the ground. The flaps surfaces elements have mechanical damage and signs of postcrash fire. The flaps transmission running along the wings aft spars is destroyed under the effect of thermal and off-design mechanical loads. There were all 8 flap retraction / extension screw jacks found. The position of the shafts relative to the position of the nuts (13–14 threads) indicates the flaps extended to the 15 degrees position. On one of the MASIs, the Airspeed Bug index-repeater (corresponds to the airspeed, set on the MCP) was set at 153–154 kt. It is impossible to identify the position of the index-repeater on the other indicator. The mechanical pointer-indices for airspeeds (set by the crew manually) are missing on both airspeed indicators.

[2] In this section, there is the description of damages to only those fragments, whose condition analysis is required for understanding the conclusions and recommendations of the Final Report. The whole description of damages and condition of the fragments is provided in the report by the engineering technical subcommission.

On the accident site, there were seats (the captain and the first officer seats and also the observer seat) fragments and seat belts/fastening system fragments found. The seats fragments with the elements of fastening systems, as well as the cockpit door were sent for investigation (the investigation results are provided in section 1.16.7).

Pitch channel of the control system (elevators and stabilizer)

The description of the design of the aircraft control system in the pitch channel is provided in section 1.6.2.

During the inspection, only small fragments of left and right pilots' control columns were found. The control cables were also broken into small fragments as a result of the aircraft impact with the ground and cannot be identified.

The left and right elevators were broken into 3 parts and after the air accident were in the "nose down" position. Visually, deflection angles of the left and right elevators were the same. The connection between the flight control actuators and the flight control surfaces was broken.

Frame 1156, on which elevator control units are located, was remained in satisfactory condition (Figure 2).

Figure 2 Appearance of frame 1156 on the air accident site (the elevators actuators are circled orange)

The elevators control moving elements, located on frame 1156, have visible deformation, caused by crash of the fuselage structure when the aircraft impacted the ground. There were no disconnections of the control system components and hydraulic lines, located on frame 1156.

The inspection of the PCUs was performed:

- the right elevator PCU housing was not destroyed. The PCU input arm was at the bottom seat. There were no foreign objects found in the clearance, there were signs of dirt and peening;
- the bolts of the left elevator PCU housing head were destroyed, which led to separation of the head from the housing. The PCU input arm was at the bottom seat. There were no foreign objects found in the clearance, there were signs of dirt and peening.

Dismounting of the actuators was performed. The PCUs were sent for special investigation (the investigation results are provided in section 1.16.6).

After disconnection of the hydraulic lines, sampling of hydraulic fluid from the actuators hollows was performed. Visually, looking at the light, there was water in the hydraulic fluid, there were no foreign particles. The hydraulic fluid samples were sent for special investigation (the investigation results are provided in section 1.16.8).

The stationary crossbeam with the stabilizer positioning nut was found, which had been destroyed in the points of its mounting to the fuselage due to off-design loads. The jackscrew with stabilizer attachment was found separately from the stabilizer (destruction due to off-design loads) with signs of thermal effect (the stabilizer does not have thermal damage).

The aft cable drum with the jackscrew gearbox was found. The jackscrew threading is damaged after thread 15 from the reduction gearing cover housing, which corresponds to the stabilizer nose-up deflection angle of about 3 degrees[3], which is confirmed by measuring the correspondence on an analog aircraft.

Roll channel of the control system

The aircraft control in the roll channel is performed by control wheels, connected to ailerons and spoilers with cables.

The control cables, passing through the fuselage, were broken into separate small fragments as a result of the aircraft impact with the ground and could not be identified. The control cables, running along the left and right wings aft spars, were remained with signs of off-design mechanical effects and fire.

[3] This value is according to the cockpit indicator readings, and this meets 0° at FDR records.

The left aileron was approximately half destroyed and partially burned. The right aileron was completely destroyed. It seems impossible to identify the ailerons position at the moment of the aircraft impact with the ground.

Out of the spoilers control system components, the actuators with the surfaces fragments were found, whose position identified that the spoilers had been retracted (the actuators piston rods had been retracted).

Directional channel of the control system

The aircraft control in the directional channel is performed by rudder pedals, connected to the main and standby rudder PCUs with control cables.

The pilots' rudder pedals were fragmented into small pieces. The control cables, passing through the fuselage, had been destroyed as a result of the aircraft impact with the ground and could not be identified. The rudder had broken into two fragments.

The inspection of the main rudder PCU was performed (Figure 3). The rudder PCU had been torn off from its normal position as a result of the fin destruction. It was established that within the framework of the program of rudder control system modification, in accordance with the US FAA Airworthiness Directive No. AD 2002-20-07R1, the aircraft had been equipped with a new main rudder PCU.

Figure 3 Main rudder PCU

Based on the results of the investigation performed, the engineering technical subcommission came to the general conclusion that on the airframe and its systems parts, assemblies and units, there were no signs of equipment failure during the last flight. All the destruction and damage had occurred due to the alternating off-design impact loads, occurring as a result of the aircraft impact with the ground and the subsequent fire. Prior to the aircraft impact with the ground, there had been no inflight fire. Both engines had been serviceable and operational prior to the aircraft impact with the ground.

1.4. Other Damage

As a result of the air accident, there were no other damages.

1.5. Personnel Information

1.5.1. Flight Crew Information

Position	**Pilot-in-command**
Sex	male
Date of birth	11.06.1966
Pilot's license	ATPL II П № 000517
License date of issue	05.04.2012
Issued by	Civil Aviation HQB of the FATA of the MT of the Russian Federation
License expiry date	28.03.2014
License validation	DCA Bermuda, 16.09.2013, № 2013/35, valid till 31.12.2013.
Medical report	Class I PA № 078859. Issued by the medical board of the medical office of "Kazan aviation company", JSC, on 29.03.2013, valid till 29.03.2014. Semi-annual medical examination passed on 29.09.2013.
Education	Higher: Kirovograd Higher Pilot School, graduated in 1991, navigator engineer.
Transition training for An-2	02.02.2008 till 20.02.2008, in "Regional General Aviation MTO", NP (Kaluga), certificate № 0229. Certificate authenticity and transition training are not confirmed.

Transition training for Boeing 737	01.10.2009 till 28.03.2010, in "Sibir" Airlines" MTO, ANEO[4], certificate № 09Л 100-07.
Weather minimum	Permitted for flights in ICAO category I weather minimum: landing 60x550 m, takeoff 200 m.
Total flying time as a pilot	According to the documents filed – 2784 hrs 30 min
Flying experience on aircraft types	An-2 – 217 hrs, «Piper M»[5] - 58 hrs 30 min, Boeing 737 - 2509 hrs. Flying time on An-2 and «Piper M» is not confirmed.
Flying time as Boeing-737 PIC	527 hrs 30 min
Flying time within the last 30 days	~ 40 hrs
Flying time within the last 3 days	07 hrs 17 min
Flying time on the air accident day	02 hrs 47 min
Landings within the last 3 days	3
Working time on the air accident day	05 hrs 14 min
Breaks in flights within the last year	24.02.2013-01.03.2013 – vacation; 12.03.2013-18.03.2013 – vacation; 18.06.2013-02.07.2013 – vacation; 04.08.2013-14.08.2013 – vacation; 02.09.2013-16.09.2013 – vacation. Within the period from 01.11.2013 till 07.11.2013 – was on vacation according to the order, but during the vacation was involved in ground operations and as a standby crew member without official recall from the vacation.
Date of last check ride	01.09.2013. Conclusion by pilot-instructor: "can continue flights as PIC", "excellent". It was established that the check ride had not been

[4] Since February, 2010 - "S7 Training", ANEO. Hereafter, both the above mentioned names are used, depending on the time span described.
[5] Such aircraft name is stated in the pilot's logbook.

	performed in fact[6], but the record was just made in the pilot's logbook, as the last check (done on 07.06.2013) validation period had been expiring. Thus, as, according to the airline FCTM, a three-month check interval is established for PICs, having flying experience of less than one year in this position, after 07.09.2013 the PIC was not entitled to perform flights and should have not been involved in flight tasks.
Simulator training and check	04.07.2013
Permission for flights during autumn-winter period	11.10.2013, Aircraft Division Commander order №170
Preliminary preparation	12.11.2013
Flight preparation	Before Flight TAK 364/363 departure, performed by the crew in Kazan airport
Rest	26 hours at home
Preflight medical examination	17.11.2013, at 10 hrs 10 min, Kazan airport start medical office
Air accidents and incidents	None

The PIC[7] graduated from Kirovograd Civil Aviation (CA) Higher Pilot School (HPS) in 1991, specializing in air transport operation as navigator engineer. The request of the commission to Kirovograd Civil Aviation Higher Pilot School about his training got the following response: "... The training was performed in accordance with the training schedule, which included flying practical training as the An-24/26 aircraft navigator that was performed by him in the scope of 217 hrs 45 min totally. He did not have initial flying practice as a pilot during his training, as it was not provided in accordance with the training schedule. The issued diploma does not mean double specialization both as a pilot and as a navigator".

From 1991 till 1992 worked in Nikolayevsk, JSC (Ukraine), as An-24 navigator. In 1992 moved to Kazan, JSC. Working in Kazan, JSC, performed duties of Tu-134, Tu-154 and Il-86 navigator. It is impossible to establish total flying time as a navigator due to lack of related documents.

[6] According to the FDR data, there were no deviations in flight.
[7] In this section, the terms "PIC" and "commander" are used to refer to the PIC even when he flew as a FO.

According to the documentation submitted to the commission, within the period from 02 till 20.02.2008, he passed training in "Regional General Aviation MTO", NP (Kaluga), based on the commercial pilots transition training program for An-2 on his own account. Flying practice according to the initial training program for commercial pilot category acquisition was performed on the An-2 aircraft in the above mentioned training organization and, according to the pilot's logbook records, was 217 hours. On 22.02.2008, a piloting check for commercial pilot category acquisition was performed. Within the period from 20 till 26.02.2008, a knowledge check of specialized subjects for commercial pilot category acquisition (confirmation) was also performed. The assessment paper was signed by the MTO flight director and the HQB Chairperson. In the HQB knowledge assessment paper, there is a record: "Meets the requirements of commercial pilot qualification. Can perform flights as the An-2 first officer in accordance with VFR". However, pilot's license was not issued.

According to the information, given by "Tatarstan" Airlines", JSC, personnel department, during the transition training, the PIC was neither on vacation, nor on sick leave. Besides, the labor remuneration flight kilometers register shows that within this period (on 09.02 and 16.02.2008) he performed flights.

It should be noted that "Regional General Aviation MTO", NP, certificate for aviation training was revoked by Rosaviatsiya on 12.11.2008 for not complying with certification requirements. Due to absence of the documentation archive, the commission could not confirm training on the stated program.

According to the documentation submitted, within the period from 10 till 12.09.2008, the PIC had recurrent assessment for class III commercial pilot license, this time by the RQB of the North-Western SACA of the FSST. Prior to this (on 06.09.2008), piloting and aircraft navigation had been checked in aerodrome conditions. On the RQB decision, provided in the protocol of the meeting № 14 on 12.09.2008, he was given the class III commercial pilot qualification and the commercial pilot license III П № 005087. During this assessment, the PIC was not on vacation as well. The request of the commission to the NW AT ITO of the FATA got the following response: "... there is no confirming documentation (assignments, assessment papers, copies of medical certificates, TQB protocols) found, giving qualification and special rating to the commercial pilot (the PIC's name) (license III П № 005087) in the NW AT ITO of the FATA archive materials. The pilot (the PIC's name) was not discussed at the meetings of the NW AT ITO of the FATA TQB and there was no decision made on him, accompanied with related documents".

The request of the commission to the HQB concerning explanations on this issue got the following response: "... The Flight Administration does not have any documents or information available on issuing a commercial pilot certificate to (the PIC's name). The archive has no data on (the PIC's name) knowledge assessment in the HQB. Taking into account the data, submitted by the NW AT ITO of the FATA, one can come to the conclusion that commercial pilot certificate III П №005087 is not legitimate...".

To confirm this conclusion of Rosaviatsiya, the commission requested all the TQB meetings protocols of 2008 from the NW AT ITO of the FATA. The PIC's name was not mentioned in any of the protocols. Protocol №14 is dated 04.07.2008. In September, the TQB held a meeting on the 19th, and the protocol was numbered as №18. All the protocols were signed by persons, not corresponding to those stated in the document from the PIC's file.

The commission established that the commercial pilot license III П № 005087 was issued by Rosaviatsiya HQB to the "North-Western General Aviation Regional Center" NEI MTO (following a request from the MTO from 12.05.2009) only on 14.05.2009, that is 8 months later than it was supposedly issued to the PIC. By this time, the MTO certificate was withdrawn from the training organization (Order by Rosaviatsiya Manager from 10.02.2009 №ГК-14-р), but pilot licenses were still being given to it. Thus, the legitimacy of the commercial pilot license acquisition by the PIC is not confirmed. It turned impossible for the commission to establish the PIC's flying experience during the stated period.

In 2009, the PIC continued working in "Tatarstan" Airlines", JSC, as a navigator-instructor. Where and how he maintained his flying skills was impossible to establish for the commission. In the pilot's logbook, within the period from April, 2009 till July, 2009, flying time on the "Piper M" aircraft is recorded with the duration of 58 hrs 30 min, which is confirmed by the stamp of the North-Western public organization "Aviation Parachuting Sports Club "Nord", but without a signature by the responsible person. Currently, the APSC "Nord" does not exist, there are no archive data concerning the club's flying time available for the commission.

In the autumn of 2009, based on the commercial pilot license, the airline management decided to retrain the PIC for a Boeing 737 first officer position, accompanied with the related assignment. On September, 28, 2009, Tatar AT ITO of the FATA TQB approved the decision to retrain the PIC.

By "Tatarstan" Airlines", JSC, referral, the PIC was retrained in "Sibir Airlines" MTO, ANEO, within the period from 01.10.2009 till 28.03.2010. The training was conducted according to the "Program of flight crew training for Boeing 737-300/400/500", approved by the Manager of the FACA of the FSST of the MT of the Russian Federation (find more information about the training in section 2.3). The theoretical training was completed on 29.10.2009. Due to unavailability of a simulator training center, simulator training was postponed. From 31.10.2009 till 31.12.2009, the PIC was on vacation. The simulator training started only on 18.01.2010 and was completed on 09.03.2010. The aerodrome training checking the possibility of permission for engagement in flights was done on 28.03.2010. On completing the training (on 28.03.2010), the related certificate was issued to the PIC.

According to the documents submitted, as a whole, during the training, the PIC performed 7 go-arounds on the simulator as the PF (5 out of them – on 2 engines, 2 go-arounds – on 1 engine) and 6 go-arounds as the PNF (2 out of them – on 2 engines, 4 go-arounds – on 1 engine). When performing check flight (on an aircraft) after the training, the PIC performed 1 go-around with 2 engines operating as a PF.

By the order of the airline general director from 15.03.2010 №23-a, the PIC was moved from the navigator to the Boeing 737 first officer position. During the period from 15.04 till 27.08.2010, the PIC was trained for assignment as the Boeing 737 first officer in accordance with “Tatarstan” Airlines” FCTP, approved by the FSA of Rosaviatsiya on 22.09.2009. On completing the training on the program, he was permitted for solo flights as a first officer.

On 05.04.2012, by the assignment of the TQB of the Tatar AT ITO of the MT of the Russian Federation (protocol № 6 from 22.03.2012), the PIC got the ATPL II П № 000517. According to the pilot’s logbook records, by this time the PIC had flown approximately 1300 flight hours on Boeing 737 (as a first officer). Taking into account the fact that the flight time on the An-2 and Piper M aircraft recorded in the pilot’s logbook, including more than 250 hours as a PIC, is not confirmed, the Commission comes to the conclusion that the ATPL was issued to the PIC groundlessly, with deviations from the FAR-147 regulations.

On 12.11.2012, the airline management issued order № 125-A concerning permission for flights as a PIC-trainee.

The PIC engagement program was completed on 11.03.2013. On 14.03.2013, the airline management issued order № 10 concerning permission of the pilot for flights as the Boeing 737 PIC.

The PIC’s professional skills analysis is provided in section 2.3.

Position	**First officer**
Sex	male
Date of birth	12.06.1966
Pilot’s license	CPL III П № 000618
License date of issue	28.11.2010

Issued by	HQV RG №6 of Ulyanovsk CA Higher Pilot School
License expiry date	till 11.12.2014
License validation	DCA Bermuda, 16.09.2013, № 2013/35, valid till 31.12.2013.
Medical report	Class I PA № 102387. Issued by the medical certification of the medical office of “Kazan aviation company”, JSC, on 11.10.2013, valid till 11.10.2014.
Education	Specialized: Kirsanov Aviation Technical College, 1989. Speciality – aviation technician. Higher: Cheboksary State University, 2008. Aviation: Ulyanovsk Higher Aviation College, 2010 (training from flight engineer to pilot).
Transition training for Boeing 737	From 03.11 till 22.12.2010 in “S7 Training” ANEO, Certificate № M10P 231-03 from 22.12.2010
Weather minimum	Permitted for flights as a crew member in ICAO category II weather minimum: landing 30x350 m, takeoff 200 m.
Total flying time	2093 hrs 36 min
Flying experience on aircraft types	NG-4 – 115 hrs Diamond-42 – 35 hrs Boeing 737 – 1943 hrs 36 min
Flying time within the last 30 days	~ 48 hrs
Flying time within the last 3 days	11 hrs 47 min
Flying time on the air accident day	02 hrs 47 min
Landings within the last 3 days	3
Working time on the air accident day	05 hrs 14 min
Breaks in flights within the last year	16.04.2013-25.04.2013 – vacation; Within the period of 30.08.2013-22.09.2013 was on vacation. Without recall from vacation, on

	21.09.2013 performed flight to Prague, on 22.09.2013 performed flight to Moscow.
Date of last check of piloting and aircraft navigation	21.09.2013, the supervisory pilot – pilot-examiner of “Tatarstan” Airlines”. Was recommended to repeat SOP, section – non-precision approach.
Simulator training and check	26.09.2013 – without comments. Conclusion: “Can continue performing flights as a first officer in ICAO CAT II weather minimum” (30x350, takeoff 200 m)”.
Permission for flights during autumn-winter period	01.11.2013, Aircraft Division Commander order №187A
Preliminary preparation	12.11.2013
Flight preparation	Prior to departure of flight TAK-364/363 under the PIC’s control in Kazan airport
Rest	26 hours at home
Preflight medical examination	17.11.2013, at 10 hrs 10 min, Kazan airport start medical office
Air accidents and incidents	None

The FO graduated from Kirsanov Aviation Technical College in 1989 with the specialty of aviation technician.

From 2002 till 2007 worked in the ATB of Kazan airport as an aviation technician maintaining the Yak-42, Tu-134 and Tu-154 aircraft.

In 2008 graduated from Cheboksary University with the specialty of automated information processing and control systems engineer.

Since 2008, after retraining, was moved to Kazan JSC, where he flew the Yak-42 aircraft as a flight mechanic. It is impossible to establish total flying time as a flight mechanic due to lack of related documents.

In 2009, by the company referral and Tatar AT ITO TQB decision (protocol № 22 from 26.10.2009), was sent for retraining to Ulyanovsk CA HPS on the program of training from a flight engineer to a commercial pilot.

From 16.08. till 03.09.2010 had training on the program “Training for commercial pilots in the Russian Federation CA training organizations for flight engineers”, approved by Rosaviatsiya order from 26.10.2009 № 477. On successfully completing the training, on the decision of HQB RG №6 (the commission meeting protocol № 79 from 28.10.2010), was given a CPL III П № 000618.

The commission was provided with the flights records of Samara (Smyshlyaevka) aerodrome, where the FO initial pilot training had been conducted. They do not contain any information on the flights of the aircraft with the registration number RA-1155G, which is mentioned in the student's pilot's logbook, with total flying time of 13 hrs 20 min. But there are records of flights on those days in the student's logbook and the aircraft logbook. This flying time is also stated in the summary form of the aircraft actual flying time total register, which is provided for payment of aeronavigation services. The request of the director of Ulyanovsk CA HPS to "Northern Volga Aeronavigation" branch for explanation of this contradiction got the following response: "... The flights register is completed in an automatic mode based on the telegraph reports, which are daily provided by the dispatcher group of the domestic airlines ATC tower from the aerodrome. ... The documents provided reflect the time of the aeronavigation services provision, due to be paid. The time, stated on the flights register, does not reflect total flying time."

Based on the analysis of the information available, the operation subcommission came to the conclusion that the F/O had completed the flight program, during which he had acquired the sufficient piloting skills, necessary to get a CPL.

Within the period from 03.11 till 22.12.2010, according to the contract between Ulyanovsk CA HPS and "S7 Training", ANEO, the pilot had transition training for performing flights on Boeing 737 -300/400/500 aircraft. The training was conducted according to the "Program of flight crew training for Boeing 737-300, 400, 500/600, 700, 800", approved on 06.10.2009 by the Manager of Rosaviatsiya FSA. On completing the training, the related certificate was issued.

This program was created in accordance with FAR-148. Prior to having the retraining in this educational institution, the FO completed the program "Additional training for pilots who are graduates of CA educational institutions and pilots having no experience of flying the multi-engine aircraft, equipped with several gas turbine engines, in a multi-member crew, having no working experience on aircraft with display indication", although this kind of training had been already completed by him while studying in Ulyanovsk CA HPS.

According to the documents submitted, as a whole, during the training, the FO performed 9 go-arounds on the simulator as the PF (6 out of them – on 2 engines, 3 go-arounds – on 1 engine) and 3 go-arounds as the PNF (2 out of them – on 2 engines, 1 go-around – on 1 engine). When performing check flight (on an aircraft) after the training, the FO performed 1 go-around with 2 engines operating as a PF.

By the order of the airline general director from 06.01.2011 №1пД, the pilot was moved from the aviation mechanic to the Boeing 737 first officer position.

On 17.01.2011, in “Tatarstan” Airlines”, the order was signed concerning the permission of the pilot for flights as the Boeing 737 FO. The pilot engagement in work was within the period from 20.01 till 20.09.2011.

On September, 20, 2011, he was permitted for solo flights on the Boeing 737 aircraft (the Flight Division Commander order from 20.09.2011 №ЗК-05.10-002/109). In this position, the pilot flew in the airline till the air accident moment.

The FO’s professional skills analysis is provided in section 2.3.

1.5.2. General comments to Boeing 737 flight operations in the airline

Flight crew training in the airline was performed based on the FCTP on aircraft types. FCTPs were part of the FCTM, approved by the Head of the Airline (25.08.2009), confirmed by Rosaviatsiya (22.09.2009) and agreed by Tatar AT ITO of the FATA (21.09.2009). It should be noted that the FCTM approval was performed before its confirmation and agreement.

Besides, the Commission states that, in accordance with the Russian Air Code (article 54, paragraph 4), training of specialists according to the list of CA aviation personnel is performed based on the training programs, approved (but not confirmed or agreed) by the CA competent authority. This Russian Air Code requirement corresponds with the provisions of Annex 6 to the ICAO Convention.

Note: ***Annex 6. Operation of Aircraft, Part 1. International Commercial Air Transport Aeroplanes.***

Chapter 9. Airplane Flight Crew

Section 9.3. Flight crew member training programmes.

9.3.1. *An operator shall establish and maintain a ground and flight training programme, approved by the State of the Operator, which ensures that all flight crew members are adequately trained to perform their assigned duties.*

Thus, the FCTM approval by the airline General Director was done in violation of the requirements of the Russian Air Code and the ICAO Standards.

Analysis of compliance of pilots of the “Tatarstan” Airlines, JSC, with the state qualification requirements

The qualification requirements for pilot license holders are written in the FAR-147. One of the qualification requirements for pilots is to demonstrate knowledge and skills concerning human resources, including human factors threats and errors control principles. These qualification requirements are applicable for all pilots, starting from a private pilot and up to a line pilot, including a pilot-instructor.

Besides, FAR-128 (paragraph 5.84) state that the operator does not permit the aircraft flight crew members to perform their functions, unless they have had training to acquire knowledge and skills, concerning human factors, including knowledge of their hazards while in flight, of preventing conditions, leading to human factors limitations violation, and of preventing human error and of its correction.

However, in “Tatarstan” Airlines”, neither of the pilots and pilot-instructors training programs contained training on human factors and methods of danger and error factors control.

Thus, the training level of the airline’s pilots did not comply with the qualification requirements and, in fact, the pilots should not be permitted to perform their duties.

Analysis of requirements for pilot-instructors and pilot-instructor-examiners in the airline

While training the flight crew, the significant role is performed by pilot-instructors. It is the quality training of instructors themselves and their responsible behavior while training pilots that flight safety is largely dependent on.

The analysis has shown that the pilot-instructors of the Airline were faced, in general, with not too high requirements. To acquire an instructor permission, it was necessary to have 1500 total flight hours (including flying time as a FO) and 500 flight hours as a PIC on the type to train on. At the same time, there was no requirement to have higher professional pilot education. These requirements were confirmed by Rosaviatsiya when they approved the airline FOM.

The requirements for pilot-instructors on the Boeing 737-300/400/500 aircraft, previously certified for other types, were even more loyal. It was enough to get a permission for flights on the aircraft type as a PIC and perform 15 landings after becoming a PIC.

Most states of the world provide instructor categorization in accordance with ICAO requirements. The instructor categorization was practiced in “Tatarstan” Airlines, JSC, as well, so that it was possible to follow the FOM requirement (Part A, Chapter 5, section 5.5), requiring that flight crew training was conducted by one pilot-instructor and that pilot’s skills were checked by another instructor categorized as “examiner” (in compliance with paragraph 8.2 of FAR-147). At the same time, the duties and responsibilities of pilot-examiners imply that they must have the highest flying qualification.

According to the airline documents, to get the qualification mark “examiner”, it was necessary to get special training and pass a check, including a check flight (possibly on the simulator) under control of a HQB or TQB member. At the same time, as for the flying time, the requirements for an examiner were less strict than those for an instructor. To get the category "examiner", it was required to fly 200 hrs on an aircraft type as a PIC, and for an instructor – 500 hrs.

In fact, even these “privileged” requirements for an airline’s pilot-examiner were not followed. The pilot-examiner category was easily given to a pilot having a commanding instructor position. None of the pilot-examiners passed any special training, as it was required by the airline FOM, which is confirmed by lack of such training program in the Airline and lack of documents confirming such training in the examiners’ files. At the same time, persons having an examiner category did not perform any check flights, and their flying files do not contain such flying check. The procedure of acquiring a pilot-examiner category consisted in simply sending a list of candidates for pilot-examiners to the regional division of Rosaviatsiya, after which followed the response from regional TQB or HQB, based on which the candidates were categorized as pilot-examiners.

Simulator training

The required procedure of recurrent simulator training

The basis of the flight crew training, especially on actions in case of failures or upset recovery, is simulator training. Due to a great number of actions trained on the simulator, total simulator training is repeated recurrently for the pilots to acquire stable skills.

ICAO provides requirements for flight crew training programs contents, and suggests that each state specifies the training recurrence on their own.

FAR-128 specify the recurrence of practicing actions in different situations. Maximum recurrence intervals (3 years) are specified for practicing actions in case of system failures, not considered an emergency. The same recurrence is specified, for example, for practicing upset recovery actions. For practicing actions in case of ground proximity warning system operation, the recurrence is specified as 1 year. And for practicing actions in case of standard emergencies, as well as of normal operation procedures, the maximum recurrence interval of 7 months is established.

The simulator training must be conducted in compliance with the FCTP. The Flight Crew Training Program for foreign-type aircraft in “Tatarstan” Airlines”, JSC, specified a three-year recurrence interval in one section and a two-year recurrence interval in the other.

Note: ***General instructions for Section 1 “Confirmation of permission for flights” of Training program 4***

5. *Practicing of actions in case of system failures and faults, not requiring emergency actions from memory, with the purpose of practicing all the necessary items, including total aircraft systems overview, is conducted with the recurrence of minimum once in 3 years.*

3. General provisions. Program №9 (Maintaining qualification of Boeing `737 flight crew)

- *training distribution through a 2-year period, considering the priority of all practical training elements.*

Training duration: The program is intended for a 2-year recurrent period and has Boeing 737 flight crew recurrent training as its main purpose.

Each of its 4 cycles (RECURRENT) includes: theoretical training, ground training and simulator training.

All kinds of training, included in each recurrent training, are thematically interconnected and oriented on a particular season (RECURRENT 1, 3 – spring/summer period, RECURRENT 2, 4 – autumn/winter period).

In fact, program №9 was the main program in the airline, and it had forms “Tasks for training”, which were used in the airline for conducting simulator training. Thus, there was a 2-year recurrent training period in the airline for simulator actions practicing. Every half a year, two simulator training sessions were planned, totally within a two-year recurrent cycle there were 8 simulator sessions (instead of 12 simulator sessions in case of a three-year recurrence). In case of the two-year recurrence, the number of tasks for each training session was considerably bigger.

Analysis of Program №9 “Maintaining qualification of Boeing 737 flight crew”

The program is intended for a 2-year recurrent period of simulator training.

Paragraph 4.1 of the program provides 32 hrs of simulator training.

Paragraph 4.4 “Training schedule of simulator training” lays out these 32 hrs. Each half a year (recurrent cycle) provides 8 hrs of simulator training broken into two sessions, each of them lasting 4 hrs. Each 4-hour session includes a break of 15 min. Besides, each session includes a preflight Briefing of 1 hr before the session and a Debriefing of 1 hr after the session.

Paragraph 4.4.1. of the program contains “Subject layout for recurrent training”. RECURRENT 1 has 28 items (while 32 items are listed in the training task), subject to be checked for every pilot, RECURRENT 2 – 29 items (36 items in the task for training), RECURRENT 3 – 33 items (38 items in the task for training), RECURRENT 4 – 31 items (37 items in the task for training).

Each RECURRENT training implies 8 hrs of simulator training (2 sessions of 4 hrs each). 2 out of 8 hrs are intended for checks. Each session includes a break of 15 min. Thus, total training time is 5 hrs 30 min.

For simulator training, two pilots are sent who need this training. Most items of the program need to be given to both of the pilots. That is, for each pilot 2 hrs 45 min on average are due. Each pilot must practice the tasks required by the program as a PF and as a PNF during the training sessions. Besides, each pilot must also be given the items of the obligatory training, not included in the RECURRENT training program.

The check must be performed not by the pilot-instructor who conducted the training for these pilots, but by another one - having a category of examiner. The pilot-instructor who conducted training, gives a permission for the check, and the examiner after the check gives a permission for flights.

During the check, correctness of the actions of each pilot must be checked and, according to the check list, each of its items must be assessed. The check list includes all the practiced items of the program in addition to the mandatory ones by every check. All the items are checked for each pilot, for which only 1 hr is given. The analysis has shown that it is impossible to perform a check of each pilot with due quality in accordance with the actual airline’s check list within the time given for each pilot.

Incidentally, the simulator sessions also include LOFT (RECURRENT 1 and 3) and minimum confirmation program training (RECURRENT 2 and 4). LOFT requires 1 hr, which decreases each trainee training time by 30 min. Consequently, the RECURRENT 1 и 3 programs provide only 2 hrs 15 min for training each pilot. While conducting the RECURRENT 2 и 4 trainings, taking into account the time given for the minimum confirmation program training, total training time for each pilot is 2 hrs 30 min.

The training time deficiency described above is most likely the cause of the fact that no RECURRENT program has either the number of flights required stated, or the time required for performing the task items, which is against the airline's FOM requirements.

Note: ***Part D of FCTP "General provisions"***

6. *In the flight crew training programs, applied in "Tatarstan" Airlines", JSC, the scope of objectives and tasks of simulator and flight training is stated as the minimum and maximum number of flights (landings), and if necessary as minimum and maximum flying time, but not less than established by the FCTP. The necessary scope of training within the limits of minimum and maximum scope is determined by the instructor.*

Analysis of the flight crew training in "Tatarstan" Airlines", JSC based on CRM and LOFT programs

Substantial is the knowledge of what the LOFT Program is, as well as the understanding of the importance of this training for flight crew and the connection of this program with the CRM course training program. The importance of the CRM training is confirmed by the fact that ICAO devoted much research to it and issued 2 separate documents: 9683 "Human Factors training manual" and 9376 "Preparation of an Operations Manual", which regulate the procedure of such training conduction.

Note: ***Doc. 9376 Preparation of an Operations Manual***

Section 4.17. Human Factors training

4.17.2 The findings of a substantial body of research support the design of Human Factors training programmes that are operationally relevant and that avoid academic approaches. The most important application of Human Factors knowledge of human performance and limitations into a training programme is known as Crew Resource Management (CRM).

CRM aims primarily at preventing accidents and incidents where ineffective crew performance as a team might be a major factor. It also contributes to the improved performance, both in terms of safety and effectiveness, of the aviation system through improved performance of the basic units: flight crew - aircraft; maintenance *crew - aircraft; flight operations officer - flight crew; flight and cabin crew, etc.*

The objectives of CRM training are to develop the communications, management and teamwork skills and to create an understanding of how humans operate, particularly in difficult and stressful situations.

CRM training typically includes an initial indoctrination following a classroom or seminar-type format. This first phase provides the framework for the acquisition of the basic concepts as well as a common language. Recurrent training is used thereafter to consolidate and update the newly acquired competency.

4.17.3 *A third and essential component of Human Factors training for operational personnel is known as lineoriented flight training (LOFT).*

LOFT is the inseparable ally of CRM, since it provides an opportunity to apply CRM concepts in practice, in operational settings and in real time.

LOFT consists of carefully structured scenarios developed in flight simulators where flight crew are confronted with operational situations where the application of sound CRM principles is the key for a successful outcome.

4.17.4 *The realization of the potential benefits CRM and LOFT can bring into the safety and effectiveness of flight operations depends on their integration into the philosophies, policies, procedures and practices of operators.*

A piecemeal approach, such as the incorporation of a CRM training module into the training curricula, may be a beginning but it is not enough.

CRM principles must be slowly embedded into every aspect of the operator' s standard operating procedures. Furthermore, CRM training should not be limited to flight crews, but it should be *extended to include maintenance personnel, flight operations officers/flight dispatchers and cabin crews.*

On the larger organizational scale, awareness packages are available for supervisory and managerial personnel. Such packages foster the notion that operational personnel practices during the course of operations will simply reflect management and supervisory policies; therefore, it is a precondition to the success of CRM that managers (including senior executives) and supervisors demonstrate and exercise appropriate CRM behaviours.

Understanding the importance of this kind of flight training for the Russian and international air legislation harmonization as well, FAR-128 require (5.84): The operator does not permit aircraft flight crew members to perform their functions, unless they have passed training based on the training program created by the operator, which provides the required training of all the flight crew members for performing their duties and:

f) provides the following:

not less often than once a year, a flight simulator training based on the real enroute flight scenario;

not less often than once in 3 years, a theoretical training and a CRM training;

yearly CRM assessment on the simulator and on the aircraft.

LOFT is a specific item of pilot training, which must be assessed by specialists, having training in psychology. It is a kind of training which allows to assess not how one pilot manages failures, but how the crew together work out the decision to counteract the failure and successfully complete the flight. In connection with this, ICAO mentions specialized training for instructors to make such training and flight crew actions assessment possible, both using the simulator and in real flight.

Note: ***Doc. 9683 Human Factors training manual***

Chapter 2 Crew Resource Management (CRM) training.

Section 2.5. Line-oriented flight training (LOFT).

Instructor training and qualifications.

2.5.31. *Each instructor should have completed a specific LOFT training course.*

***2.5.35** Instructors and check pilots selected to conduct LOFT exercises should receive training in the concepts and conduct of LOFT.*

For realization of this kind of training, specialists are required who have passed special training. LOFT is closely interconnected with CRM training course and is part of it. In the framework of LOFT, based on CRM training course, the flight crew works out behavior norms, facilitating correct decision making in different situations related to flight operations.

The airline CRM documentation contents comply with the ICAO requirements provided in Doc 9683 “Human Factors training manual”. However, the airline just copied the ICAO requirements, but did not manage to implement them.

Thus, there were no simulator training scenarios (basis of this kind of training) for LOFT. At the moment of the air accident, in the airline, there was no pilot-instructor having knowledge required for conduct of such training and, particularly, for flight crew actions assessment. This follows from absence of this training in the instructors’ flight files and from the explanation note by the CRM specialist, working in the APTC of “Tatarstan” Airlines”, JSC.

In the airline’s FCTP, there was no CRM training program. Moreover, there was neither initial, nor enhanced training program, required based on CRM instructors’ categorization.

Thus, “Tatarstan” Airlines had no complete CRM instructors training program, which did not allow to conduct sufficient flight crew training and assess pilots’ qualification adequately when checking this item.

PIC simulator training

In accordance with the business assignment №774 from 28.06.2013, the PIC was in Moscow from 03.07 till 05.07.2013 and had simulator training in “S7 Training”, ANEO, base. The PIC departed on 03.07.2013 at 19:50 (MSK) from Kazan as a passenger on flight TAK 368 and arrived in Moscow at 21:15 (MSK). According to the training slots available, his first training session time was at night on 04.07.2013 from 02:30 (MSK) till 06:30 (MSK). In accordance with the MTO requirements, taking into account the preflight Briefing conducted before the session for 1 hr, trainees’ appearance was to be at 01:30 (MSK), and the postflight Debriefing lasting for 1 hr after the session should have completed the training session at 07:30 (MSK). Already 9 hrs later (at 16:30 (MSK) on 04.07.2013), after the Debriefing, the second simulator training session was to be started. However, in accordance with the airline FOM (FOM, Program №9b, part D, section 4.4), time interval between training sessions should be not less than 10 hrs. The mentioned section of the FOM completes the other one (Part A, Chapter 5 “Regular complex simulator training”, section 5.7), which implies two consecutive days for regular simulator training.

According to the slots provided, the simulator training itself started for the PIC at 17:30 (MSK) and finished at 21:30 (MSK). However, there was no postflight Debriefing. This is confirmed by the fact that the PIC, already in 55 min (at 22:25 MSK) after the finish of the simulator training, having signed for the flight task, departed on flight TAK 367 from Moscow to Kazan. That this schedule had been planned follows from the fact that on 05.07.2013 the PIC was scheduled to fly from Kazan to Dushanbe and back, although his business assignment for simulator training was officially closed on the same date - 05.07.2013.

With such an arrangement of the simulator training, there stands the question of its quality. Besides, there was one more important item missing - there had been no Debriefing. One can judge the importance of this item based on the airline FOM, which describes what is included in the Debriefing.

Note: ***FOM, Part D, Program №9***

4.5.3. *Simulator training*

During the Debriefing, the instructor makes a brief analysis of the flight crew actions, noting positive and negative points, and <u>provides the trainees with information on their faults with the causes, as well as recommendations on their prevention</u>.

It is obvious that, without the Debriefing, the major aim of instructor’s work in training pilots is gone.

Preliminary preparation of the flight crew before the simulator training is of great importance when training the flight crew as well. Moreover, during this preparation, pilots’ knowledge is assessed and credits are given, with filling in an assessment paper. Considering the importance of the preparation before the simulator training, which takes 8 training hours in accordance with the ground training schedule, that is the whole training day, such briefing must be scheduled and reflected at least in the Scheduling registers of working time.

Note: ***FOM, Part D, Program №9***

4.1. *The training schedule of the Boeing 737-300/400/500 flight crew recurrent training includes the following sections (kinds of training):*

- *theoretical training – 64 hrs;*

- *ground training – 32 hrs;*
- *simulator training – 32 hrs.*

4.2. *The theoretical training schedule of the Boeing 737-300/400/500 flight crew recurrent training includes lessons according to the schedule – 64 hrs, including examinations:*

- *test after the cycle "First semester" – 3 hrs;*
- *test after the cycle "Second semester" – 3 hrs;*

4.3. *Ground training is conducted with the flight crew not earlier that 7 days before the simulator training date assigned.*

The ground training schedule of the Boeing 737-300/400/500 flight crew recurrent training includes lessons according to the schedule – 32 hrs. The scope of ground training in each recurrent cycle is 8 hrs.

Each recurrent cycle of the ground training corresponds with its cycle of the simulator training. Everything that the pilots practice during the simulator training is revised by them during the theoretical training, and the scope of the theoretical training material of the ground training corresponds with the scope of training tasks, which is, as mentioned before, quite a big scope, depending on the ordinal number of the RECURRENT training – from 32 to 38 items. If the trainee has not passed the ground training, the simulator training time will be used ineffectively and will influence the quality of training. It will be required to revise the theory first, and only then practice the training items, which will lead to deficiency of time for completing the training program. It should be noted that the training schedule of the ground training before the simulator training does not include revision of the theoretical knowledge on performance of a go-around.

The commission was not able to establish the time when the PIC had completed the ground training before the simulator training. Neither the working schedule, nor the Flight plan or working time register of the PIC have this information recorded. In fact, the PIC was officially on vacation from 18.06.2013 till 02.07.2013, and on the first day after returning from his vacation, on 03.07.2013, he flew to Moscow for the simulator training. Most probably, the simulator training preparation was conducted only nominally, and the instructor just filled in the assessment paper.

It is also a confirmed fact that having arrived in the evening and passed the training at night, the crew was not provided with hotel accommodation in Moscow. It was impossible to establish where and how the crew had rest and prepared for the evening session.

It should also be noted that the instructor, who trained the crew, assessed them himself, which goes against the airline FOM.

First officer simulator training

The same situation can be observed with the FO simulator training.

The FO departed on September, 25 at 19:50 (MSK) as a passenger on the flight from Kazan to Moscow, and returned in the evening the next day, on September, 26. As well as the PIC, having completed the simulator training at 21:30 (MSK), already in 55 min he departed as a passenger from Moscow to Kazan. His simulator slots were the same as those of the PIC: the first session from 02:30 (MSK) till 06:30 (MSK), the second session from 17:30 (MSK) till 21:30 (MSK), with all the described questions as to the quality of the training.

Questionable is the fact that for the FO business assignment №1138 from 23.09.2013 was issued only two days prior to the start of the simulator training and only for 2 days: September, 25 and 26. Probably, the decision on his assignment for the simulation training was made only on September, 23. Officially, the FO was on vacation from 30.08 till 22.09.2013. Being on vacation, on September, 21 and 22, he performed flights. On September, 23 he performed flights again, and on September, 24, in accordance with the daily flight plan, he was on duty, although in the working Schedule, it is said he was on seasonal training. Besides, on September, 25 the FO departed for the simulator training, which means, as well as with the PIC, the theoretical training before the session was conducted nominally (or was not conducted at all).

As well as in the case with the PIC, the instructor, who trained the crew, performed the check himself.

And as well as in the case with the PIC, the crew was not provided with hotel accommodation in Moscow.

Financial support of the flight crew simulator training

One of the fundamentals in pilot training is financial support of training in the required scope. However, the airline financial problems led to the debts of financing simulator training. In accordance with the document provided by the airline, there were heavy debts to the simulator training organizations. During the simulator training, no one of the working pilots in the airline was provided with extra training sessions, and no pilot was suspended from flights after the simulator training due to poor knowledge or skills. The facts mentioned, as well as not providing the crew with accommodation during their assignments for the simulator training, can indicate that the simulator training was conducted formally, only for the purpose of nominally taking all kinds of training, required for continuing flights.

1.5.3. Data on the air traffic service personnel of Kazan center of ATM of "Tataeronavigation" branch of the "State ATM Corporation", FSUE

Position	**FIR Manager (RFM)** (on the day of the air accident performed duties of the shift manager)
Sex	male
Date of birth	20.06.1967
Education	Higher. Kazan State Pedagogical University, 2004. Personnel Training Course (PTC) for controllers. CA center in Ulyanovsk, 1992.
Class	Class 1. HQB protocol from 12.06.1999 № 12/y
Permission for work	Control Area "North", Control Area "South", Control Area 3, Control Area "Out of route", Local Control Point (LCP), instructor. Permission for RFM – protocol from 13.03.2008 of RQB of ATM Administration and Aerospace Search and Rescue (ASR) of Privolzhskiy AT ITO of FATA. Recurrent training in English in Privolzhskiy branch of Aeronavigation Institute in 2011. Additional training (short-term courses) in English within the period from 2011 till 2013. Permitted for ATM in English.
ICAO level of English	ICAO level 4 – certificate № CMP 1868.1866, valid till 16.09.2016.
Medical Certification	Till 27.03.2015
License expiry date	Till 06.09.2014
Practical skills check:	- RFM - 28.03.2013. - LCP - 22.08.2013. - Control Area "North" - 24.08.2013. - Control Area "Out of route" - 26.08.2013. - Control Area "South" - 04.09.2013.
Simulator training	18.09.2013

Total ATM experience	21 years
Experience as RFM	1 year 1 month

Position	**Aerodrome Flights Manager (AFM)** (on the day of the air accident performed duties of the AFM)
Sex	male
Date of birth	20.07.1959
Education	Higher. Saint-Petersburg CA Academy, 1981
Class	Class 1. RQB protocol from 19.02.1997 № 1
Permission for work	Radar Control Point (RCP), RCP-2, Tower Control Point (TCP), Ground Control Point (GCP), Tower and Ground Control Point (TGCP), AFM, instructor. Recurrent training for shift supervisor, Saint-Petersburg CA Academy, 2009 Recurrent training in English in Privolzhskiy branch of Aeronavigation Institute in 2011. Additional training (short-term courses) in English within the period from 2011 till 2013. Permitted for ATM in English.
ICAO level of English	ICAO level 4 – certificate № CMP 1253.16721, valid till 30.05.2014.
Medical Certification	Till 06.05.2015
License expiry date	Till 06.11.2016
Practical skills check:	- AFM – 11.04.2013 - RCP – 30.09.2013 - RCP-2 – 30.09.2013 - TGCP – 09.09.2013 - GCP – 13.09.2013 - instructor – 22.05.2013
Simulator training	28.08.2013
Total ATM experience	32 years
Experience as AFM	18 years

Position	**Air Traffic controller** (on the day of the air accident performed duties of the Control Area “South” (“Kazan - Control”) till 15:05)
Sex	male
Date of birth	17.11.1980
Education	Higher. Kazan State Pedagogical University, 2010. ATC dispatchers training, shortened basic educational program of secondary professional education “Air transport traffic control”, in Saint-Petersburg CA Academy, in 2013.
Class	Class 3. HQB protocol from 10.10.2013 № 6
Permission for work	Control Area “South”. Permitted for ATM in English.
ICAO level of English	ICAO level 4 – certificate МСК № 4971.19468, valid till 23.05.2016.
Medical Certification	Till 03.06.2015
License expiry date	Till 10.10.2014
Practical skills check:	16.08.2013
Simulator training	20.08.2013
Total ATM experience	1 month

Position	**Air Traffic controller** (on the day of the air accident performed duties of the Control Area “South” (“Kazan - Control”) from 15:05)
Sex	female
Date of birth	27.02.1990
Education	Higher. Ulyanovsk CA HAC, 2012.
Class	Class 3. Protocol of the TQB of Privolzhskiy AT ITO from 13.12.2012 № 22
Permission for work	Control Area “South” Permitted for ATM in English.

ICAO level of English	ICAO level 4 – certificate № КИ-00037, valid till 15.06.2015.
Medical Certification	Till 04.05.2014
License expiry date	Till 13.12.2013
Practical skills check:	20.08.2013
Simulator training	18.09.2013
Total ATM experience	11 months

Position	**Air Traffic controller** (Radar position on the day of the air accident)
Sex	male
Date of birth	04.08.1976
Education	Higher. Riga Aeronavigation Institute, 1997.
Class	Class 1. HQB protocol from 09.06.2010 № 1
Permission for work	RCP, RCP-2, TCP, GCP, TGCP. Recurrent training for shift supervisor, Saint-Petersburg CA Academy, 26.04.2013. Recurrent training in English in Privolzhskiy branch of Aeronavigation Institute in 2011. Additional training (short-term courses) in English within the period from 2011 till 2013. Permitted for ATM in English.
ICAO level of English	ICAO level 4 – certificate CMP № 429.3517, valid till 25.11.2013.
Medical Certification	Till 20.04.2014
License expiry date	Till 26.04.2014
Practical skills check:	- RCP – 29.08.2013 - RCP-2 – 22.05.2013 - TGCP – 26.08.2013 - TCP – 19.09.2013 - GCP – 20.09.2013
Simulator training	04.09.2013
Total ATM experience	16 years
Experience in the position	5 months

Position	**Air Traffic controller** (Tower position on the day of the air accident)
Sex	male
Date of birth	03.04.1988
Education	Higher. Ulyanovsk CA HAC, 2010 (Technological processes and production safety). ATC dispatchers training, shortened basic educational program of secondary professional education “Air transport traffic control”, in Saint-Petersburg CA Academy, in 2013.
Class	Class 3. Protocol of the TQB of Privolzhskiy AT ITO from 08.08.2013 № 17
Permission for work	TCP. Permitted for ATM in English.
ICAO level of English	ICAO level 4 – certificate № ЯЦ-01254, valid till 17.05.2016.
Medical Certification	Till 29.05.2015
License expiry date	Till 08.08.2014
Practical skills check:	TCP – 14.09.2013
Simulator training	14.09.2013
Total ATM experience	3 months

1.6. Aircraft Information

Aircraft appearance before the air accident is provided in Figure 4.

Figure 4 Aircraft appearance before the air accident

Type	Airplane, Boeing 737-500 (53A)
MSN	24785
Manufacturer, production date	The Boeing Company, 13.06.1990
Registered charterer (according to the registration certificate)	AWAS (BERMUDA) LIMITED, Clarendon House, 2 Church Street, Hamilton HM 11, Bermuda
Operator	“Tatarstan” Airlines", JSC
State and registration numbers	VQ-BBN (Bermuda)
Certificate of registration	№ 1416 from 19.12.2008, issued by Bermuda Department of Civil Aviation
Certificate of airworthiness	№ 1278 from 25.01.2013, issued by Bermuda Department of Civil Aviation, valid till 24.12.2013. The Agreement, according to article 83 bis of ICAO Convention, between Bermuda government and the RF government was concluded in 1999. The VQ-BBN aircraft was entered into the related appendix (page 28, the

	latest amendment from April, 15, 2013) to the Agreement.
Total Time Since New (TTSN)	51547 hours, 36596 cycles
Service life	Not established, in service depending on technical condition
Base maintenance	2C-check (every 500 hrs), on 29.03.2012 after service time of 48163 hrs, 34998 cycles, performed by “S 7 ENGINEERING”, LLC, Domodedovo airport, maintenance sheet №BN032C/12. 1A-check (every 250 hrs), on 15.11.2013, performed by “Tulpar Technic”, LLC, Kazan airport, maintenance sheet №0618.
Last line maintenance	Daily-check, on 17.11.2013, performed by “Tatarstan” Airlines", JSC, Kazan airport, maintenance sheet №0002815. Transit-check, on 17.11.2013, performed by “Tatarstan” Airlines", JSC, Kazan airport, maintenance sheet №0002817.
Preflight check	Preflight Check, in Domodedovo airport, performed by the crew[8].

Engines

	left	**right**
Type of engine	CFM56-3C-1	CFM56-3C-1
Manufacturer	CFM (France)	CFM (France)
MSN	724225	724607
Production date	07.06.1989	08.03.1990
Total TSN, CSN	61527 hours, 40126 cycles	47107 hours, 32286 cycles
Service life	Not established, in service depending on technical condition	Not established, in service depending on technical condition

[8] The crew members had related certificates on training in “S7 Training”, ANEO, on the program “Flight crew training course on B-737-300/400/500 Transit Check”.

Overhauls	4	3
Date and place of last overhaul	09.04.2008, BEDEK Aviation Group, Israel Aerospace Ltd.	16.03.2008, BEDEK Aviation Group, Israel Aerospace Ltd.
Operating time, cycles since last overhaul	10 717 hrs, 5134 cycles	10 717 hrs, 5134 cycles

The Boeing 737-500 aircraft, registration number VQ-BBN, was transferred to “Tatarstan” Airlines", JSC, in accordance with the subcontract from 09.12.2008 with “Bulgaria Air”, JSC. Actual operation of the aircraft in “Tatarstan” Airlines", JSC, started in 2010. Prior to that, the aircraft was operated by[9]:

- 1990 – 1995 Air France F-GGML;
- 1995 – 1998 Uganda Airlines 5X-USM;
- 2000 – 2005 Rio Sul PT-SSI;
- 2005 – 2008 Blue Air YR-BAB;
- 2008 Bulgaria Air (parked) LZ-BOY.

The aircraft was maintained in accordance with the Maintenance Program of “Tatarstan” Airlines", JSC (Maintenance Program Ref. TAT/B737/300/400/500 MP Rev.02), approved by the aviation authorities of the states of registration (Bermuda) and operator (Russia).

The documentation analysis showed that maintenance was scheduled timely and was performed in full scope.

Base maintenance of the Boeing 737-500 VQ-BBN aircraft was performed by the following organizations:

- “S7 ENGINEERING”, LLC according to and in compliance with the Contract between “S 7 ENGINEERING”, LLC and “Tatarstan” Airlines", JSC № С7-ИН/0409-09 from 20.04.2009;
- “Tulpar Technic”, LLC according to and in compliance with the Contract between “Tulpar Technic”, LLC and “Tatarstan” Airlines", JSC № 13106 from 17.05.2013.

[9] At periods, not mentioned in the list below, the aircraft was on storage.

The maintenance organizations mentioned are certified in compliance with EASA PART-145 rules (certificates №№ EASA.145.0130, EASA.145.0581), approved by the aviation authorities of the state of the aircraft registration (certificates №№ BDA/AMO/265, BDA/AMO/268).

Line maintenance, as well as engineering technical tracking, planning and control of maintenance, were performed in Kazan airport in “Tatarstan” Airlines", JSC facilities. Line maintenance was performed in “Tatarstan” Airlines", JSC line maintenance station in Kazan airport, having EASA approval, as well as approvals of Bermuda and Russian aviation authorities.

The analysis of following mandatory service bulletins and airworthiness directives concerning airframe and engine was performed. All the required service bulletins and airworthiness directives, applicable for the airframe and engines, had been followed.

The procedure of opening Deferred Maintenance Items was checked. According to MEL and Technical Logbook records, at the moment of departure from Domodedovo airport on 17.11.2013, there were no deferred items of categories A, B, C.

There is a record of two deferred items of category D:

- electrical ovens in the aft galley are removed. Defect rectification deferred till 14.11.2013[10];
- water heater in the forward galley is removed. Defect rectification deferred till 11.03.2014;

Estimated takeoff weight was approximately 45 000 kg (maximum takeoff weight is 59 193 kg), estimated CG was approximately 21% of MAC; estimated landing weight was approximately 42 000 kg (maximum landing weight is 49 895 kg), estimated CG (according to the simulation results) was 19.23% of MAC, which did not go beyond the acceptable limits.

At Domodedovo airport, the aircraft was refueled with TC-1 fuel in the volume of 2547 kg in accordance with the requirement №030581. Total fuel quantity before takeoff (taking into account fuel consumption during engine startup and taxiing) was 7800 kg.

It was impossible to perform sampling of fuel from the aircraft systems, due to their complete destruction on impacting the ground. The analysis of the fuel samples, taken from the fuel tanks, proved their normal quality.

[10] By the air accident day, defect rectification was expired.

All the aircraft systems had been refilled, the quantity of oil and special liquids had been in compliance with the norms, which follows from the provided confirming documents and lack of records of binary signals about low pressure of oil in the engine and hydraulic fluid in the hydraulic systems in the FDR readout.

1.6.1. The aircraft construction features to be noted

Figure 5 shows the appearance of the PIC's instrument panel of an analog aircraft[11].

Figure 5 The PIC's instrument panel on an analog aircraft

As it is seen from the figure, electronic attitude direction indicator (EADI) had "common" cross bars. In the right lower corner of the instrument, flight radio altitude (height), measured by radioaltimeter, is indicated. Pressure altitude and vertical speed indication is not provided on EADI. These parameters are indicated on separate instruments, located right of EADI (pressure altimeter - at the same level, and vertical speed indicator (VSI) - lower).

At great (>40°) roll and/or pitch angles, height, measured by radioaltimeter, differs greatly from the aircraft actual height, while EADI indicates actual radioaltimeter readings. There are no limitations on radioaltimeter operation, related to great roll and/or pitch angles, provided by aircraft operations manual.

Another construction feature of radioaltimeter is that its operation heights range starts from measured height of 2500 feet, which means that at bigger values of measured height they are not indicated on the EADI, the related box stays blank.

[11] At the Commission's disposal, there was no photograph of the VQ-BBN aircraft instrument panel of satisfactory quality.

On 02.03.2011, by «Bulgaria Air» personnel, in the facilities of “Tatarstan” Airlines", JSC ATB, the aircraft was equipped with an FMC, rev. 5.0 (p/n 168925-07-01, s/n 2116) (the work was performed in connection with the failure of the FMC p/n 168925-15-01, rev. 10.7). According to the information available, the FMS had a navigation data base valid from November, 14 till December, 11, 2013. The data base had information on Kazan aerodrome, including standard arrival UW 29D.

For navigation and flight control, FMS[12] was used, which includes FMC, as well as other equipment. FMC determines aircraft current position, using inertial reference system (IRS) data, as well as ground navigation aids data. FMC calculates current position as a mathematic combination of coordinates, determined by IRS, and ground navigation aids data.

The inertial system (the aircraft has two independent IRSs) provides other aircraft systems with different navigation data, including data on current position. The information, provided by IRS, does not depend on ground navigation means. Before flight, IRS must go through an procedure, during which the crew enters current aircraft position manually. During alignment, the aircraft must be stationary. The accuracy of the current position determination by IRS in flight becomes worse due to its natural “shift”. Error accumulation may be up to 2 nautical miles per hour. In case of entering imprecise current aircraft position or its moving during system alignment, the value of the error may become greater.

To rectify occurring errors, in flight, correction of position determined by FMC is provided, using signals from ground navigation aids. The correction is done continuously, in an automatic or manual mode. The correction is performed with signals from the following navigation aids available, which are listed in the order of decreased priority:

- two or more DME beacons;
- one VOR beacon, joined with DME beacon;
- one localizer beacon, joined with DME beacon;
- one localizer beacon.

The most accurate one is the correction, using two or more DME beacons. The VOR/DME correction is less accurate due to inevitable errors in determining VOR beacon bearing. The VOR/DME correction is done only if the aircraft is within 25 nm from the beacon. The localizer beacon correction is possible only at the aerodrome area, with manual setting of the ILS frequency.

[12] The aircraft was not equipped with a GPS receiver.

When the signals from ground navigation aids are unavailable, FMC uses coordinates, determined by IRS, as approximate value, and then uses corrections to determine its estimated coordinates. These corrections to IRS data allow for the errors, connected with the standard IRS “shift”, and are estimated in advance, on flight stages, when information from ground navigation aids is available.

It should be noted, that FCOM provides information that a single FMC is not certified as an autonomous source of navigation information. The required navigation accuracy is reached in operations in «accurate radio navaid environment». Under «accurate radio navaid environment» one should understand the conditions, when area navigation (RNAV) accuracy is provided in accordance with the provisions of the FAA directive AC 90-45A.

Thus, in case of lack of VOR and DME beacons on the flight path in the required quantity, accuracy of FMC determination of the current aircraft position may be insufficient. The related information is provided in the FCOM, with the description of the conditions of generating various warning signals, provided for the crew in such situations. On appearance of such warnings, to reach the required accuracy in navigation, it is necessary to use all onboard and ground means combined.

In the aircraft type certificate (TC) issued by Aviation Register of IAC is stated that the flights in the airspace of States of the Agreement are conducted only along the routes with the permanent SSR surveillance provided.

1.6.2. Elevator control system

The elevator control is performed with control columns, connected with left and right control cables with input arms (cranks) of PCUs, located on frame № 1156.

The PCUs are installed vertically in the fuselage tail section (Figures 6a and 6b).

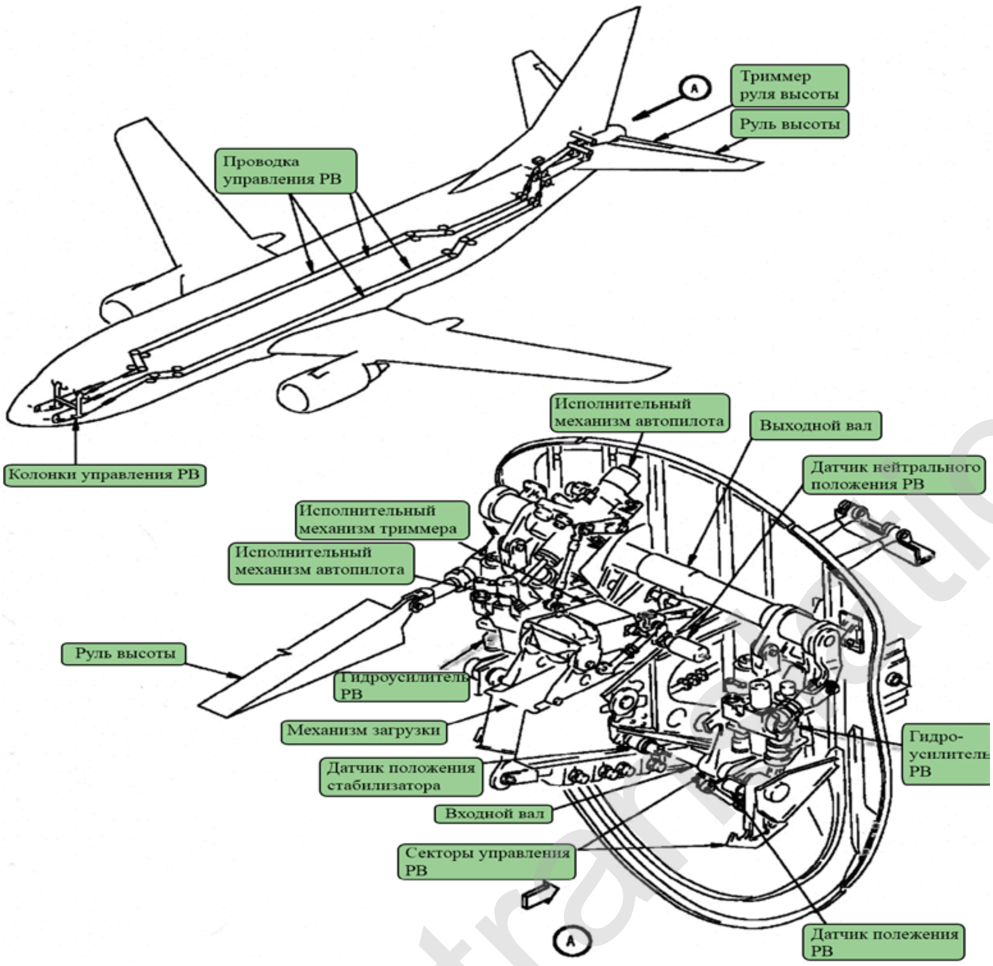


Figure 6a Layout of the elevator control system components

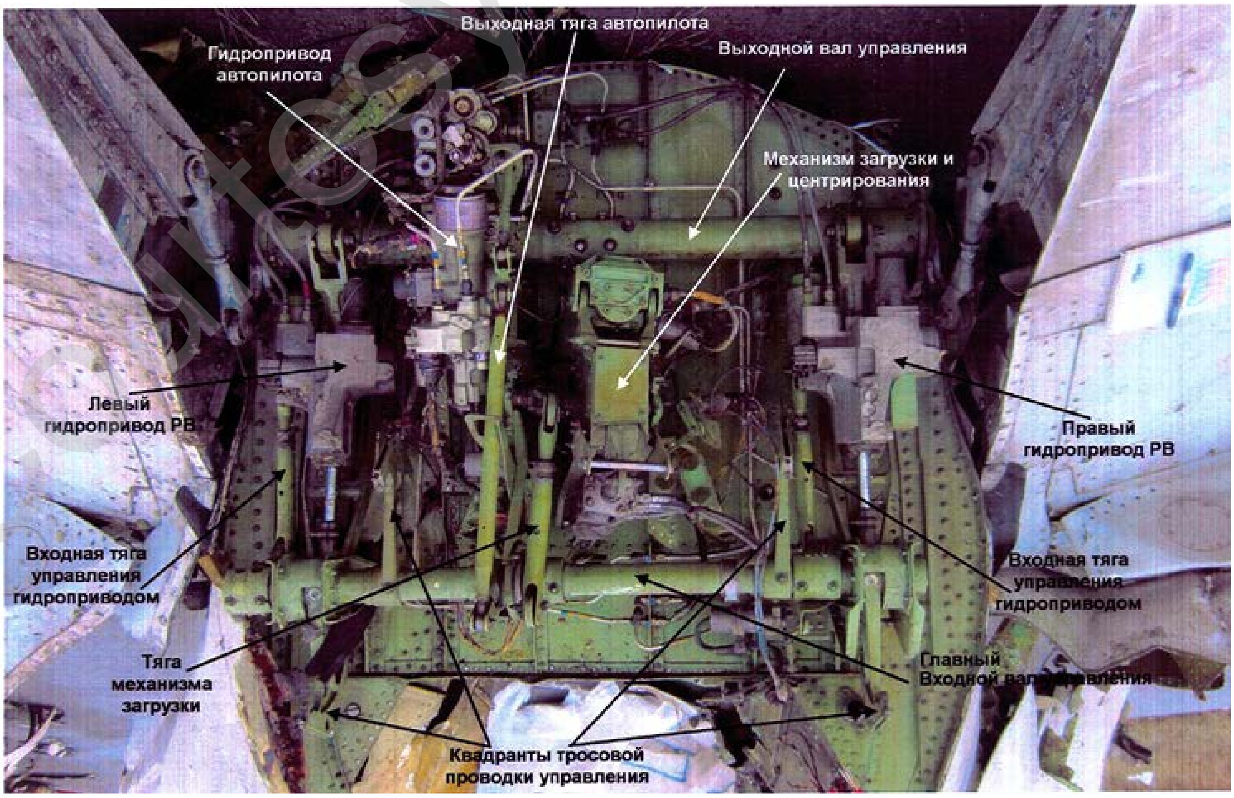


Figure 6b View of the elevator control system components on frame 1156 after the air accident

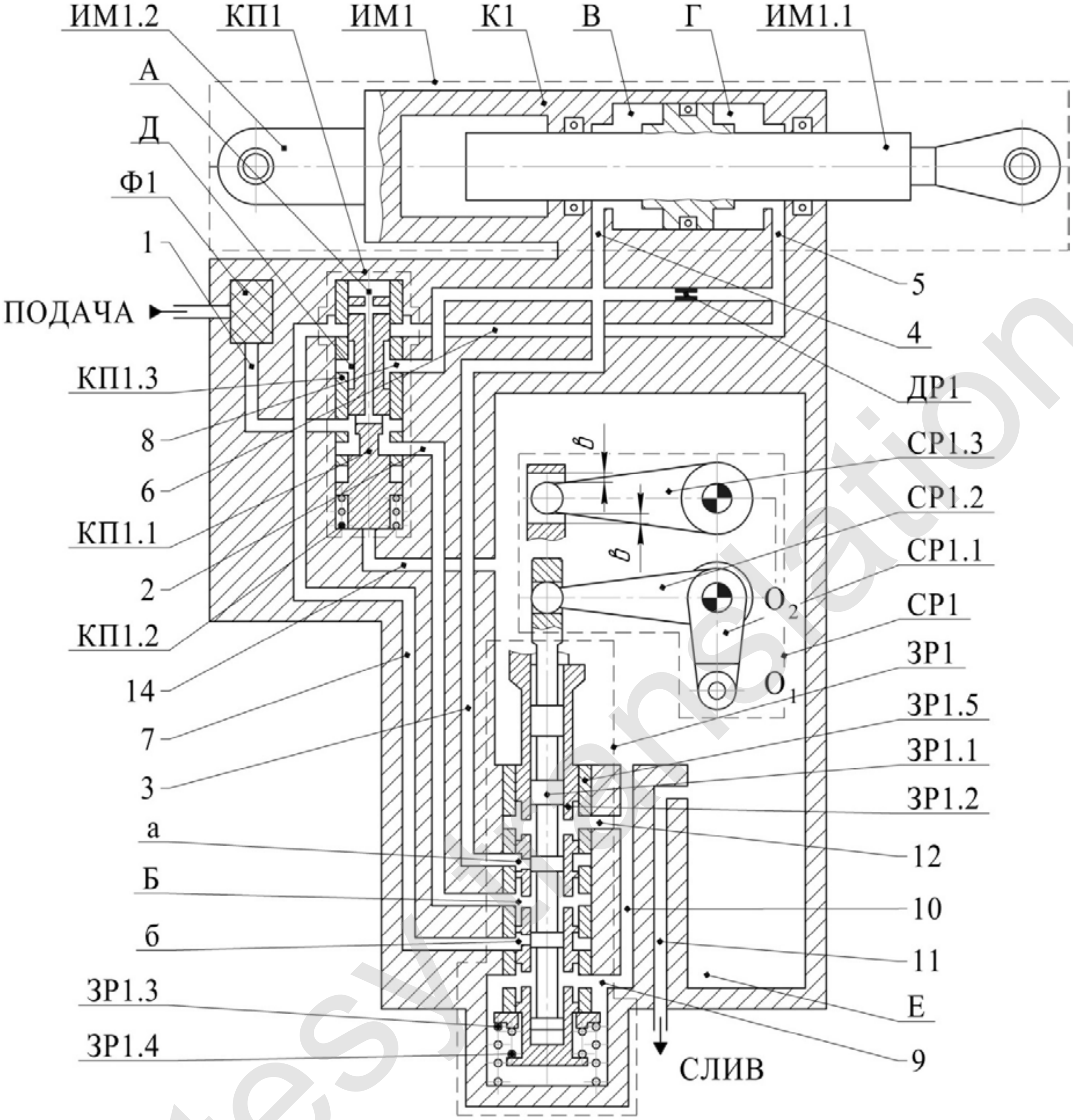
The aircraft was equipped with two PCUs, operated by two independent hydraulic subsystems.

The PCU is mounted in two points: with the flange fork to the operated surface and with the piston link to the aircraft structure.

The PCU control is actuated by a mechanical input signal, generated in the control system in the manual or automatic mode.

The PCU is a hydromechanical one-channel servodrive with a throttle and linear motion of the output link and a backward linkage, closed through the aircraft structure. The output link of the PCU moves at a speed, proportional to the deflection of the input arm.

The basic schematics of the PCU is provided by Figure 7.



К1 - корпус
Ф1 - входной фильтр
КП1 - клапан перепуска
КП1.1 - золотник клапана перепуска
КП1.2 - пружина клапана перепуска
КП1.3 - гильза клапана перепуска
ДР1 - дроссель
ИМ1 - исполнительный механизм
ИМ1.1 - шток с поршнем
ИМ1.2 - вилка фланца
ЗР1 - золотниковое распределительное устройство
ЗР1.1 - основной золотник распределительного устройства
ЗР1.2 - вторичный золотник распределительного устройства
ЗР1.3, ЗР1.4 - пружины распределительного устройства
ЗР1.5 - гильза распределительного устройства
СР1 - система рычагов
СР1.1 - входная качалка
СР1.2, СР1.3 - рычаги
1...14 - каналы для протока рабочей жидкости

Figure 7 PCU basic schematics

- the PCU consists of the piston housing К1, input filter Ф1, bypass valve КП1, throttle ДР1, actuator ИМ1, control valve ЗР1 and cranks СР1;
- the housing К1 is the main load-bearing element, in which the above mentioned components are mounted and which houses hydraulic connecting lines;

- the input filter Ф1 is used to prevent the PCU from mounting contamination when connected to the aircraft hydraulic system;
- the bypass valve КП1 is used to disconnect the main cavities of the PCU from the input line, and to connect the actuator ИМ1 working cavities В and Г (circuit closing) in case of lack (wind load) or decrease of input pressure. To limit the speed of the actuator ИМ1 travelling, in order to provide smooth movement of the output link in the mode of wind load damping, the bypass valve КП1 is fitted with a throttle;
- the throttle ДР1 is used to connect the working cavities В and Г of the PCU of the actuator ИМ1 (circuit closing) in case of bypass valve КП1 jamming in an open position and decrease of input pressure;
- the actuator ИМ1 is used to turn the working fluid pressure energy into the mechanical energy of the linear motion of the housing К1 and transfer of the force through the flange fork ИМ1.2 to the surface operated;
- the control valve ЗР1 is used to regulate the fluid flow and to distribute the working fluid through the actuator ИМ1 cavities in accordance with the changing value of the input control signal; the principle of the control valve ЗР1 operation is based on the movement of the valves ЗР1.1 and ЗР1.2, located one inside the other, under the effect of mechanical force from the input rod of the aircraft through the arms (cranks) system СР1;
- the arms (cranks) system СР1 is used to transfer the motion from the aircraft input rod to the control valve ЗР1, as well as to perform backward link together with the aircraft structure.

Normal operation

In PCU normal operations, the working fluid form the aircraft hydraulic system through the INPUT coupling and the input valve Ф1 goes via line 1 into cavity А of the bypass valve КП1, which, under the input pressure, moves downward, overriding the spring КП1.2 pressure, and provides access for the working fluid via line 2 into cavity Б of the control (servo) valve ЗР1. The spring cavity of the bypass valve КП1 is connected with the return through line 14, cavity Е and line 11.

With the input arm (crank) СР1.1 motionless, that is neutral position of the slides ЗР1.1 and ЗР1.2 of the control valve ЗР1, the flow outlets “а” and “б” of the secondary slide ЗР1.2 are closed by the collars of the primary slide ЗР1.1 and the working fluid does not enter the cavities (В, Г) of the actuator (piston) ИМ1.

With the shift of the input arm (crank) СР1.1 to the shaft of the primary slide ЗР1.1, point O_1 turns relative to stationary point O_2. The arms СР1.2 and СР1.3, tightly interconnected on the same shaft, move clockwise and move the primary slide ЗР1.1 upward, opening the flow outlets "а" and "б" in the secondary slide ЗР1.2. At this time, the secondary slide ЗР1.2 stay motionless due to the clearance «в» between the arm СР1.3 ball and the response hole in the secondary slide ЗР1.2. The clearance «в» equals half of the full range of the primary slide ЗР1.1. Further shift of point O_1 of the input arm (crank) СР1.1, after the clearance «в» adjustment, leads to combined shift of the slides ЗР1.1 and ЗР1.2. Thus, the combined shift of the two slides occurs when the PCU receives an input signal of great value, that is when it is required to provide maximum speed of flight control surfaces movement. The spring cavity of the control valve ЗР1 is connected with the return through lines 9 and 10, cavity E and line 11.

The working fluid moves via line 2, through outlet "а" and via line 3:

- through line 8 into cavity Д of the bypass valve КП1;
- through line 4 into cavity В of the actuator (piston) ИМ1 and moves the housing К1 to the left (extension). The housing К1, moving, forces the working fluid out of cavity Г of the actuator (piston) ИМ1 through lines 5, 6, 7, outlet "б", lines 9 and 10 into cavity E, and then through line 11 into the hydraulic return line.

After the input arm СР1.1 stop, the housing К1, moving, changes the angular position of the PCU. Point O_1 of the input arm, fixed on the housing К1 of the PCU, moves relative to stationary point O_2. At this time, the arms СР1.2 and СР1.3 turn counterclockwise and move the primary slide ЗР1.1 downward to the neutral position. The secondary slide ЗР1.2, under the springs' ЗР1.3 and ЗР1.4 pressure, also takes the neutral position. The motion of the housing К1 stops.

With the shift of point O_1 of the input arm (crank) СР1.1 from the shaft of the primary slide ЗР1.1, it turns relative to stationary point O_2. The arms СР1.2 and СР1.3, the same way as described above, move counterclockwise and move the primary slide ЗР1.1 downward, opening flow outlets "а" and "б" in the secondary slide ЗР1.2. Further shift of point O_1 of the input arm (crank) СР1.1, after the clearance "в" adjustment, leads to combined shift of the slides ЗР1.1 and ЗР1.2. The spring cavity of the control valve ЗР1 is connected with the return through the lines 9 and 10, the cavity E and the line 11.

The working fluid via line 2, outlet "б" and lines 7, 6, 5 moves to cavity Г of the actuator ИМ1 and moves the housing К1 to the right (retraction). The housing К1, moving, forces the working fluid out of the cavity В of the actuator (piston) ИМ1 through lines 4, 3, outlet “a”, lines 12 and 10 into cavity E, and then through line 11 into the hydraulic return line.

After the input arm СР1.1 stop, the housing К1, moving, changes the angular position of the PCU. Point O_1 of the input arm, fixed on the housing К1 of the PCU, moves relative to stationary point O_2. At this time, the arms СР1.2 and СР1.3 turn clockwise and move the primary slide ЗР1.1 upward to the neutral position. The secondary slide ЗР1.2, under the springs' ЗР1.3 and ЗР1.4 pressure, also takes the neutral position. The motion of the housing К1 stops.

Operations during a stop

During a stop, with hydraulic power disconnected, the PCU dampens the rod motion under the wind load. The rod slowly sinks due to the working fluid movement from one cavity to another through the bypass valve throttle.

With no hydraulic pressure supply, the slide КП1.1 of the bypass valve КП1, under the spring КП1.2 pressure, closes the line 2 and prevents the working fluid outflow into the INPUT hydraulic line.

During the rod extension motion under the wind load, the PCU changes its angular position. Point O_2 turns relative to stationary point O_1, as the friction in the PCU system is greater than in the control valve ЗР1 system. The working fluid from cavity Г via line 4 moves:

- through the bypass valve throttle into cavity Д of the bypass valve КП1, via lines 5 and 3 into cavity В of the actuator;
- through the outlet “б”, lines 6 and 7 into cavity E under the return pressure.

During the rod retraction motion, the same way as described above, the working fluid moves from cavity В into cavity Г.

Note: *Based on the aircraft structure and PCUs operation principles, to establish the elevator PCUs output links position and, accordingly, the elevator surfaces position at the moment of the air accident is possible only based on the FDR data as the PCUs output links (elevator surfaces) with low pressure in the aircraft hydraulic systems can sink in one direction or in the opposite one under the external forces, including the gravity force and the forces, occurred at the moment of the aircraft impact with the ground and affecting the control surfaces. Low pressure in the hydraulic system was caused by destruction of the hydraulic lines at the moment of impacting the ground due to off-design loads. Thus, the elevator PCUs output links and, accordingly, the elevator surfaces, at the* *moment of observation, could have been located randomly relative to these components position at the moment of the air accident.*

1.7. Meteorological Information

The meteorological support of Flight TAK 364/363 on 17.11.20113 on the route Kazan - Moscow (Domodedovo) - Kazan was performed by:

- shift on duty of the CA meteorological station of “Kazan International Airport”, JSC (Rosgidromet license from June, 17, 2013, registration number P/2013/2356/100/Л);
- shift on duty of Domodedovo branch of “Rosgidromet MAMC”, FSFO (license registration number P/2012/2035/100/Л from March, 26, 2012).

The flight crew briefing was performed in the briefing room of Kazan airport. During the briefing, the crew was provided with the following meteorological documentation:

- Russian Gidrometcenter map of specific phenomena in layer FL 250-630 for the fixed time 12:00 from 17.11.2013;
- London WAFS wind and temperature forecast at FL 340 for the fixed time span 12:00 from 17.11.2013;
- Form AB-11 №18 with forecasts from 09:00 on 17.11.2013 till 09:00 on 18.11.2013 and actual weather for 10:00 at the departure airport (Kazan), at the destination airport (Domodedovo), at the alternate airports (Vnukovo, Nizhniy Novgorod, Saint-Petersburg).

At 10:26 the PIC signed in the Meteorological information familiarization logbook for receiving form AB-11 №18 with the destination airport (Domodedovo) and the alternate airport (Saint-Petersburg) stated.

At 11:22 the aircraft performed take-off from Kazan airport (Flight TAK 364).

The landing in Domodedovo airport was performed at 12:43.

At the time of the aircraft final approach and landing in Domodedovo airport, complicated wind conditions in the ground air layer were observed. Actual weather in Domodedovo airport for 12:44:

surface wind 240-7 m/sec about 11 m/sec, at height 100 m 240-13 m/sec, at circuit height 280-25 m/sec, at 60 m - wind shear, visibility 10 km, clouds 7 octas cumulonimbus, cloud *base 410 m, temperature +6.8, dew point temperature +5.9, relative humidity 94%, pressure 736.6/982.1/1000.5, moderate turbulence in the surface layer.*

After landing, the PIC had meteorological briefing in the briefing room of Domodedovo airport, where he received the form with meteorological data, which included the actual weather for 13:00 on 17.11.13 in METAR code and the forecasts in TAF code for 12:00 on 17.11.13 for the departure airport (Domodedovo), the destination airport (Kazan), the alternate airports (Samara and Ufa).

Actual weather in Domodedovo airport on 17.11.2013 at 13:00:

METAR *UUDD* 171300Z 26007G12MPS 9999 – SHRA SCT008 BKN019CB 07/06 Q1000 32290095 82290095 NOSIG=

Surface wind 260 degrees 7, gusting 12 m/sec, visibility 10 km, light shower rain, clouds scattered (1-4 octas), cloud base 240 m, clouds broken (5-7 octas) cumulonimbus, cloud base 570 m, air temperature +7 degrees, dew point temperature +6 degrees, QNH pressure 1000 hPa, RWY 32 left, wet, braking action good, RWY 32 right, wet, braking action good, without changes.

Actual weather in Kazan airport on 17.11.2013 at 13:00:

METAR UWKD 171300Z 24008G11MPS 9999 OVC011 03/02 Q0997 R29/2/0055 NOSIG RMK QFE736/0982=

Surface wind 240 degrees 8, gusting 11 m/sec, visibility 10 km, overcast (8 octas), cloud base 330 m, air temperature +3 degrees, dew point temperature +2 degrees, QNH pressure 997 hPa, RWY 29 right, wet, friction coefficient 0.55, without changes, AAL (QFE) pressure 736 mm of mercury/982 hPa.

Weather forecast in Kazan airport for 17.11.2013:

TAF UWKD 171055Z 1712/1812 24006G12MPS 9999 OVC007 SCT013CB 650070 530001 TEMPO 1712/1715 25009G15MPS 2000 SHSNRA BKN005 BKN010CB TEMPO 1715/1724 2000 SHRA BKN003 BKN010CB=

The forecast was prepared on November, 17, at 10:55, valid from 12:00 on November, 17 till 12:00 on November, 18, surface wind 240 degrees 6, gusting 12 m/sec, visibility 10 km, overcast (8 octas), cloud base 210 m, clouds scattered (1-4 octas) cumulonimbus, cloud base 390 m, moderate icing in cloud layer 210 to cloud top, moderate turbulence beyond clouds, frequent in layer 0-300 m; sometimes on November, 17 from 12:00 till 15:00 surface wind 250 degrees 9, gusting 15 m/sec, visibility 2000 m, moderate downpour snow *with rain, clouds broken (5-7 octas), cloud base 150 m, clouds broken (5-7 octas) cumulonimbus, cloud base 300 m; sometimes on November, 17 from 15:00 till 24:00 visibility 2000 m, moderate downpour rain, clouds broken (5-7 octas), cloud base 90 m, clouds broken (5-7 octas) cumulonimbus, cloud base 300 m.*

The aircraft takeoff from Domodedovo airport was performed at 14:25.

On the route Domodedovo-Kazan, the aircraft flight was performed in the cyclone hollow. The wind at FL290 was 310 degrees, velocity approximately 200 km/hr. The weather forecast en route on the specific weather phenomena map predicted moderate to strong turbulence at FL270 to FL370. In fact, on the flight route, there were no dangerous phenomena noted.

The weather conditions on November, 17, 2013 in Kazan Control Area, were determined by the warm cyclone sector with the center in the area of Archangelsk, with minimum pressure of 971.1 hPa in the center. The occluded weather front system, which affected the weather in the area of Kazan, moved in north-western flows at speed 50 km/hr. The warm front was located to the east of Nizhniy Novgorod, the cold front – to the south of Vologda and Rybinsk. The loss of pressure before the warm front was 3.3 millibars, and the front was expected to pass through Kazan at 18:00, and the cold front - at night, after 00:00. At the surface, along the warm front line and in the warm sector, strong south-western winds were observed.

For Kazan aerodrome, storm warning №4 was issued for surface wind strengthening from 09:00 till 15:00 and №6 from 15:00 till 21:00: for Kazan aerodrome, wind 240 degrees 09 m/sec, gusting 15 m/sec is predicted.

For Kazan Control Area of Unified ATM System and the aerodrome area, storm warning №5 from 12:00 till 18:00 was issued: moderate turbulence, moderate icing in the clouds were predicted.

At the area of Kazan airport, high air humidity was observed, which caused additional compression of the front stratocumulus and altostratus clouds, which produced light precipitation of rain with snow. Based on the atmospheric radio sounding data of aerological station Kazan for 12:00 on 17.11.2013, the aerological diagram was made. According to the stratification curve, cloudiness was multilayer: the cloud top of the lower cloud layer was at 1600 m, altostratus clouds were located from 3000 m till 4200 m. At 1500 m and 2000 m, there were inversion layers 120 m and 380 m thick accordingly.

Based on the atmospheric radio sounding data for 12:00, the following values of wind heading and speed at heights were calculated.

Height, m	Wind heading	Wind speed
100	241	8
200	252	9
300	256	10
400	246	13
500	237	15
600	246	15
700	254	15
800	260	15
900	263	14
1000	266	14

By the time of Boeing 737-500 VQ-BBN entering Kazan Control Area, the information of actual weather at Kazan aerodrome, transmitted by ATIS (information “Juliet” for 14:42), was:

surface wind 220 degrees 9 m/sec, gusting 12 m/sec, at 100 m 230 degrees 8 m/s, at circuit – 250 degrees 16 m/sec, visibility more than 10 km, light shower with snow, overcast (8 octas), cloud base 270 m, air temperature +3 degrees, dew point temperature +2 degrees, AAL pressure 735 mm of mercury/980 hPa, light icing in the clouds, without significant changes.

When contacting the air traffic controller, the crew confirmed receiving this information.

By the moment of the aircraft final approach at Kazan aerodrome, another ATIS information “Kilo” was transmitted with actual weather for 15:00:

surface wind 220 degrees 9 m/sec, gusting 12 m/sec, visibility more than 10 km, light shower with snow, overcast (8 octas), cloud base 250 m, air temperature +3 degrees, dew point temperature +2 degrees, AAL pressure 735 mm of mercury/980 hPa, light icing in the clouds, friction coefficient 0.55, forecast for landing – without changes.

At this time, for Kazan aerodrome, the forecast from 15:00 on 17.11.2013 till 15:00 on 18.11.2013 was actual:

TAF UWKD 171355Z 1715/1815 24009G15MPS 9999 OVC007 SCT013CB 650070 530001 TEMPO 1715/1724 1200 SHRA BKN004 BKN010CB TEMPO 1800/1806 2000 SHRA BKN005 BKN010CB BECMG 1810/1812 30014G20MPS=

Surface wind 240 degrees 9, gusting 15 m/sec, visibility 10 km, overcast (8 octas), cloud base 210 m, clouds scattered (3-4 octas) cumulonimbus, cloud base 390 m, moderate icing in cloud layer from 210 m to cloud top, moderate turbulence beyond clouds, frequent in layer surface to 300 m; sometimes from 15:00 till 24:00 visibility 1200 m, downpour rain, clouds broken (5-7 octas), cloud base 120 m, clouds broken cumulonimbus, cloud base 300 m; sometimes from 00:00 till 06:00 on November, 18 visibility 2000 m, downpour rain, clouds broken (5-7 octas), cloud base 150 m, clouds broken cumulonimbus, cloud base 300 m, gradually changing from 10:00 till 12:00 to wind 300 degrees 14 m/sec, gusting 20 m/sec.

After the air accident, at 15:24, the Tower ATC transmitted the “Emergency” signal to the technician-meteorologist through PAE.

The actual weather, measured at Kazan aerodrome after receiving the “Emergency” signal was:

15:24: surface wind magnetic 220 degrees 07 m/sec, gusting 10 m/sec, wind at 100 m – 230 degrees 08 m/sec, wind at circuit height (500 m) – 250 degrees 16 m/sec, visibility 10 km, light shower with snow, overcast (8 octas), cloud base 220 m, air temperature +3.2 degrees, dew point temperature +2.5 degrees, relative humidity 95%, AAL pressure 734.7 mm of mercury/979.6 hPa, magnetic heading 292, friction coefficient 0.55, forecast for landing – without changes.

Thus, the actual weather in the area of Kazan aerodrome at the moment of the air accident corresponded with the forecasted weather. The meteorological equipment (KRAMS-4), used for weather observation at Kazan airport, was operative and complied with the requirements AON-92, CA MSD-95 and Instruction on meteorological support of flights at Kazan airport. The actions of the shift on duty of Kazan CA meteorological station, performing meteorological support of aircraft flights on the aerodrome and in the area of Kazan aerodrome, and their coordination with the duty on shift of ATC prior to the air accident and after receiving the “Emergency” signal, were in compliance with the requirements of the regulative and normative documentation. The meteorological support of the flight of Boeing 737-500 VQ-BBN was in compliance with the requirements of the regulative and normative documentation.

1.8. Aids to Navigation, Landing and ATC

The operation of the navigation aids of Kazan ATM for November, 17, 2013 for descent, final approach and go-around of Boeing 737-500 VQ-BBN:

- “Galaktika” ATC automation aids complex operated with a 100% reserve. The location and planning information processing servers of the ATC automation aids complex operated with a 200% standby, without comments. The sources of the radiolocating information: Monoimpulse secondary radiolocator “Avrora” and aerodrome radiolocator complex “Lira A10”. The location positions operated without comments with a 100% standby.

- Voice recording was performed by the taperecorder “Granit” on the main and standby discs.
- Radiolocating and planning information recording and recording of all the air traffic controller actions was performed in the modes of active and passive documenting on the computers of the air traffic controller and the server accordingly.
- Automatic radio direction finder “Platan” operated without comments.
- With heading 292° magnetic, radio beacon ILS of type SP-200 was installed, which includes a course beacon, a glidepath beacon, DME beacon. SP-200: MSN 12119, production date 2012, in service since 03.06.2013 (order of Director of “Tataeronavigation” branch of the “State Corporation of Air Traffic Organization”, FSUE from 03.06.2013 №195), inflight check performed on 03.06.2013 (Act of flight check from 03.06.2013); landing DME beacon DME90-NP: MSN 1276, production date 2012, in service since 03.06.2013 (order of Director of “Tataeronavigation” branch of the “State Corporation of Air Traffic Organization”, FSUE from 03.06.2013 №196), flight check performed on 03.06.2013 (Act of flight check from 03.06.2013). The listed navigation aids operated without comments.
- NDB with a marker beacon incorporated: radio beacon RMP-200, MSN 12152, production date 2012, in service since 03.06.2013 (order of Director of “Tataeronavigation” branch of the “State Corporation of Air Traffic Organization”, FSUE from 03.06.2013 №198), inflight check performed on 26.12.2012 (Act of flight check from 26.12.2012); marker radio beacon RMM-200, MSN 12183, production date 2012, in service since 03.06.2013 (order of Director of “Tataeronavigation” branch of the “State Corporation of Air Traffic Organization”, FSUE from 03.06.2013 №198), flight check performed on 26.12.2012 (Act of flight check from 26.12.2012). The NDB operated without comments.
- The VOR combined with the DME (VOR+DME). VOR-90, MSN 1212, production date 2012; РМД-90, MSN 1277, production date 2012. In service since 27.12.2012 (order of Director of “Tataeronavigation” branch of the “State Corporation of Air Traffic Organization”, FSUE from 27.12.2012 №365), inflight check performed on

24.12.2012 (Act of flight check from 24.12.2012). The beacon operated without comments.

- The aerodrome radiolocator complex: The aerodrome radiolocator complex “Lira A10”, MSN 210006, production date 2011, in service since 27.12.2012 (order from 27.12.2012 №364), inflight check performed on 25.12.2012 (Act of flight check from 25.12.2012).

All the listed equipment was certified. There were no comments of the flight and ATC personnel, according to the flight crew feedback register “Operation of landing and navigation equipment”, to the operation of flight radio support aids and aviation electrical communications with Kazan airport from 14.11.2013 till 18.11.2013. The last check of the landing system with heading 292° magnetic was performed on 17.11.2013 at 12:11 by the A319 flight crew of “Sibir” airlines, performing flight СБИ 65 Moscow (Domodedovo) – Kazan, without comments.

The lighting equipment system OVI-I with axial lights with heading 292° magnetic left on the man-made surface RWY-1 was in service since June, 26, 2013. By its composition the group of the lights complies with the requirements of tables 5.7 and 5.8 of AON, the location of the lighting equipment system complies with the requirements of tables 5.14 and 5.16 of AON. The electrical supply of the lighting equipment system corresponds to the specific group of category 1 by the degree of electrical supply reliability of table 7.1 of AON.

The flight check of the lighting equipment system OVI-I with axial lights with heading 292° magnetic left, glidepath visual indication system PAPI with heading 292° magnetic left was performed when putting into service the lighting equipment system from May, 27, 2013 till May, 29, 2013 by the crew of the laboratory aircraft Ан-26, board № 26521, equipped with flight checking equipment ASLK-NU, MSN №1002, “Flight checks and systems”, JSC. Certificate of airworthiness for the lighting equipment system OVI-I operation with axial lights with heading 292° magnetic left № 84 was valid till June, 26, 2016.

The ATC personnel had been taught the rules of the lighting equipment system operation.

At the moment of the Boeing 737-500 VQ-BBN aircraft landing, the OVI-I system with axial lights with heading 292° magnetic left was set at group 1 (pushbutton) of meteorological visibility distance in accordance with Table 5.13 of AON “Lights groups and their brightness stages on control pushbuttons for systems ОВИ-I, II, III”.

There were no failures in the flight electrical lighting equipment. The cabin crew communications analysis showed that the FO observed the PAPI lights before going-around. Thus, at the moment of Boeing 737-500 VQ-BBN landing, all the lighting equipment was operative and electrical lighting technical support complied with the requirement.

1.9. Communication

During descent and approach, the aircraft flight crew had consistent radio communication with the air traffic controllers of Kazan Control Area (sector “South”), RCP and TCP of Kazan airport at very high frequencies 133.1, 119.4 and 120.3 mHz accordingly. Very high frequency radio communication operated in a normal mode, without comments.

The analysis of communication between the crew and the air traffic controller, recorded by the CVR and the ATC ground recorder, showed that the radio communication quality was good. At the same time, during going-around, the flight crew (the FO) did not get clear the go-around height value given by the controller first, which required additional clarification. The possible causes of that are considered in section Analysis.

1.10. Aerodrome Information

Kazan aerodrome of class “A” is an aerodrome of joint bases (with the Ministry of Inner Affairs of Tatarstan) and is part of class I airport, it is approved for 24-hour operation in accordance with the required minima for international flights. The aerodrome is a federal property and is supervised by “Kazan International Airport”, JSC.

Note: *The aerodrome class is determined by the man-made runway class, and the runway class - by the runway length in normal conditions according to table 2.1 AON-92.*

On the aerodrome, there are bases of: “Tatarstan” Airlines", JSC, “Kazan aviation company” airline”, JSC, “Tulpar Air”, LLC, “AK Bars Aero”, JSC, “KAPO-Avia”, Closed JSC, special aviation division of Ministry of Inner Affairs of Tatarstan.

The aerodrome has the Aircraft Operating Certificate valid till 22.11.2015.

The aerodrome is approved to receive the Boeing 737-500 aircraft type.

The aerodrome has a man-made surface runway, with area 3750 x 45 m. The magnetic declination is +14°53’. The aerodrome AAL is +119.1 m. The magnetic takeoff/landing headings are 112° (RWY 11) and 292° (RWY 29). The runway threshold altitude with landing heading 112° magnetic - 105.63 m, with landing heading 292° magnetic - 124.97 m.

The profile of the area around the airport does not have any significant artificial or natural obstacles.

According to the logbook of aerodrome condition and preparedness for flights, on 17.11.2013 for 12:20 there is the following record: «RWY with landing heading 292° magnetic, wet in some places. Friction coefficient 0.55/0.55/0.55, major taxiway, taxiways, stands, ramps are wet in some places”. For 14:50: “The aerodrome facilities have been inspected. The conditions are without changes”.

After the air accident, at 16:27, the RWY control inspection has been performed and the Act was made, which said: “The RWY with landing heading 292° magnetic, wet, friction coefficient 0.55/0.55/0.55, no foreign objects found.”

The aerodrome support of the Boeing 737-500 VQ-BBN flight complied with the requirements, the aerodrome RWY was prepared for the aircraft arrival.

Below is the arrival pattern from MISMI waypoint (the flight should have followed STAR UW 29D), and the ILS DME approach pattern on RWY 29.

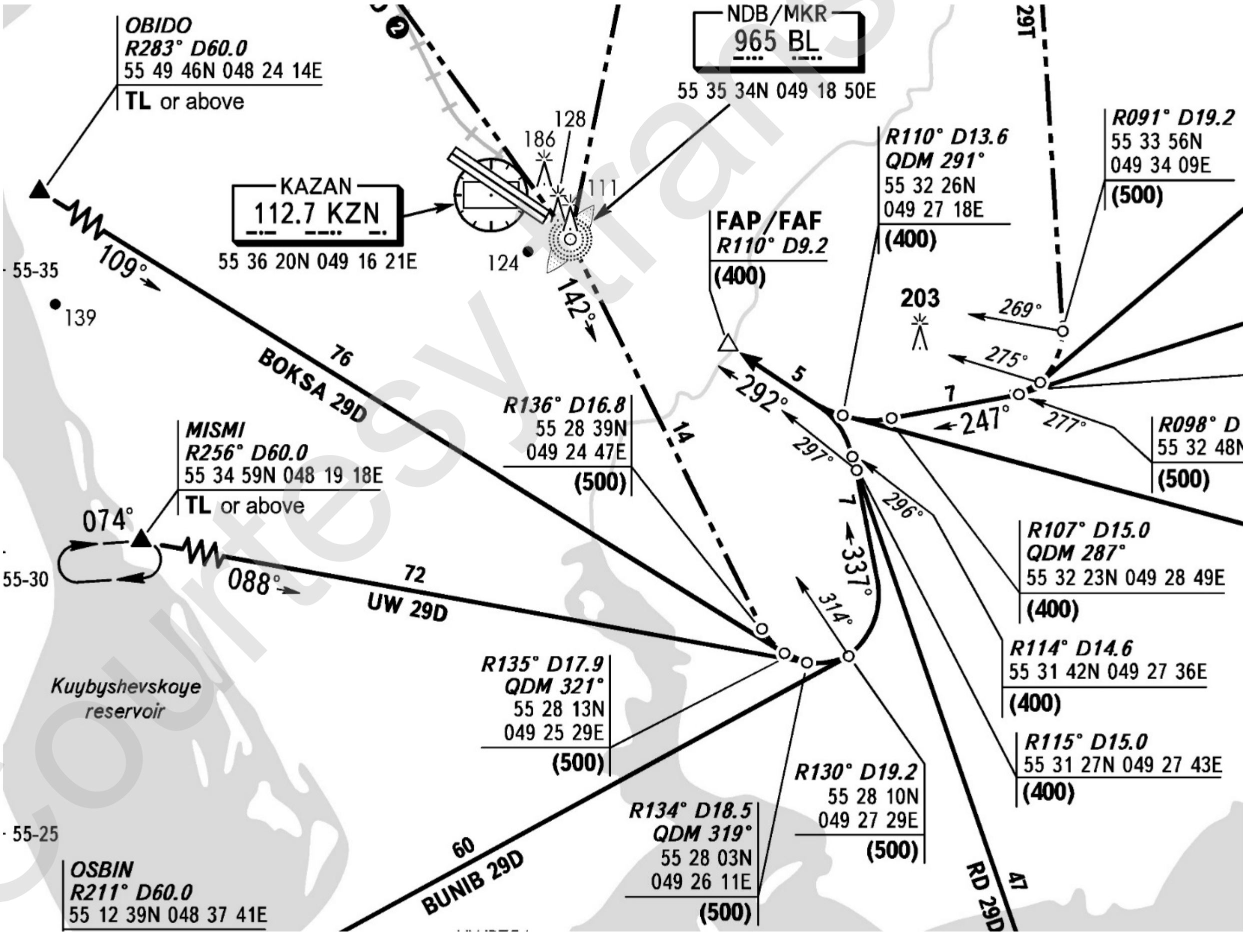


Figure 8 Arrival pattern (STAR UW 29D) from MISMI waypoint

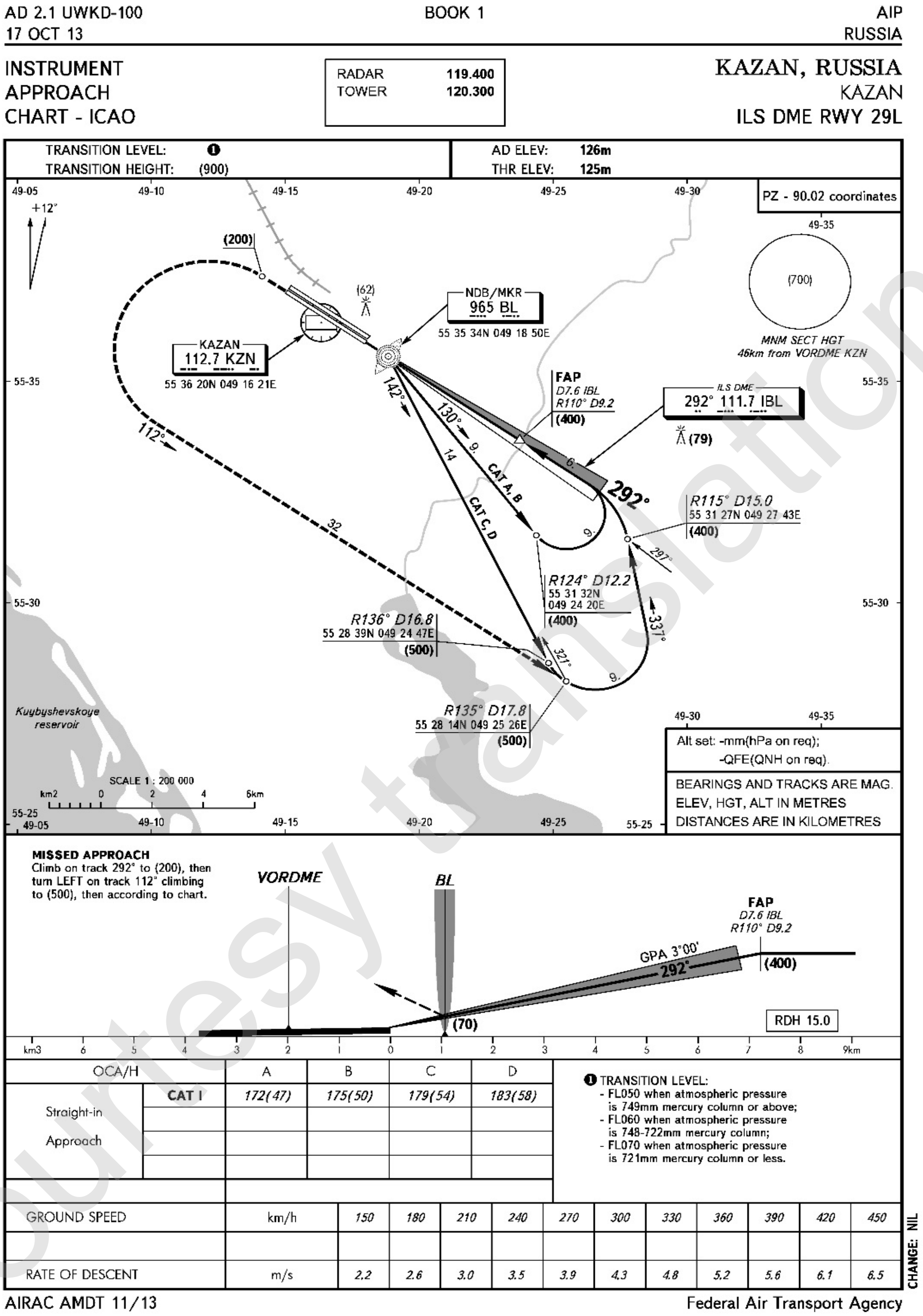


Figure 9 ILS DME approach pattern on RWY 29

1.11. Flight Recorders

Flight Data Recorder

The aircraft was equipped with an FDR manufactured by L3 (Fairchild), model – F1000, p/n S800-2000-00, s/n 02109. It was found at the accident site with severe damage (Figure 10).

Figure 10 FDR at the accident site

The FDR readout was performed at AAISTSC laboratory, IAC.

Due to significant damage to the FDR processing unit the protected memory module was transferred to the service chassis of an FDR of the same model. After the memory unit was linked to the service chassis all the recorded FDR data were read out with the help of the L3-Communication Rose readout equipment.

The flight data were processed and analyzed with the help of the WinArm software.

The flight data analysis revealed the following:

- The FDR contained data of 34 flights of the Boeing 737-500 VQ-BBN (approx. 61 hours of records) including the accident flight record;
- The Boeing 737-500 VQ-BBN FDR was operative on the flight of November 17, 2013 and recorded analogue data in full compliance with the list of Boeing 737-500 recordable parameters as well as event signals compatible to the their generation conditions.

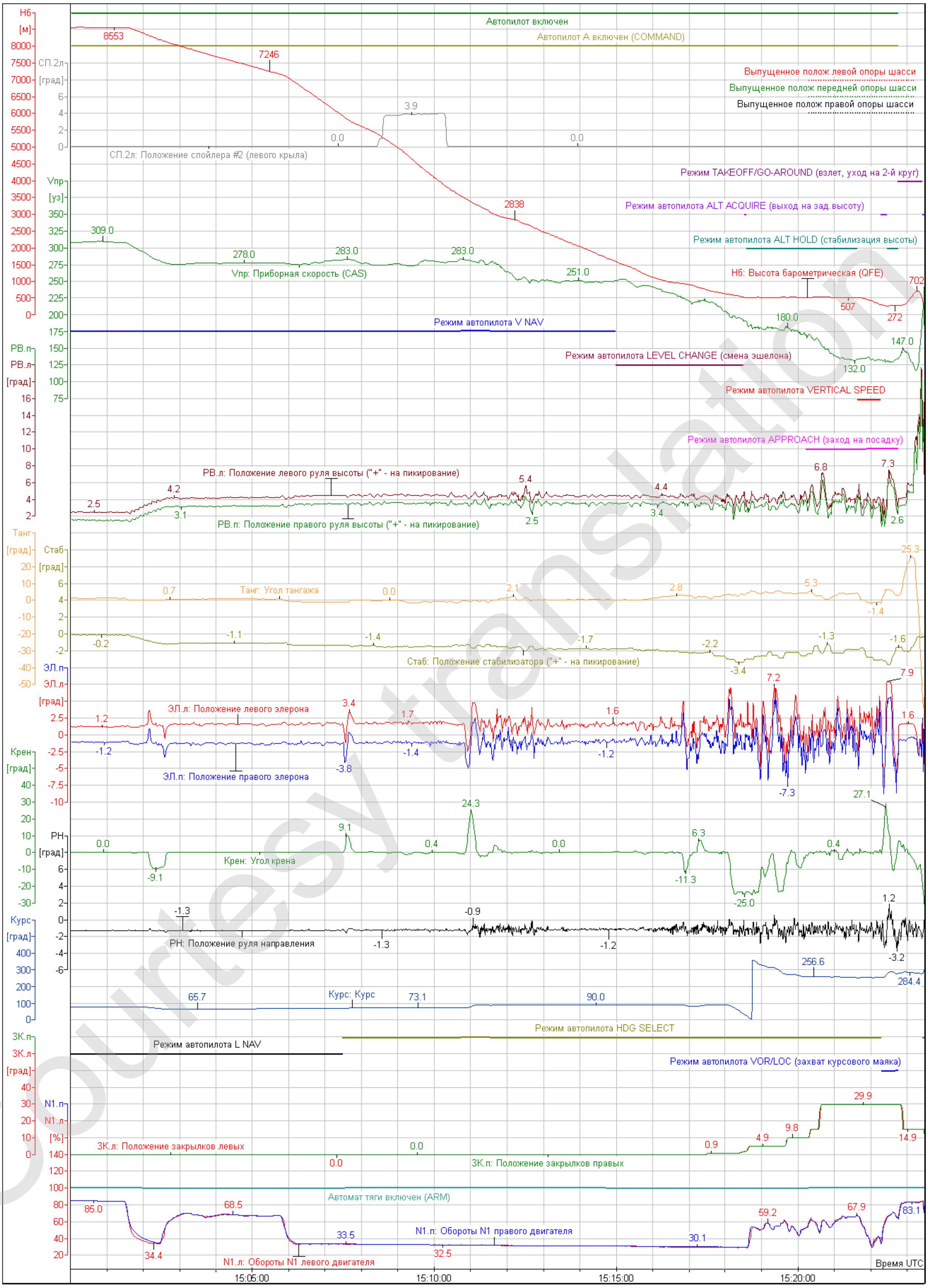


Figure 11 Boeing 737-500 VQ-BBN Flight Data for 17.11.2013 (descent)

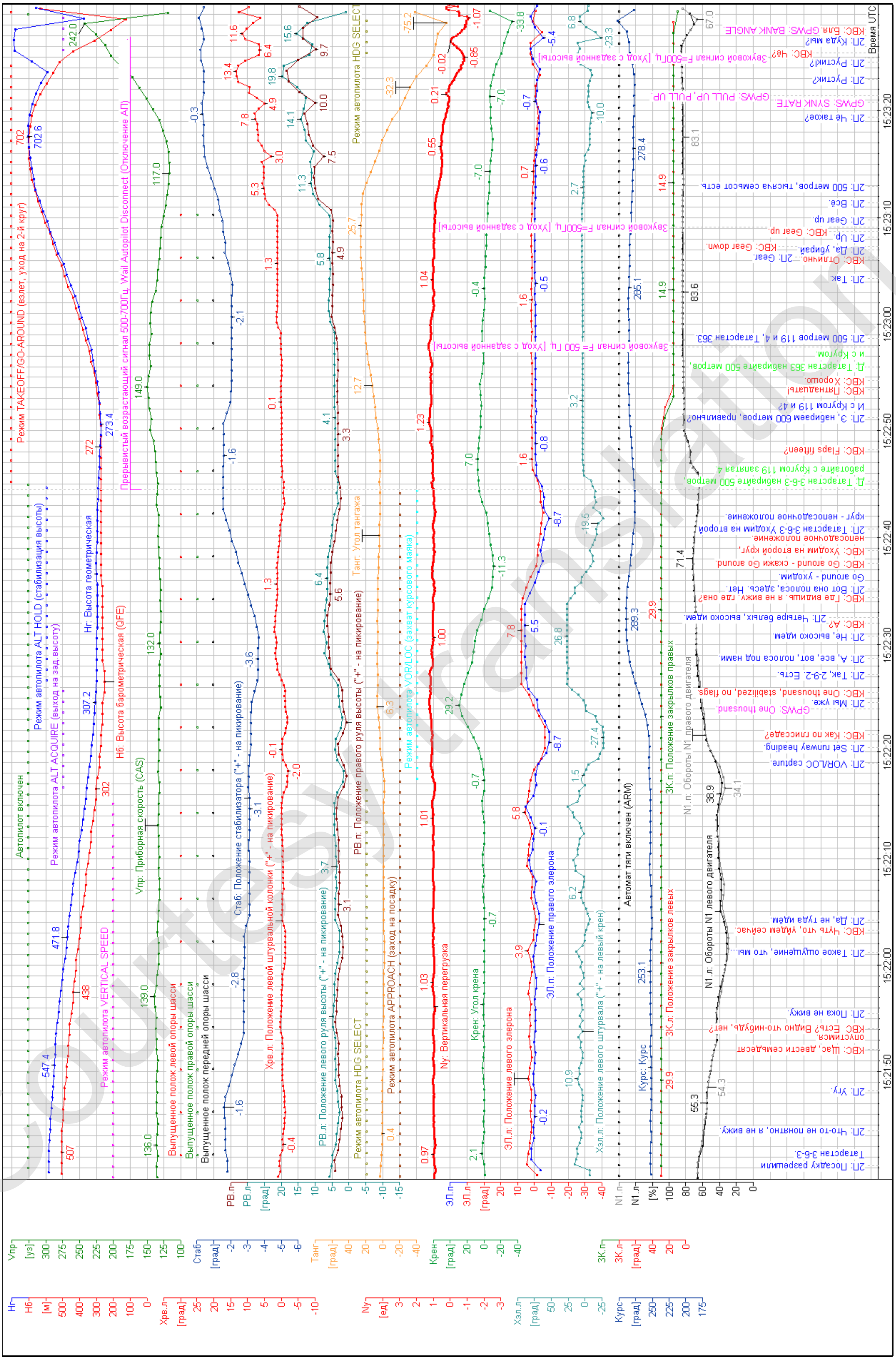


Figure 12 Boeing 737-500 VQ-BBN Flight Data for 17.11.2013 (final segment)

Cockpit Voice Recorder

The aircraft was equipped with an A100S CVR manufactured by L3 (Loral/Fairchild). The CVR housing was recovered from the accident site with severe external damage. The protected memory unit was not present inside (Figure 13).

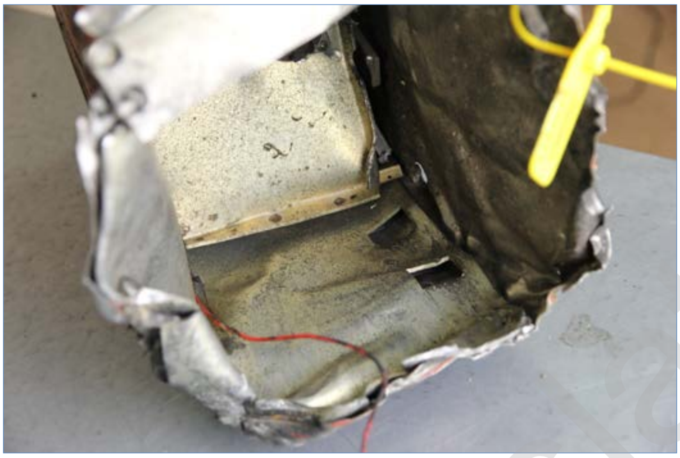


Figure 13 CVR housing without the memory unit

The protected memory unit was found at the accident site later (Figure 14) and provided to the IAC on November 20.

Figure 14 CVR memory unit at the accident site

The CVR elements were examined and the data were read out at AAISTSC laboratory, IAC.

The external examination revealed that the housing of the CVR was severely deformed, the front panel was damaged and had marks of thermal influence. The nameplate with the CVR marking was absent. Therefore it was not possible to identify the CVR part number. The print circuit board on the protected memory unit was destroyed due to thermal damage, the protected memory unit did not show any mechanical damage.

Due to significant damage to the CVR service chassis it was not possible to use it to readout the recorded information, so the memory unit was transferred to another CVR service chassis of the same model. After the memory unit was linked to the service chassis, the L3-Communication readout equipment was used to play and record the whole of the CVR record: 4 channels with a duration of 30 minutes and 16 seconds each.

As the copied information was played, it was established that it was consistent with the last 30 minutes and 16 seconds of the accident flight of the Boeing 737-500 VQ-BBN on 17.11.2013 up to the impact.

After the readout, the cockpit communication transcript was compiled that was used in the course of the investigation. The voice identification was conducted by flight experts of Tatarstan Airlines and instrumentally, by distinguishing among the record channels. The voice identification revealed that there were no persons other than the crew in the cockpit.

ATC information

Within the framework of the investigation a transcript was made of the crew to ATC communication recorded by the ground recorder. The ATC radar data were also analyzed.

Flight Data and Voice Synchronization

The time of the ground recorder was taken as a basis as it is consistent with UTC time. The data were synchronized by way of matching mike switch signals with the relative phrases recorded by the CVR and ground recorder.

Flight Path Calculation

The flight path was calculated based on the L3 (Fairchild) F1000 FDR data and ATC radar data. The results are shown in Figure 15.

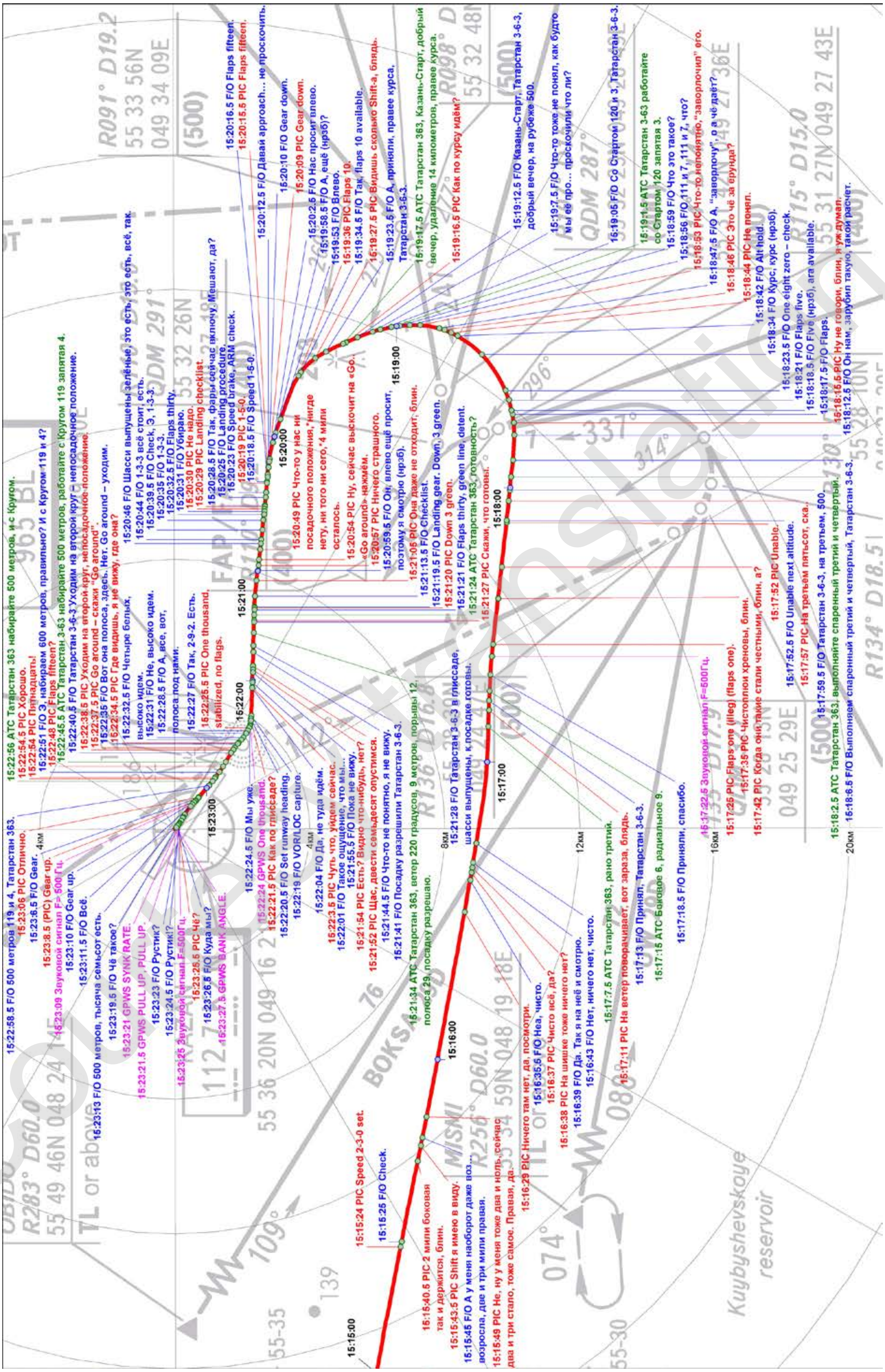


Figure 15 Boeing 737-500 VQ-BBN flight path on 17.11.2013 near Kazan Airport (there is a gap on the STAR pattern from the base turn point to MISMI waypoint, MISMI position is out of scale)

1.12. Wreckage Information

The aircraft was approaching to land with magnetic heading 292 degrees. The accident occurred at the airfield of Kazan International Aerodrome between the runway, main taxiway, Taxiway C and taxiway B (Figures 16 and 17). The airport is located in the plain. The runway threshold elevation is 125 m for heading 292 degrees, and 106 m for heading 112 degrees. The elevation at the accident site is 115 m.

Figure 16 Accident site general view from opposite to the flight direction

Figure 17 Accident site general view from 90° right of the flight direction

The aircraft impacted the ground between the runway in use (RWY 29) and the main taxiway at point 5 (Figure 18) (N55°36.5291’ and E49°16.6111’). The wreckage spread area was insignificant and is marked with points 1-2-3-4 (Figure 18). The perimeter distance between the points was:

1-2 –120 meters;

2-3 –160 meters;

3-4 –220 meters;

4-1 –140 meters;

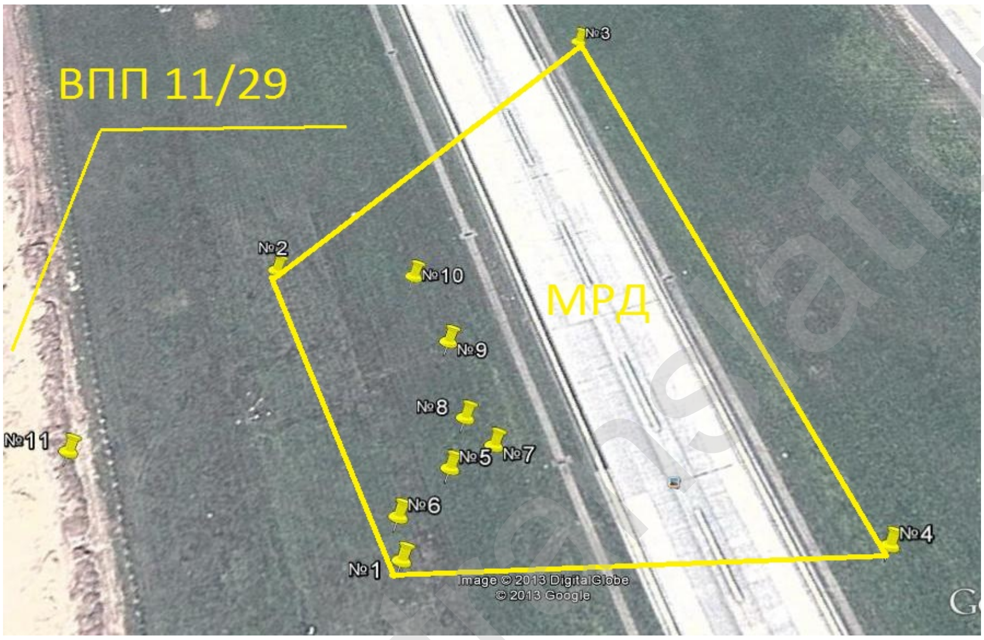


Figure 18 Wreckage plot

The largest structural fragments are marked with points 5 through 11.

The accident site examination revealed that the aircraft impacted the ground with a large nose down pitch angle. This is determined by the nature of the crater (Figure 18), as well as engine position being almost vertical in the ground.

The presence of typical small fragments in the wreckage spread area proves that the ground collision occurred with a large speed (significant energy) and this the most probably caused the fuel tank rupture at the time of the impact, the fuel fire when the released fuel dropped on hot engine parts, and the ground fire.

Figure 19 Impact crater

The investigation revealed that the right engine was closer to the crater, which makes it possible to assume that the left wing was sooner to impact the ground. This is confirmed by the fact that the right wing had less severe damage than the left one.

After the impact the fuselage was destroyed with the tail cone detached (Figure 20), the latter being found 20 m ahead of the impact point in the direction where the aircraft was heading (point 8, Figure 18).

Figure 20 Tail cone fragment

Forty meters ahead of the tail cone fragment in the flight direction (point 9, Figure 18) a rudder fragment was found (Figure 21).

Figure 21 Rudder fragment

At distance of 120 m from the first impact point and 25 m from the right edge of RWY 29 (runway in use) (point 11, Figure 18) a red fire extinguisher bottle was found (Figure 22). This fragment was the closest one to the runway.

Figure 22 Fire extinguisher bottle

The runway examination made immediately after the accident revealed no aircraft marks or fragments on the runway and beyond the fragment spread area (Figure 18). Thus, there were no signs of uncontained inflight damage.

1.13. Medical Information

Since 1992 the PIC had passed medical certification at the medical certification board of Kazan Aviation Enterprise Medical Unit. He passed the last certification on 29.03.2013. According to Article 38.2, 52 graph II of FAR MA CA the PIC was certified as fit for flights as a pilot. Within the last year he had neither been on sick leave or suspended from flights due to health.

The PIC died as a result of the accident. The forensic medical examination results were as follows: “Having studied the conclusion of the forensic biological expertise of tissues (DNA analysis) № 95 as well as conclusions №№ 31, 86, 109, 195, 201, 293, 350, 543, 664, 688, 730, 733, 734, 756, 778 the forensic medical board has come to a conclusion: …the PIC died due to a combined trauma with multiple severe body fragmentation as a result of the impact followed with the explosion and fire. …The forensic chemical expertise of tissues (Conclusion № 730 of 22.11.13 based on Conclusion № 5989 of 21.11.13) revealed no ethanol or other aliphatic alcohol. No narcotic substances or strong medicines were found”.

The FO had also passed medical certification at the medical certification board of Kazan Aviation Enterprise Medical Unit. He passed the last certification on 11.10.2013. According to Article 38.2, 52 graph II of FAR MA CA the FO was also certified as fit for flights as a pilot.

The FO died as a result of the accident. The forensic medical examination results were as follows: “Having studied the conclusion of the forensic biological expertise of tissues (DNA analysis) № 98 as well as conclusions №№ 98, 233, 369, 378, 541, 598, 617, 646, 651, 738, 739, 740, 741, 742, 748, 755, 758, 759, 766, 794, the forensic medical board has come to a conclusion: …the PIC died due to a combined trauma with multiple severe body fragmentation as a result of the impact followed with the explosion and fire”. The forensic chemical expertise of FO’s tissues (Conclusion №№ 759/E 10-184(3)-607, 766/E 10-147-629, 738/E 10-172 №2-631, 646/Ж11-11-852, 742/E 10-176-625) revealed no narcotic substances, strong medicines or ethanol”.

1.14. Survival Aspects

There were 44 passengers, 2 pilots and 4 cabin attendants on board the aircraft. At the time of the impact the indicated airspeed was approx. 450 km with a nose down pitch angle of approx. 75 degrees. The impact resulted in total hull loss and ground fire. It was virtually impossible to survive in the accident.

1.15. Search and Rescue. Fire

The accident occurred at 15:24. The Emergency Alarm was declared at 15:25. The cooperating organizations were notified at 15:28. Since 15:26 the aircraft was closed, 19 flights were delayed, 3 requested to proceed to alternate airdromes.

The firefighting operations were initiated at 15:26. By the time the search and rescue brigade arrived at the accident site, the conditions were as follows: the fire was extended to an area of 150 x 200 m^2, having 2 main cells and multiple smaller ones. The fire was localized at 16:04. It was completely extinguished at 01:00 on 18.11.2013. The long-term duration of the firefighting resulted from the fact that there was a fire cell inside the impact crater that contained a significant number of fuel and aircraft fragments.

Resources applied:

- Search and rescue brigade – 18 persons, 5 fire vehicles, search and rescue supervisor’s car, search and rescue vehicle.
- Medical station brigade – 4 persons, medical vehicle, medical aid kid;
- Transportation service brigade– 39 persons, passenger bus, a truck and mobile stairway;
- Line police division brigade – 29 persons;
- Airport security service – 5 persons, an UAZ jeep;
- Special transport service 30 persons;
- Maintenance base – 17 persons, a tow tractor, a maintenance kit;
- Aerodrome service – 13 persons, 2 UAZ jeeps;
- Cooperating organizations – 350 persons, 18 machines.

No deficiencies were revealed in the conduct of the search and rescue activities that could have affected the survivability of the passengers or crew.

1.16. Tests and Research

1.16.1. Engineering Simulation

An engineering simulation and a kinematic consistency analysis on the FDR data were performed in order to establish consistency of the aircraft stability and controllability with the type design parameters and also to assess the values of probable external disturbances.

The simulation was done on the segment of the accident flight from middle marker passing to impact. The simulation used a six degree-of-freedom non-linear Boeing 737-500 model that has been updated to match flight test data.

According to the available documents the planned landing weight was approximately 42 000 kg with the center of gravity of 20.97 percent. The adjustment of the simulation match determined that the stabilizer angle most consistent with FDR data was achieved with a simulated MAC of 19.23 percent. The above value was used for further simulations.

The high lift devices, stabilizer and landing gear position as well as wind and OAT data were taken from the FDR data and other investigation materials. The throttle lever angle was adjusted to match the recorded engine N1.

A mathematical pilot model was used for the column, wheel, and rudder inputs to match pitch attitude, bank angle, and heading, respectively with reasonable degree of accuracy.

The simulation results are shown at Figures 23 and 24[13].

[13] In this section the negative control column values correspond to nose down pitch.

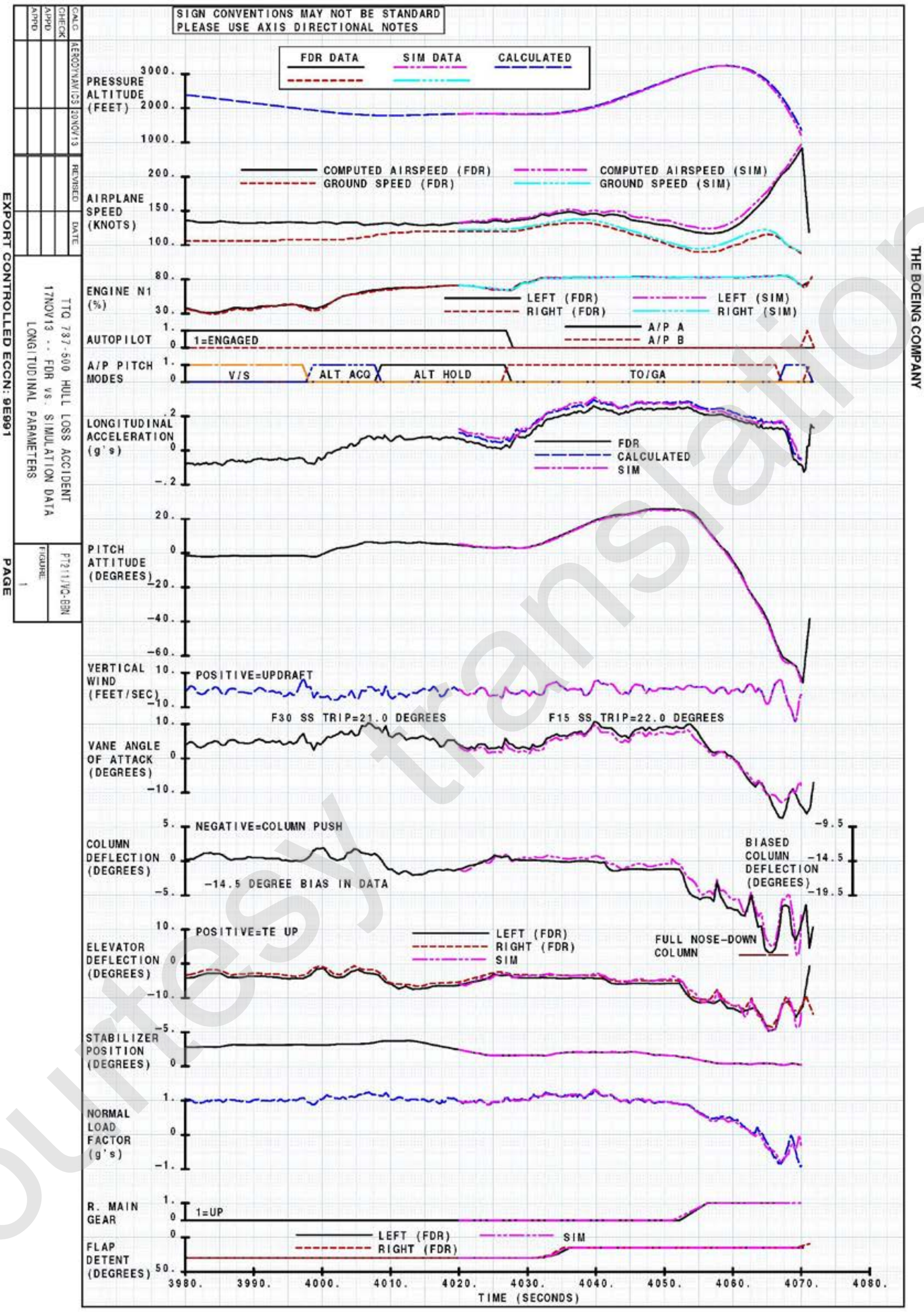


Figure 23 Simulation data (longitudinal parameters)

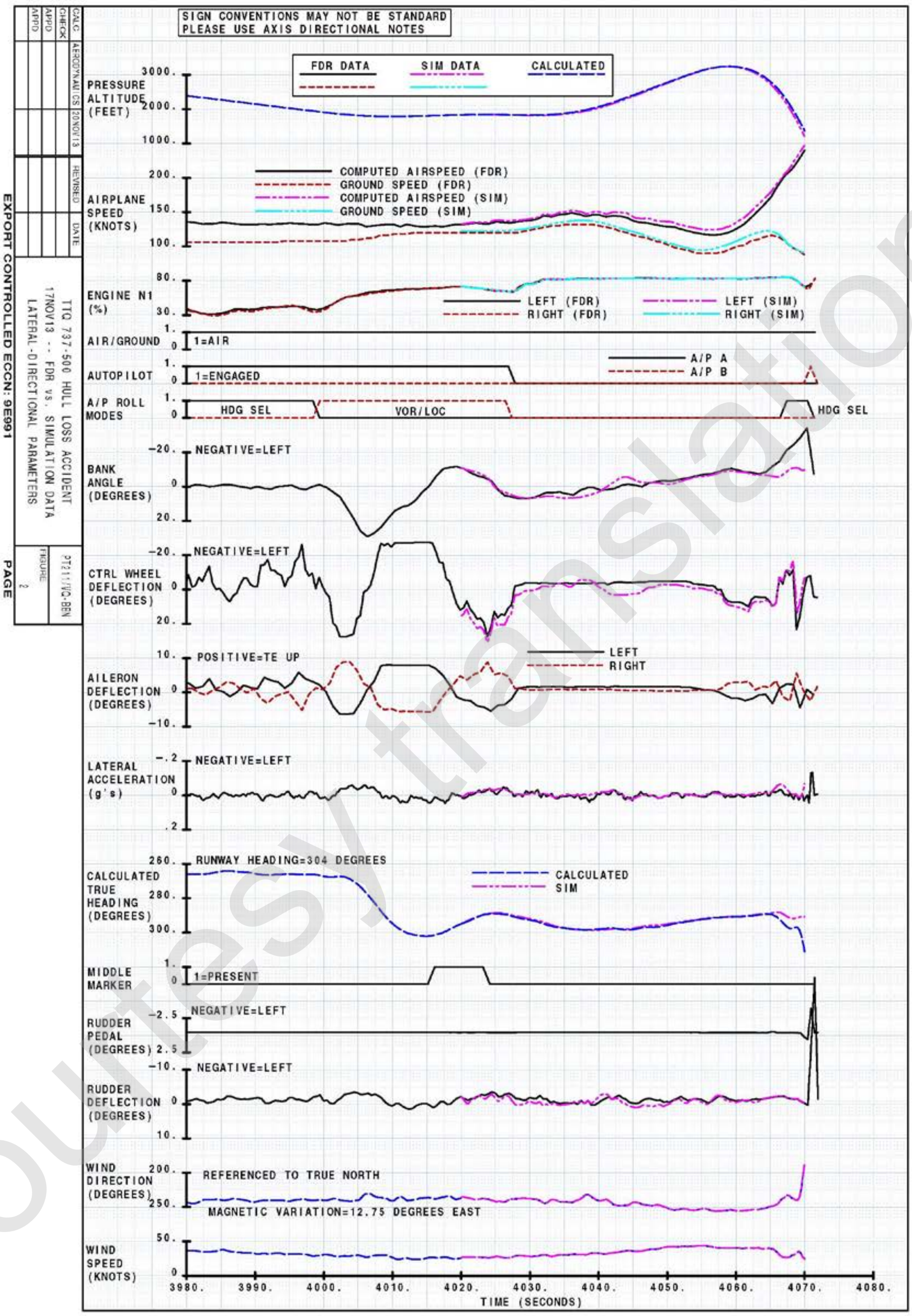


Figure 24 Simulation data (lateral-directional parameters)

The analysis of the simulation match results shows that before the aircraft reached significant negative angle of attack values (about 5 to 7 seconds before the impact) the calculated data were well consistent with the FDR records for the flight controls (column, wheel and pedal deflections) as well as for the control surfaces (aileron, elevator and rudder deflections) respectively. Thus it can be concluded that during the final flight segment the aircraft movement corresponds to registered control inputs, actual engines power and actual wind profile. The stability and controllability parameters were well consistent with the type design. No additional external forces (windshear, icing) were affecting the aircraft. The flight control system including the elevator was operating as per design. During the emergency situation development the angle of attack values exceeding the threshold level for stick shaker activation were not achieved.

Note: *Simulated control wheel position necessary to create registered bank angle values began deviating from the recorded values starting at 5 to 7 seconds before the impact. This difference is caused by the fact that the negative values of angle of attack experienced by the accident airplane exceeded the angle of attack range of the simulation lateral/directional aerodynamic coefficient data tables.*

An additional chart was created to correlate elevator deflections to the column inputs (Figure 25). The same Figure contains data calculated as a result of the simulation. The Figure shows that both the values and curve slope are well consistent, which confirms the normal operation of the flight control system without any extra resistance, that means without any jamming or seizure (no extra column forces that would have led to linkage extension resulting in inconsistence of the calculated and recorded elevator deflections at the same wheel position, see also 1.18.7).

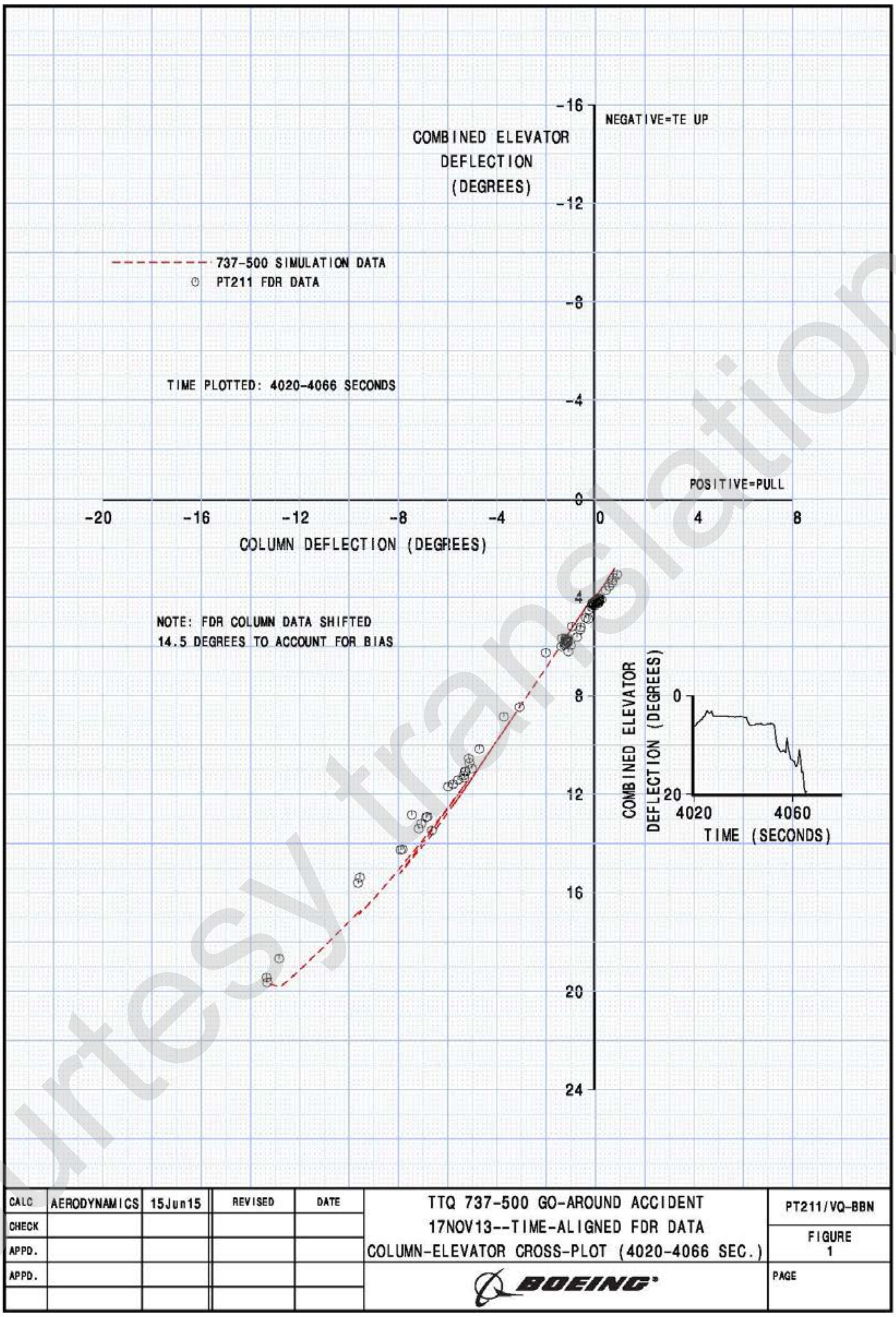


Figure 25 Column-Elevator cross-plot

The simulation enabled calculating the column forces (Figure 26).

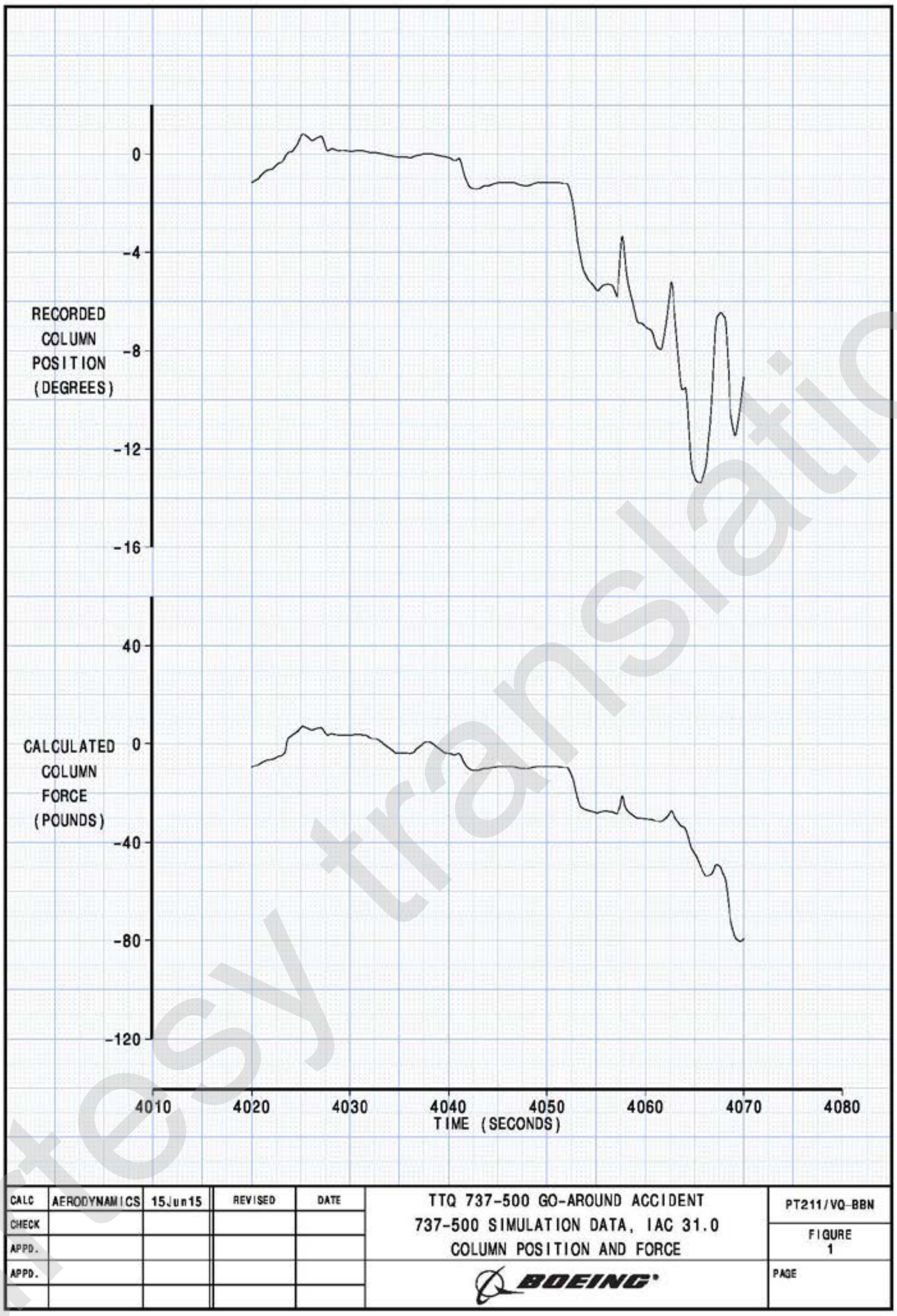


Figure 26 Column position and force

The EADI pitch FD bar position during the go-around was also simulated (Figure 27). The “null” value corresponds to the situation when the pitch bar is at the aircraft symbol position.

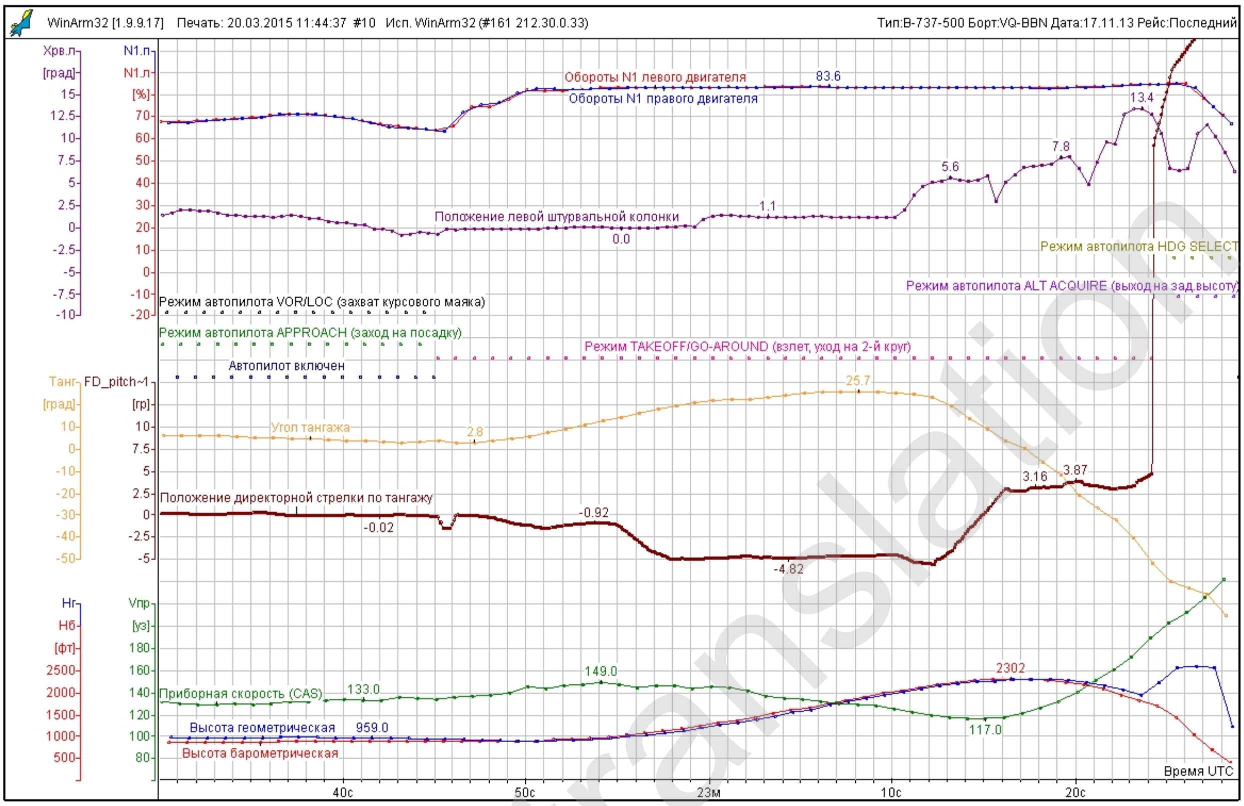


Figure 27 EADI FD pitch bar position simulation

1.16.2. Results of Speed Trim System Validation

The Speed Trim System is installed for better speed stability which is achieved by automatic (no pilot input) stabilizer deflection. The STS functions in manual flight mode (autopilot disengaged) only and provided the following conditions are met:

- middle or aft CG;
- engine N1 above 60 percent;
- low airspeed (Mach number below 0.6);
- angle of attack below the stick shaker threshold level;
- column (when deflected in the direction opposite to the expected stabilizer motion) is deflected from neutral position for less than the predefined (threshold) value.

The system is armed 10 seconds after the liftoff or 5 seconds after a pilot presses the manual stabilizer trim button or at autopilot disengagement. The system deflects the stabilizer to a certain pitch up value when the airspeed increases and to a nose down value when it decreases. The deflection value is determined on the basis of predetermined table values stored in the system memory (Figure 28) as well as aircraft vertical speed (additional damping of long-period process).

As the climb vertical speed increases the stabilizer goes to nose down, going nose up as the vertical speed decreases.

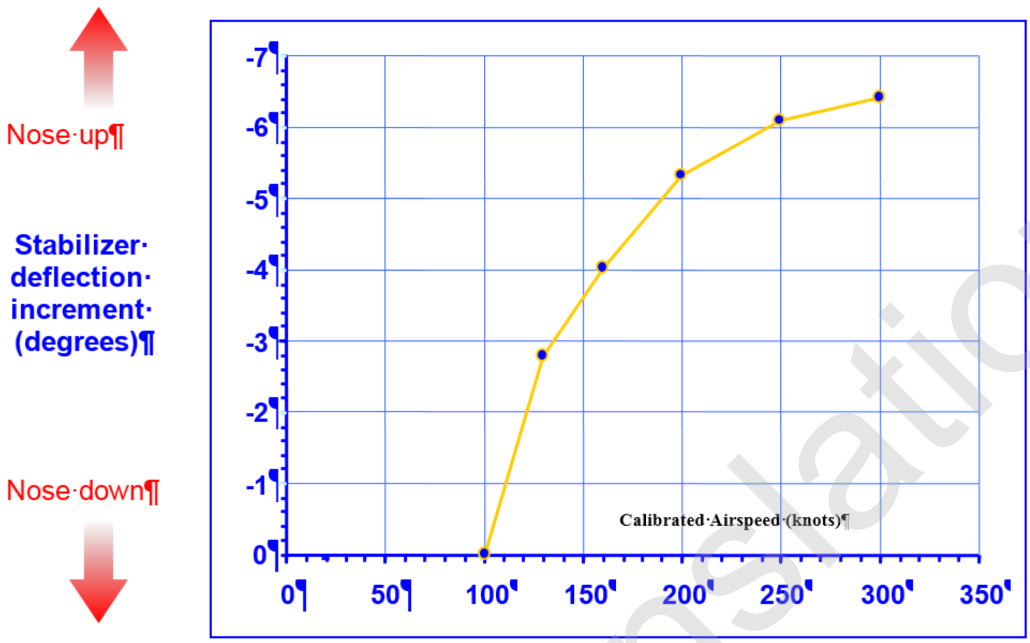


Figure 28 STS stabilizer deflection

Depending on the flap position the coefficient determining the vertical speed influence is:

- 0.011 degree stabilizer deflection/(feet/second) with flaps retracted;
- 0.022 degree stabilizer deflection/(feet/second) with flaps extended.

No additional stabilizer deflection depending on the vertical speed is made with the activated TO/GA mode.

The STS function after autopilot disengagement was assessed using the mentioned algorithms. The STS was initialized at 15:22:45 as the autopilot was disengaged at 136 knots with the stabilizer at minus 1.6° As the TO/GA mode was activated right after that, there was no stabilizer deflection increment caused by the changing vertical speed, thus the actual extra stabilizer deflection was to be determined in accordance with the chart on Figure 28.

Figures 29 to 31 show the three specific segments of the final flight stage. In the first segment (Figure 29) as the airspeed increased from 136 knots to 148 knots the stabilizer made an increment 0.5° nose up deflection, which corresponds to the value determined by the chart on Figure 28. In the second segment (Figure 30) as the airspeed decreased from 145 knots to 118 knots the stabilizer made an increment 1.7° nose down deflection, which also corresponds to the value determined by the chart on Figure 28. In the third segment (Figure 31) despite the extensive airspeed increase the stabilizer did not deflect nose up as the crew deflected the column nose down to a value exceeding the threshold value, which deactivated the STS as per design.

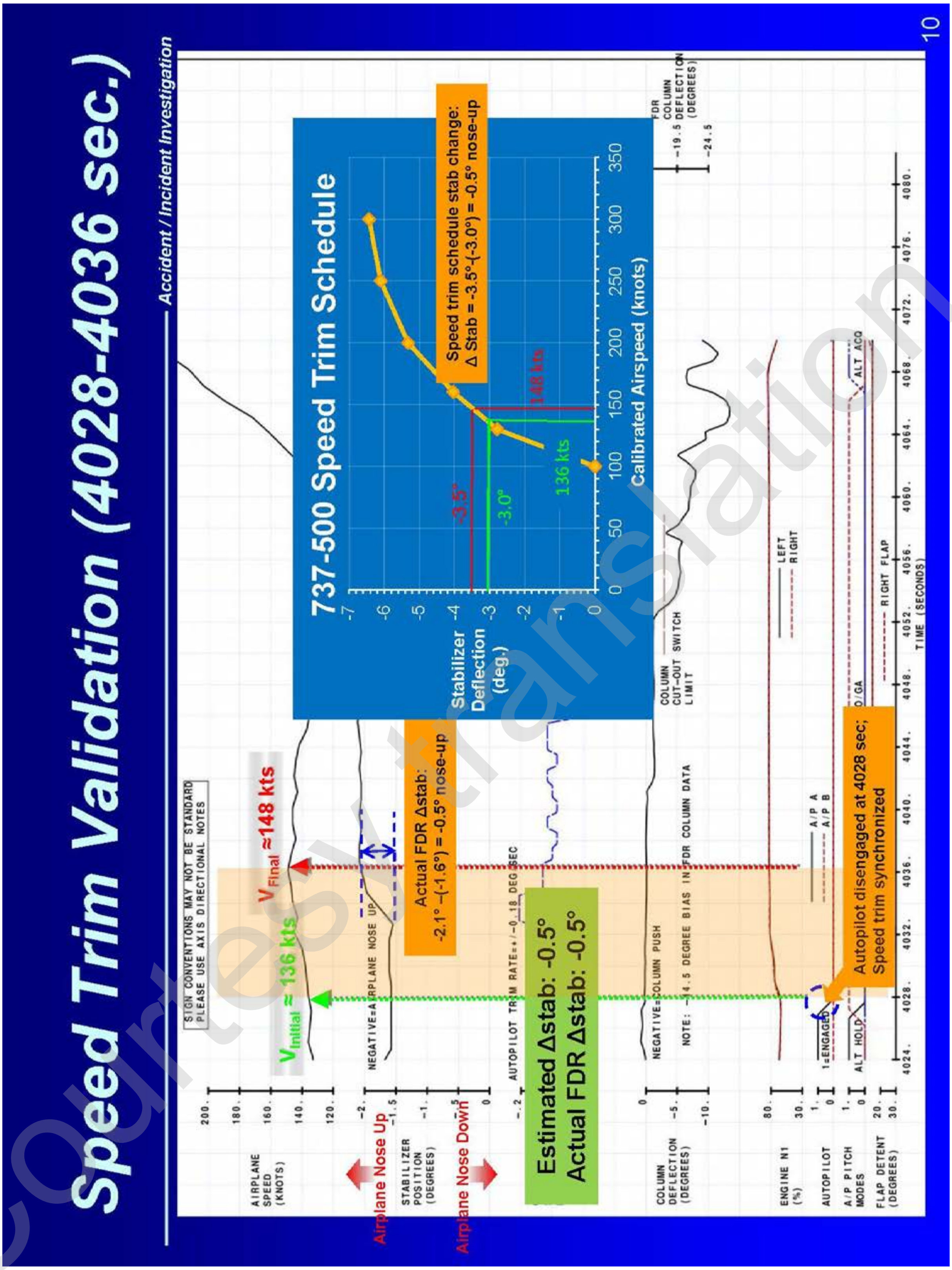


Figure 29 STS validation (15:22:46 – 15:22:44)

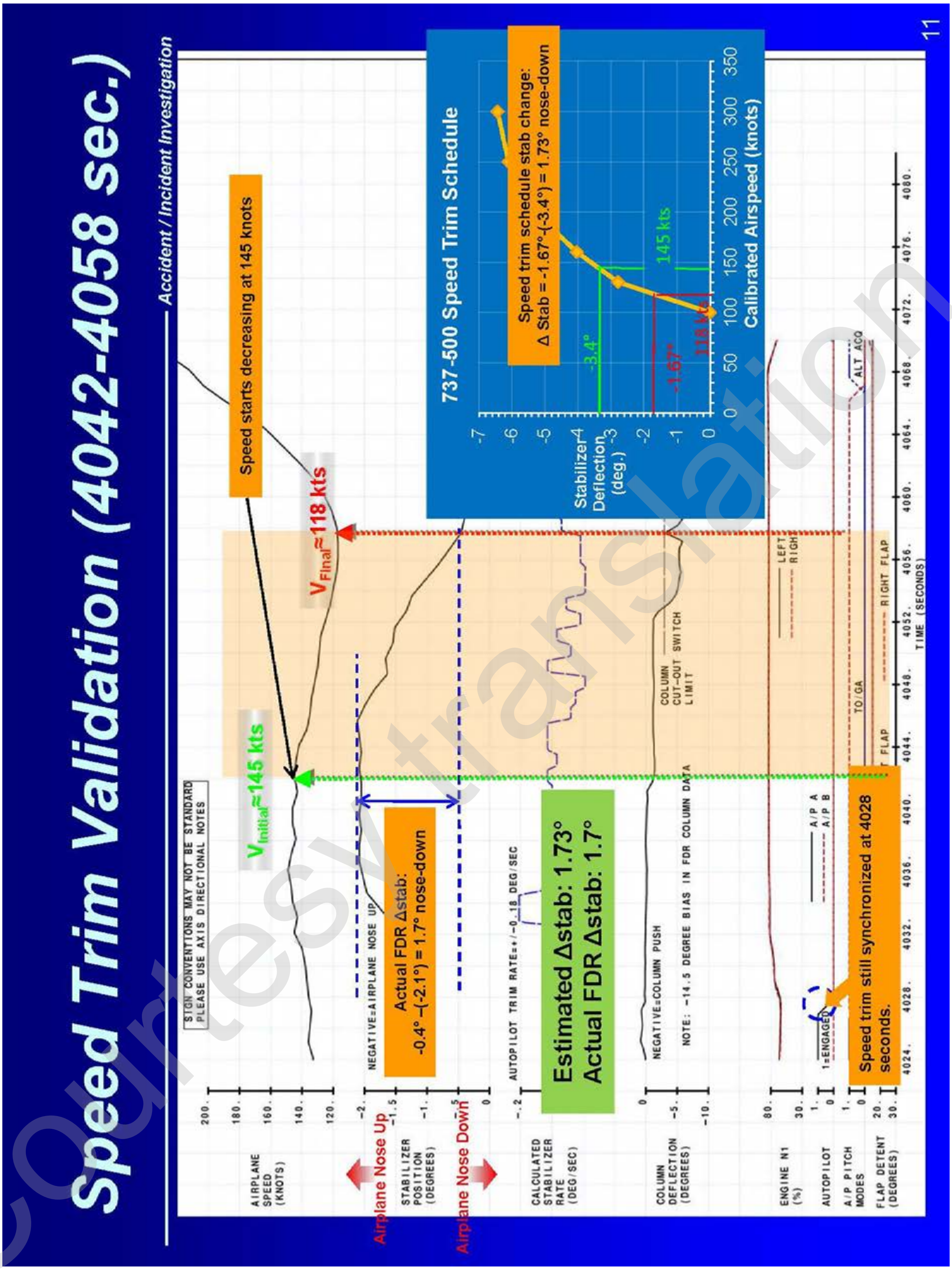


Figure 30 STS validation (15:23:00 – 15:23:16)

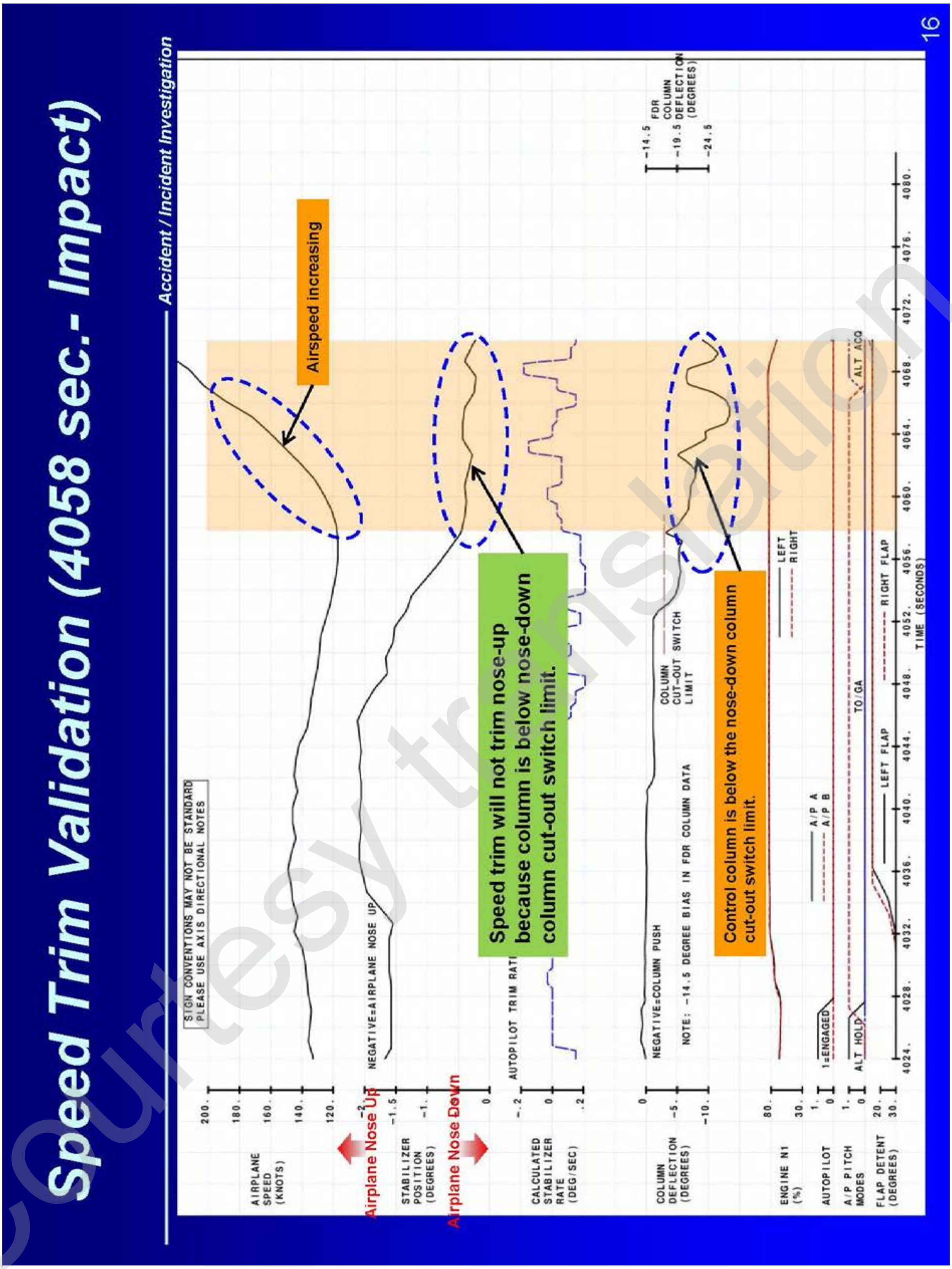


Figure 31 STS validation (15:23:16 – end of record)

Thus, the Speed Trim System was operating normally in the accident flight.

1.16.3. Sensorial Modelling Results

BEA Modelling

Upon request by the investigation team the BEA performed sensorial modelling to estimate the possibility of the crew experiencing spatial disorientation as to pitch and/or bank angle. The model developed by the BEA was used that is based on a number of characteristics of the human vestibular organs[14]. This model uses the parameters recorded by the FDR to calculate an estimate of the pitch and bank angles as well as rotation rates perceived by the pilot and estimate the possibility of somatogravic illusions that can be created by the vestibular system during accelerating, pitching or turning maneuvers when the pilot does not monitor flight instruments, especially the ADI (Attitude Directional Indicator) flying in instrumental weather conditions when there is no outside visual reference.

The applied model has a number of limitations. The modelling results require verification when the actual pitch is greater than 25 degrees or lower than -15 degrees and could not be used when the normal acceleration is lower than 0 G (negative load factor). The abovementioned conditions are applicable to the 9 last seconds of the flight (Figure 32, see the red area)[15].

[14]The model does not take into account the probable pilot's head movements as there is no evidence of that.
[15] On this figure as well as the following one the negative values for column inputs correspond to nose down pitching.

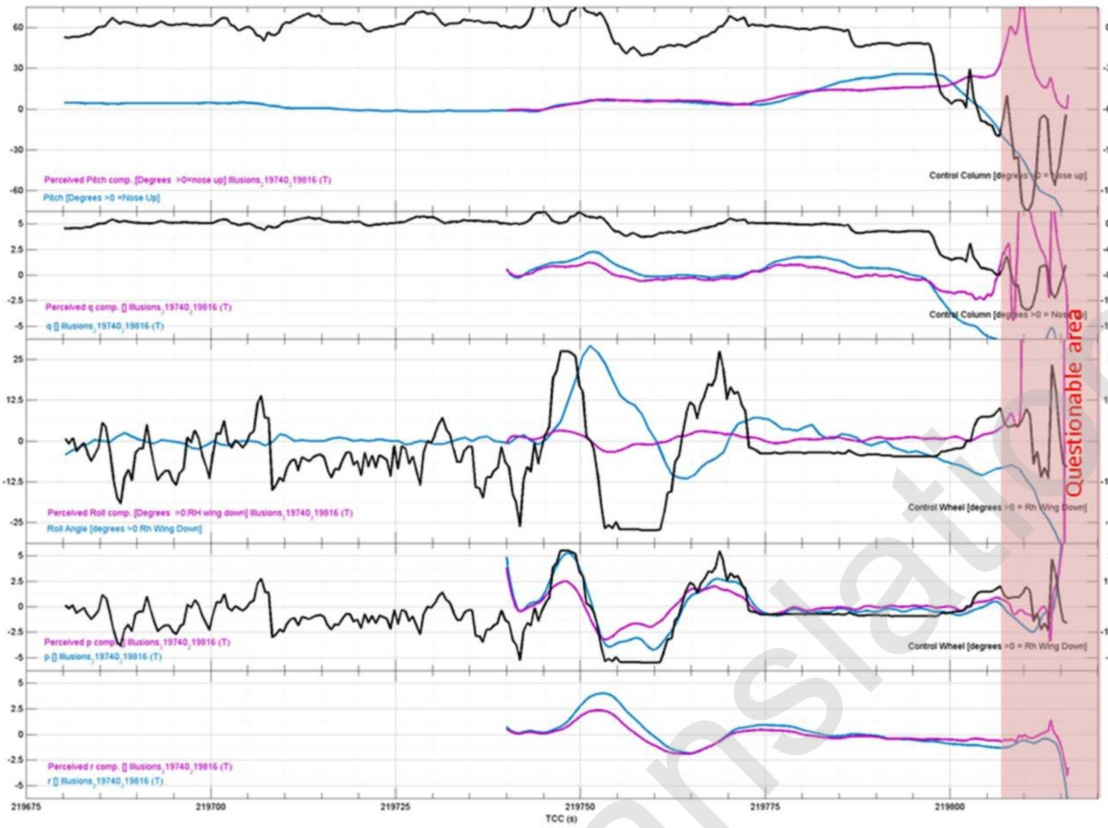


Figure 32 BEA Sensorial Modelling Results

The pitch component parameters are plotted in Figure 33. Four zones are designated.

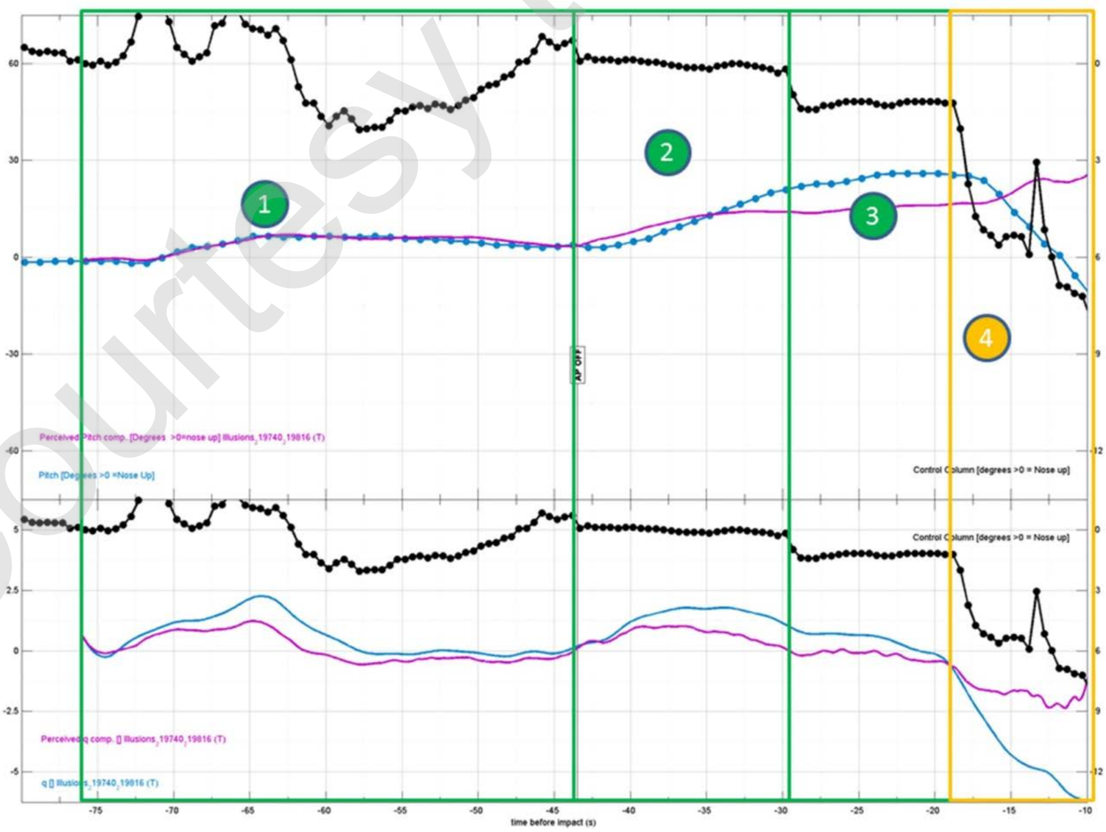


Figure 33 BEA Sensorial Modelling Results (cont.)

In zone 1 the actual and perceived pitch angles were quite similar. The autopilot was engaged during this segment.

In zone 2 the actual pitch angle quickly increased up to 20° nose up. The perceived pitch angle had quite the same rate (even a bit quicker) at the beginning and then tended to stabilize at a level of around 14°.

In zone 3 the actual pitch angle continued increasing gradually up to 25° while perceived pitch angle increased up to 17°. During this phase, the first slight nose down pitch input was recorded (around 1° for the control column angle).

At the beginning of zone 4 the decreasing actual pitch angle was recorded due to nose down column inputs. During that period, the perceived pitch angle continued to increase to reach 25°. At the end of that period, having the actual nose down pitch rate, the recorded control column inputs underlined an even more important request to pitch nose down, while the actual pitch went below zero degrees as well.

Thus, zone 4 gives ground for discussions concerning potential spatial disorientation in pitch:

- divergence between the actual and perceived pitch angles;
- divergence between the actual and perceived pitch rates.

A possible spatial disorientation can be confirmed by pilots' nose down inputs while actual pitch angle tended to decrease continuously and below zero degrees whereas perceived pitch angle remained up to 25° nose up.

No spatial disorientation was revealed in roll.

AAIB UK Modelling

The AAIB UK also assessed the probability of somatogravic illusions effect on the pilots during the go-around. During the research they used a method successfully applied during some other investigations. Based on the calculations a chart was built (Figure 34) that shows the probable effect of the illusions.

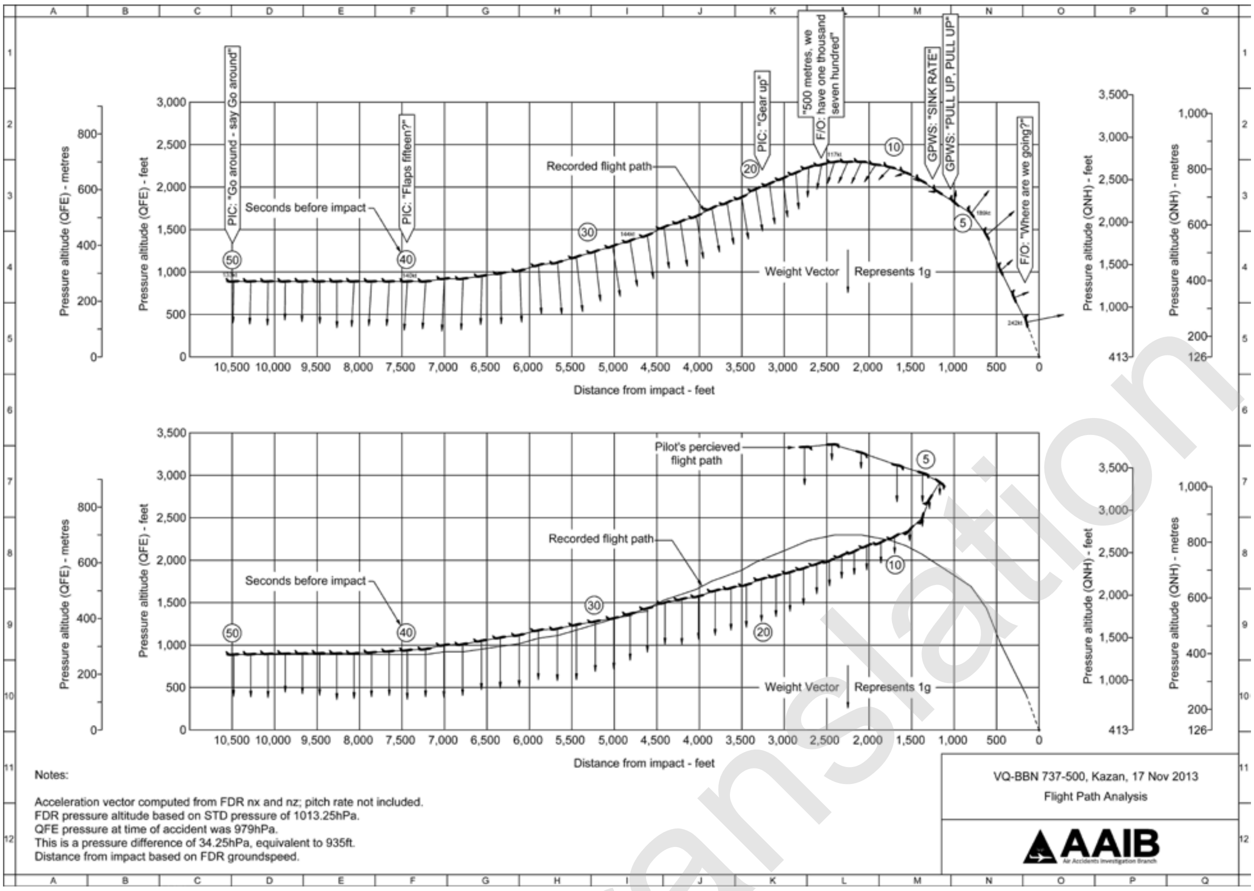


Figure 34 AAIB UK Sensorial Modelling Results

The modelling led to a conclusion that provided the pilots did not monitor the flight instruments in due manner they could have experienced the so-called “inversion” illusion during a change from climb to descent and during descent, which could have forced the PIC to apply nose down pitch control to correct the perceived pitch angle increase (sensed “looping” flight path).

1.16.4. Flight assessment results

In the course of the investigation a flight operations working group was formed to assess the accident flight circumstances and crew actions. The group members included an honored test pilot of the Russian Federation test pilot of Gromov Flight Research Institute, a test pilot of Tupolev Design Bureau, deputy flight squad commander chief pilot-instructor from UTair, head of flight certification department of Aeroflot, a pilot-instructor from training center of Transaero airlines.

The materials of the mentioned assessment are widely used in the Analysis section of the present Report. The Analysis section also reflects the opinion of the working group concerning the upset recovery issue in general as well as Boeing 737-500 QRH content in particular. The present section reflects the basic conclusions of the assessment.

The working group concluded that the Tatarstan Airlines Boeing 737-500 VQ-BBN accident is related to the aircraft upset as it was carrying out a go-around from a relatively great height (900 feet/270 meters). Due to the lack of control inputs the aircraft initial upset started nose up and then as a result of the PIC’s erroneous control inputs the upset position was reverted to nose down. Taking into consideration the quickly changing situation as well as the PIC’s lack of pertinent skills and his actual level of training and qualification, he was not able to apply the required upset recovery techniques. The attempts to recover resulted in abrupt nose down pitch and impact.

The combination of the following factors could have contributed to the aircraft upset during the go-around and the crew failure to recover:

- PIC lacking situational awareness skills that should have been received, first and foremost, during initial (basic) training and further developed in the course of line operations and training sessions. Lack of attention allocation skills and ability to distinguish the most important issue, lack of prompt analysis of flight parameters and insufficient manual flight skills;

- insufficient crew qualification (professional training) including go-around techniques and the PIC having no go-around experience or skills (as a PIC) in line Boeing 737 operations, which resulted in time deficiency and increased stress level of the crew, especially the PIC, which further turned into distress and stupor;

- PIC lacking upset recognition and upset recovery skills;

- non-compliance with SOP and lack of pitch attitude monitoring, as well as delayed setting of go-around altitude;

- long-term distraction of the FO by the air-to-ground communication, violation of the "Aviate – Navigate – Communicate" concept;

- crew formed of two “weak” (unexperienced) pilots, converted from flight engineers or navigators, without due consideration of their actual qualification level and low flying experience as pilots.

Listed below are the factors that caused significant deviations from the approach pattern, missed approach and the necessity to go-around:

– a significant inaccuracy of the FMC in determining the aircraft position (map shift) and lack of position update based on ground navigation aids signals;

– pilots not using (despite the map shift awareness) complex piloting techniques utilizing other radio navigation aids (VOR/DME, NDB) for precise navigation. No request for vectoring to set the aircraft to the landing track;

– the ATC officer not offering vectoring to establish the aircraft on the landing course though they were tracking the aircraft position and cleared the crew to turn for landing course and land despite considerable deviations from the approach pattern.

1.16.5. FFS experiment result

The experiment was carried out from December 01, 2014 to December 11, 2014 on a B737-300 FFS located at S7 Training aviation training center.

It was carried out by a test pilot of Gromov Flight Research Institute as well as type rating examiners (TRE) from UTair. A TRI from Transaero training center (type rating instructor) took part in the preparation of the experiment program.

The experiment was participated by 11 pilots flying Boeing 737 from five Russian airlines with various flying experience and qualification (PIC-instructor, PIC, FO) including pilots who converted from navigators or flight engineers.

Before the experiment the adequacy of the FFS was assessed as related to the final stage of the accident flight (stabilized flight at height of approximately 900 feet QFE, go-around with significant nose up pitching, nose down control column inputs and further nose down pitch). In general, the assessment revealed a satisfactory compatibility of the results except that unlike on real aircraft during the final segment of flight (as the speed decreases when the aircraft starts climbing for the go-around) the Speed trim system does not activate on the FFS[16]. Therefore, in order for more accurate simulation of the aircraft motion and control column inputs during the final segment the stabilizer was trimmed manually from the FO’s station by 1.5 degrees nose down incrementally to match the accident flight data.

Before the experiment each pilot was requested to give written answers to a number of questions related to the knowledge of the basic principles and logics of the autopilot, flight director and A/T functioning during a go-around as well as of airline’s SOP provisions in terms of approach and go-around.

Before they started with the actual simulation of the accident flight circumstances, each pilot was given an opportunity to get accustomed to the FFS within 30 to 40 minutes and conduct

[16] This is explained by the difference in STS working algorithms on Boeing 737-300 and Boeing 737-500. At the same time the Boeing Company considers these modifications as one aircraft type.

simulator flights on their discretion from the left pilot seat (to train IFR and VFR takeoffs, approaches and landings).

All approaches were conducted with one A/P on. The height where go-arounds started was 600 to 950 feet (with the go-around altitude of 1700 feet). Increased workload was simulated for the PF:

- the approach and go-around were carried out in clouds without any ground references. The crew had to monitor the aircraft attitude only by flight instruments, which increased psychophysiological stress;
- before the approach the crew was notified on the runway visual range degradation (due to weather) down to or below the minima and (or) on the unstable function of the aerodrome glideslope beacon. The pilots were instructed to carry out landing, they were requested to land below the minima so that the go-around would have been unexpected for them.
- in the course of the go-around the FO's distraction by the radio communication was simulated, that could have led to several PM actions (landing gear and flaps retraction, attitude and flight parameters monitoring) partly underdone or omitted.

The second part of the experiment aimed to evaluate the pilots' upset recovery skills.

Based on the experiment the following conclusions can be drawn with that are expected to be quite trustworthy.

1. Only 7 pilots had executed real life go-around within their flying experience (one to four go-arounds each). Four pilots had never conducted go-arounds in real life. The go-around skills are trained on FFS, the training scenarios basically focus on low go-around (from decision height) and mainly with one engine operative. Go-arounds from an intermittent height had never been trained as per the pilots' words.

2. The absolute majority of the pilots involved in the experiment consider go-around as a difficult element for a line pilot, mainly because of the increased workload and stress, especially if the go-around is conducted on the ATC officer's request. Some of the pilots evaluated this process as distress or close to distress state. It was mostly noticeable during the experiment when the PF did not receive the expected assistance from the PM (FO).

It should be noted that after the TO/GA button is pressed the visual and aural alerts are activated to signal the A/P disengagement. The aural alert has an exceptionally attracting effect. However, not all pilots noticed the alert, a significant number of them (3 pilots) delayed disengaging it by pressing again the A/P disengage button on the control column, while one pilot did not disengage it at all. This is a vivid indication of the go-around being a complex procedure for a significant number of pilots that channels their ability to receive information (span of attention). During some of the go-arounds (conducted by three of the pilots) the visual and aural A/P disengage alert was deactivated on purpose. When the pilots were asked right after the go-around completion if there was an A/P disengage alert the pilots could not give a definite answer.

3. When completing the questionnaire before the FFS flights, some of the pilots experienced difficulties when answering questions related to the autopilot, flight director and A/T functioning logics during the approach and go-around. Four of the pilots «cheated» when answering these questions using documents they had on their personal electronic devices. Despite that, no pilot was able to answer all the seven question concerning the logics of the complex functioning of the aircraft automation system. Besides, after the go-around completion on the FFS 2 pilots stated that the go-around was conducted in automatic mode by the A/P (even when A/P disengagement alert was triggered!). This indicates the insufficient level of basic knowledge as well as a gap between theoretical knowledge and practical skills.

4. The reaction time between the ATC instruction to go-around and the start of go-around (TO/GA pressed) was 2 to 8 seconds, in half the cases the time exceeded 4 seconds. During the debriefing the pilots had different explanations for such a delay: 2 of the pilots explained the long delay saying prompt reaction was unnecessary because of the relatively great go-around height, 3 of them stated the ATC instruction was unexpected and they had to realize the meaning of the instruction and take a decision to go-around.

5. Based on the pilots' initial go-around actions they can be divided into three groups: the first group (8 pilots) applied the TO/GA mode as prescribed by the FCOM; the second group (2 pilots) changed the A/P modes (by pressing the V/S or LEVEL CHANGE buttons) without pressing the TO/GA button; only one pilot pressed the TO/GA button and then switched the A/P to LEVEL CHANGE mode (the latest seems most reasonable in the simulated situation).

6. During the initial go-around phase (as the aircraft started climbing) while maintaining the flight path only 2 pilots used the FD bars. Most of the pilots were piloting at that stage guided by the pitch angle trying to set and maintain it at 15 degrees. They explained that they used this go-around technique as the difference between the cross bar pitch attitude and the aircraft silhouette is small (the cross bar has a low sensitivity), while the climb flight paths when following the FD or maintaining 15 degrees nose up pitch seem similar. For most of the pilots pitch angle and speed are more important at this phase of go-around, therefore "there is no need to try and catch the FD bar".

7. Only a third of all the involved pilots completed a successful go-around. The following mistakes can be considered typical during the go-around:

- lack of PM actions cross-check; the actions that the distracted PM failed to do (like flaps or landing gear retraction) either were performed with a long delay or not performed at all, the PF being at that time distracted from flying the aircraft. In particular, 3 pilots did not retract the landing gear at all, 4 pilots retracted it 20 to 100 seconds after the start of the go-around. It becomes clear that in case of the PM incapacitation the PF is not always ready to cope with the urgency. This is mostly noticeable when the PF was pilot qualified only as FO;
- delayed interference into aircraft control. As a result the pilots took manual control of the aircraft when it reached 20 to 37 degrees nose up pitch and the airspeed fell below V_{LS} (5 of the pilots), being actually upset. Three of the 11 pilots allowed the aircraft to go 25, 27 and 37 degrees nose up and loss of airspeed down to 113 to 108 knots with flaps 15, which is 20 to 25 knots lower than V_{LS} with flaps 30. As the pilots got aware of the upset they applied too much nose down column (the load force was less than 0.5g during the recovery).

  One of the pilots lost control of the aircraft (**twice!**) during the go-around, the maximum pitch angle being 35 degrees and loss of speed down to 90 knots, meaning the aircraft was close to stall (as the stick shaker was triggered at 100 to 103 knots no timely and correct actions were taken to prevent stall);
- weak manual control and attention allocation skills, mainly typical for FOs; This became apparent in terms of the accuracy of establishing and maintaining the go-around altitude of 1700 feet. Only 4 pilots managed to do this. Seven pilots failed to establish the target altitude and maintain it. Six of the pilots had average altitude oscillations (provided the target altitude was 1700 feet) from 2300 to 1400 feet, and one of them had oscillations from 3800 (!) to 1300 feet. It is also worth mentioning that in the course of manual control the PF tried to apply the relative AUTO FLIGHT modes (engage autopilot) as soon as possible, which they not always managed, as it happened with either the column or the wheel was deflected from the neutral position. During that segment there was little or no control over aircraft flight and/or the PM actions.

8. The second part of the experiment, as it was mentioned above, aimed to evaluate the pilots' upset recovery skills. The test pilot simulated nose up or nose down upset and the pilots were asked to recover the aircraft. As a result, none of the pilots managed to recover properly, including experienced instructors. A typical mistake during the upset recovery from

nose-up position was that the pilots applied almost full nose-down column (10 of the 11 pilots responded to the relative question in the questionnaire that the QRH instructs to apply full nose-down elevator). Such actions, in their turn, result in high negative pitch rate and vertical acceleration that is close to zero (Ny=0.5 to 0 g) or in some cases can be negative (Ny=0 to -1.2 g). In real flight conditions such accelerations would have apparently led to temporary or total crew incapacitation and injuries to passengers. At present, this is not taken into consideration during upset recovery training, as modern FFS cannot simulate such acceleration for even a short period of time. Flight data records (in particular, vertical acceleration values) that are available on some simulators are not used to assess the quality of the recovery performance.

A typical mistake during the nose down upset recovery, especially if the aircraft is banked, is using non-optimal recovery procedure without taking into account the combination of the current flight parameters, aircraft configuration and flight height. In most of the cases, speed brakes are not used, the configuration is not changed (flaps are not retracted), which as a rule results in exceeding the airspeed limitations and additional loss of height.

After the right technique was demonstrated, almost all pilots were able to perform it, which confirms it can be practically used in line pilots training.

9. Within the pilots involved in the accident there were 6 pilots that did not have initial flight training (they had either undergone conversion training from navigators or flight engineers into pilots or completed dubious flight schools). Three of these 6 pilots demonstrated rather satisfactory piloting techniques during the experiment, correcting the deviations made, although with a delay. The other three pilots demonstrated significantly worse results, they had obvious difficulties when coping with a more complex situation, assessing it and taking the right decision. Mistakes made by them during the go-around were more serious, one of them even approaching stall. Within the framework of this experiment there was no aim to compare the qualification and skills of the pilots who had initial flight training and those who did not (such an evaluation would require a wider experiment program and much more FFS time), however it is noticeable that the average qualification level of pilots who graduated from flight schools and had initial (basic) flight training is higher.

1.16.6. Elevator PCU Examination Results[17]

Taking into account the accident circumstances and FDR data readout (intense nose down pitching during the final phase of the flight and no nose up inputs) as well as earlier in-service occurrences related to PCU malfunctioning (Section 1.18.7) the investigation team decided to request an examination of the elevator power control units. Figures 35 and 36 below show the PCU as they arrived for the examination.

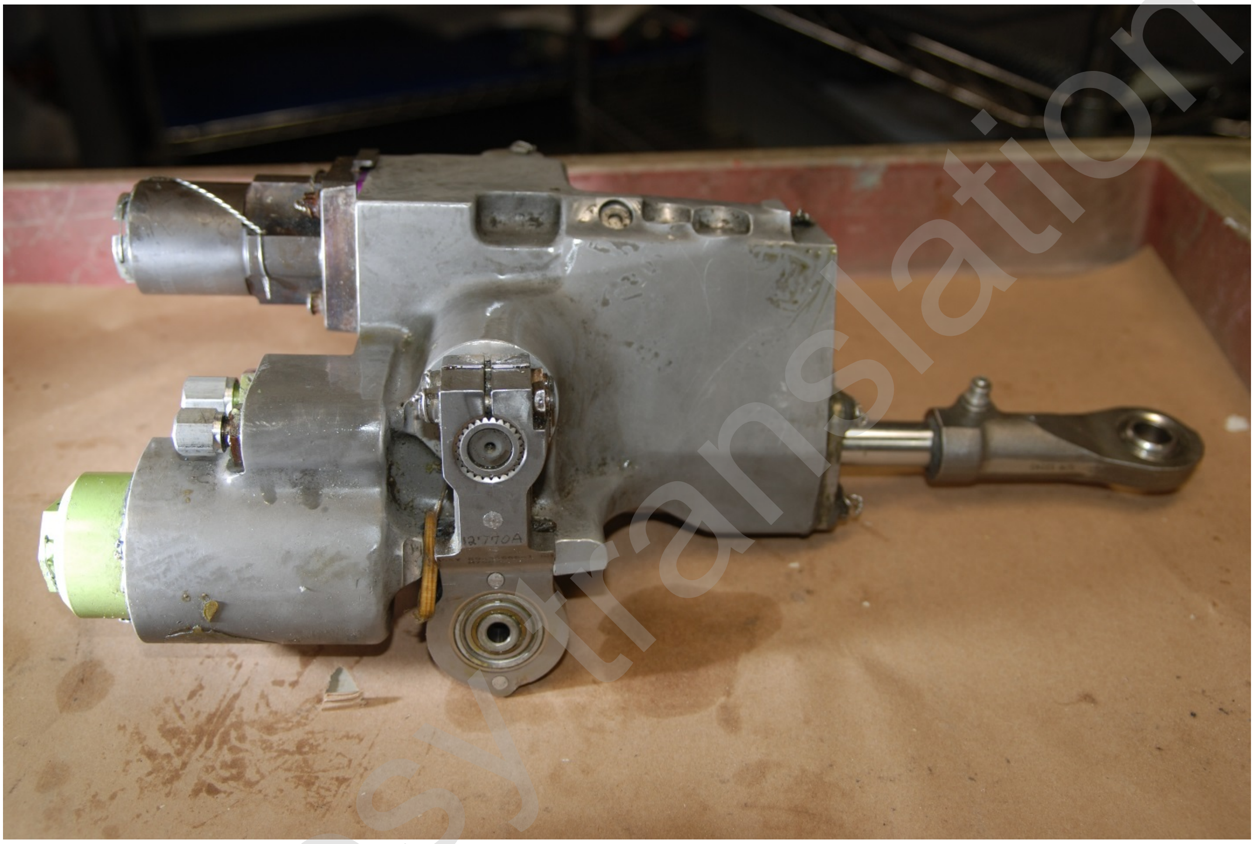


Figure 35 Left hand actuator

[17] The description and operation principles of the PCU is provided in Section 1.6.2.

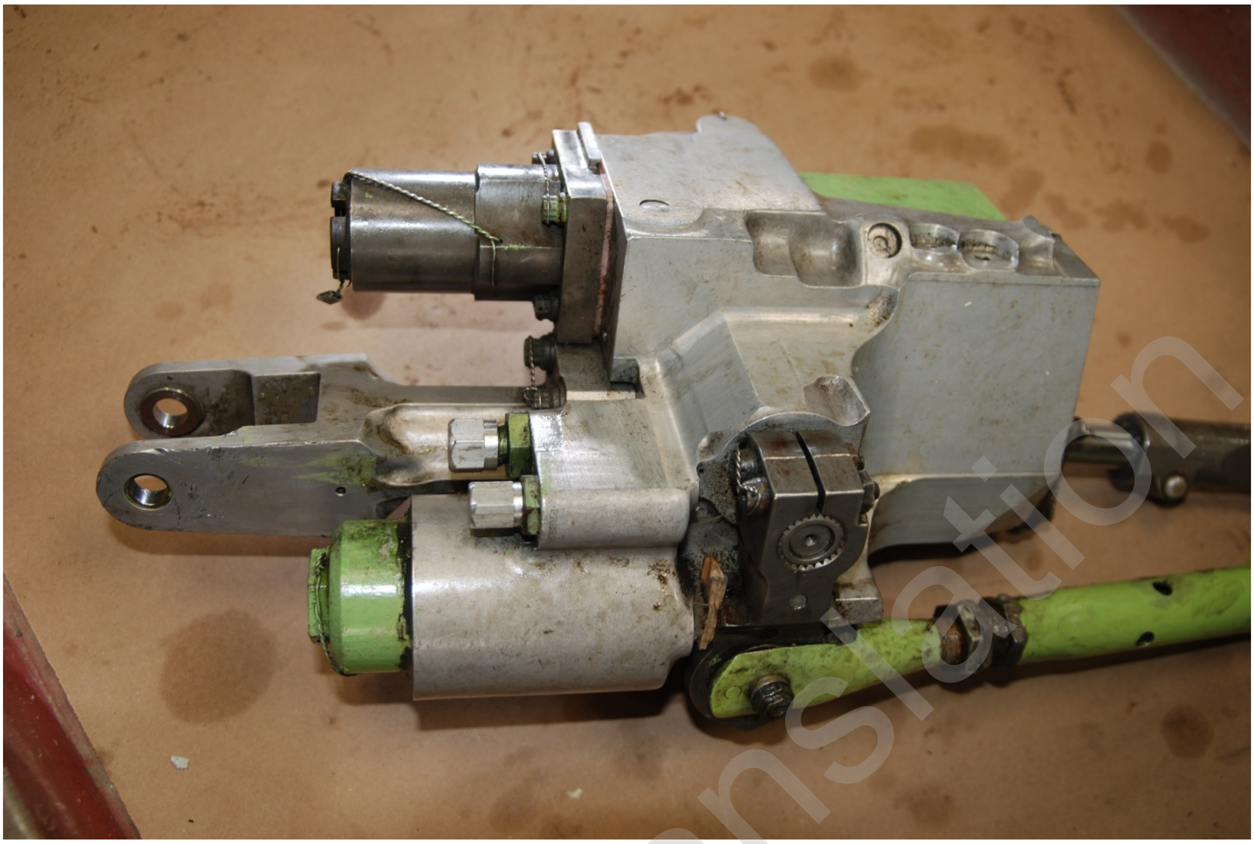


Figure 36 Right hand actuator

PCU Scanning

Before the actuators were disassembled the tomography (scanning) was performed. The purpose of the examination was to evaluate the internal condition of the actuators in terms of damage, deformations or improper geometry, as well as foreign objects inside.

The scanning was conducted at Varian facilities (Chicago, USA). The scanning provided over 700 sections for each PCU with a pixel size of 0.137 x 0.137 mm.

Based on the scanning results NTSB created actuators' 3D images with high resolution (Figures 37-64), and this allowed conducting the analysis of their internal state.

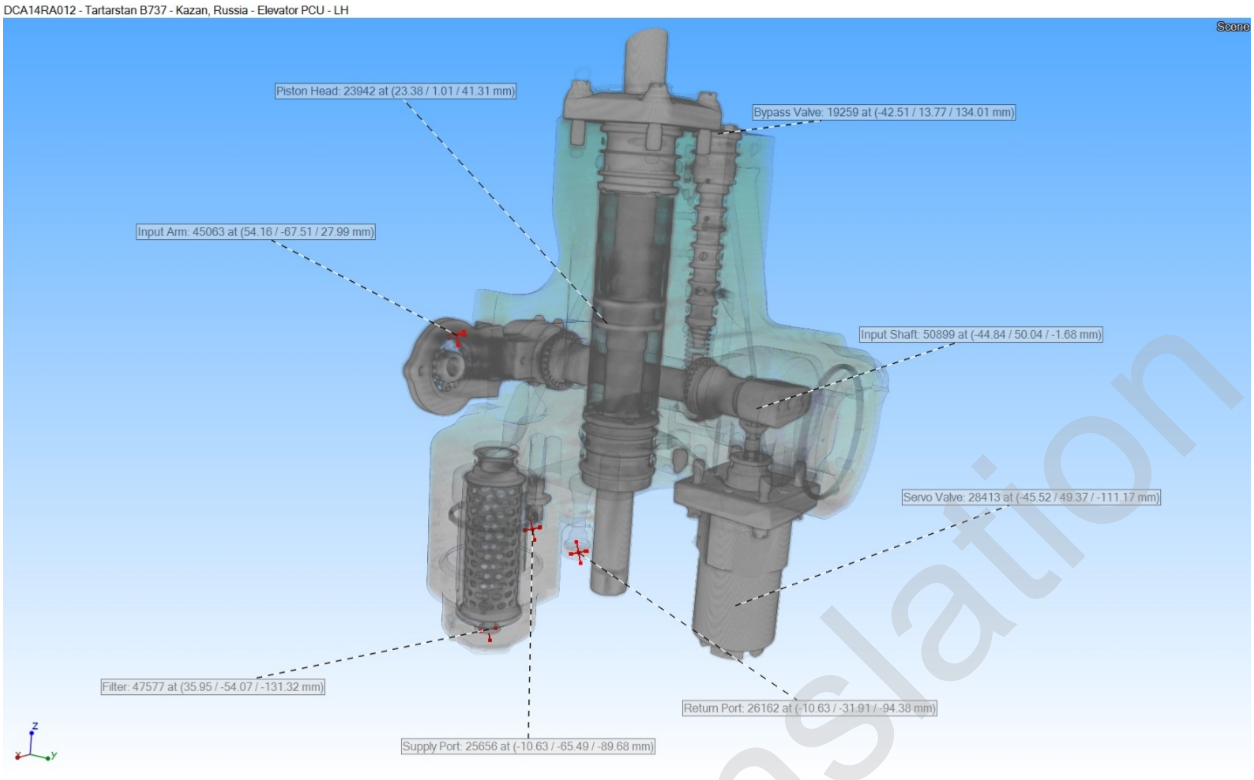


Figure 37 Elevator PCU Left Hand. General view

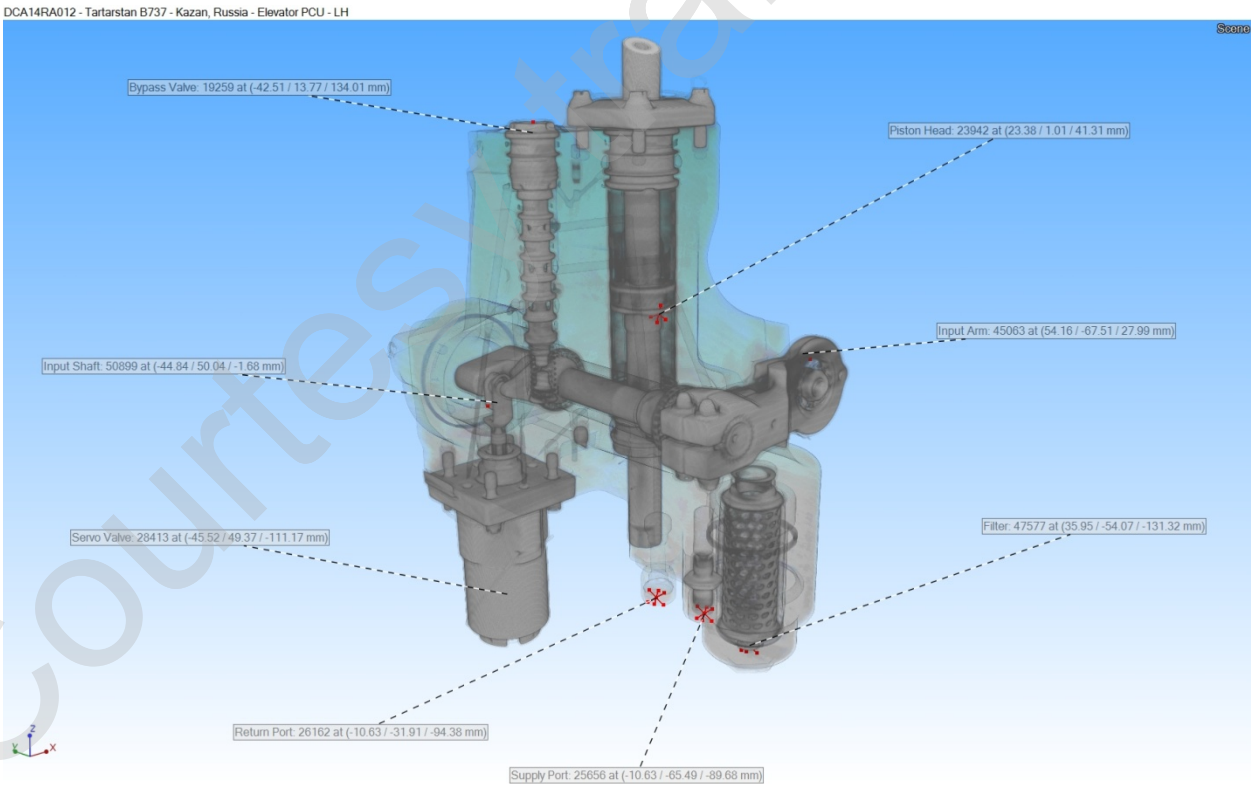


Figure 38 Elevator PCU Left Hand. General view

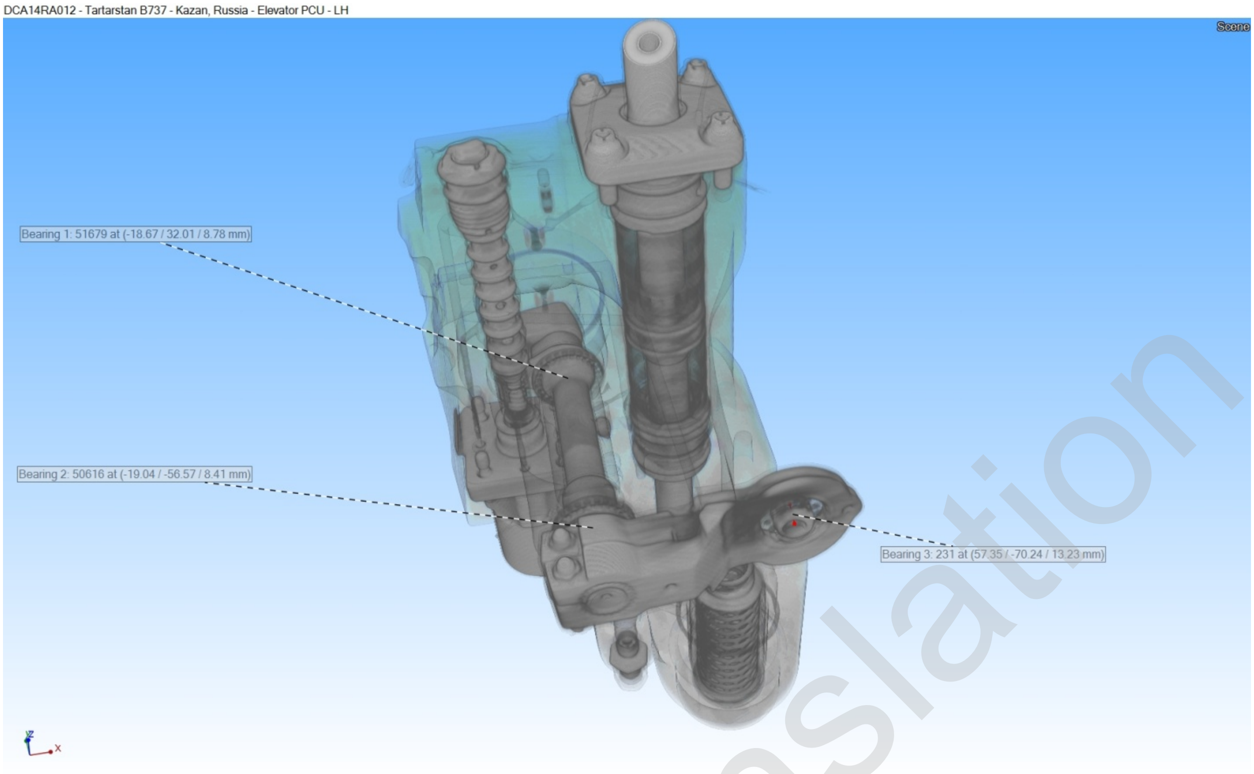


Figure 39 Elevator PCU Left Hand. General view of bearings.

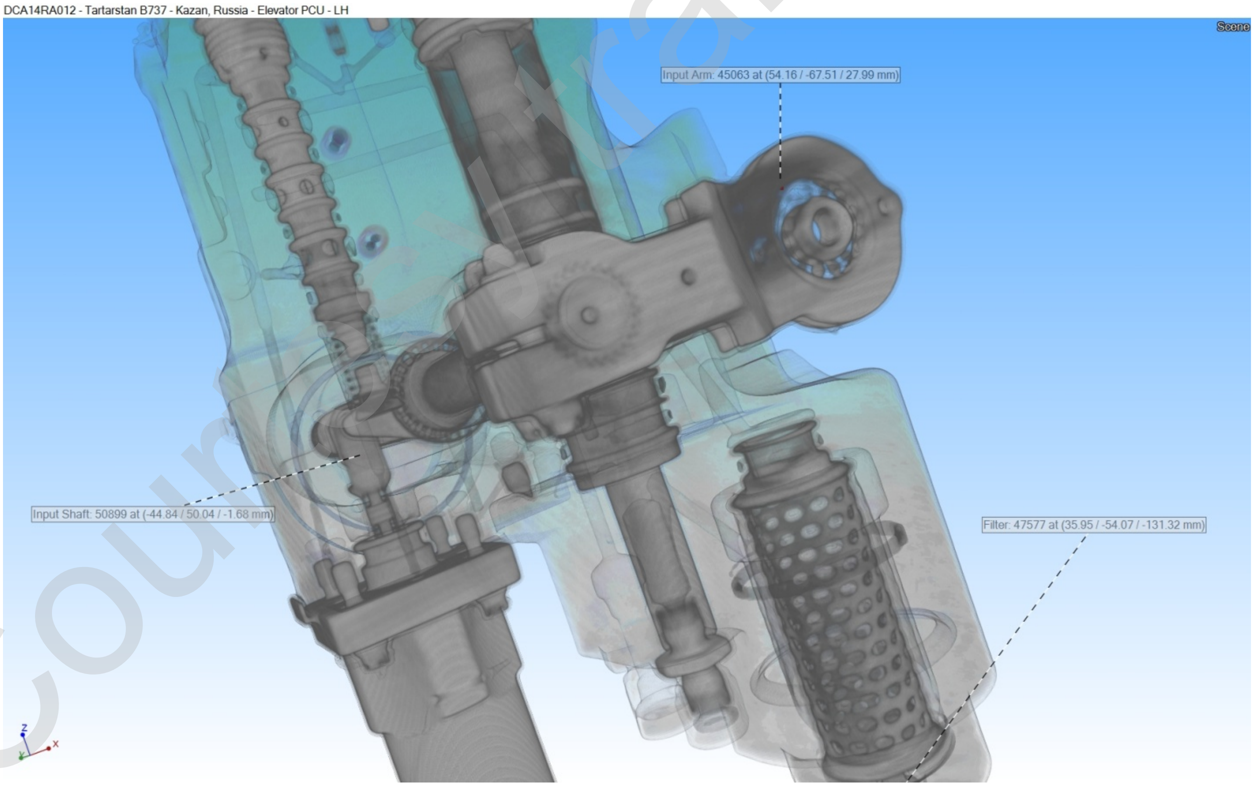


Figure 40 Elevator PCU Left Hand. Input arm and filter.

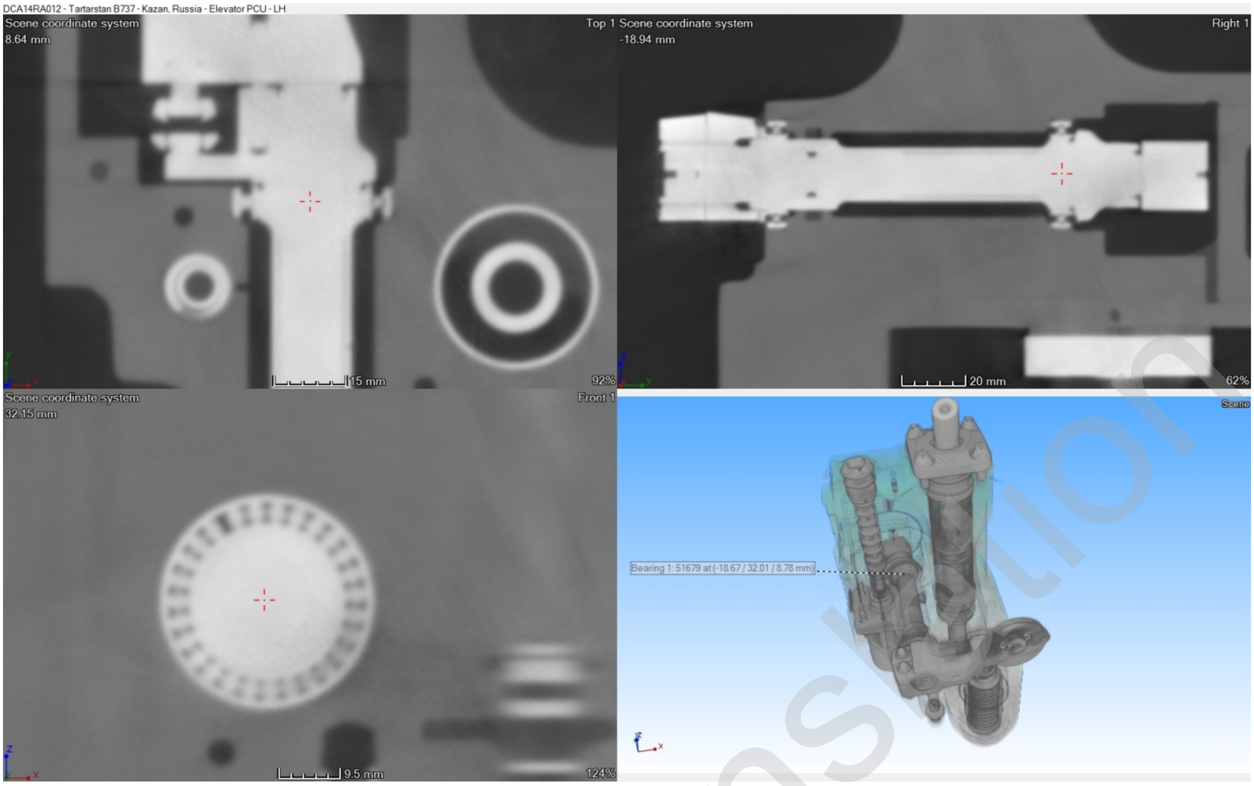


Figure 41 Elevator PCU Left Hand. Bearing 1

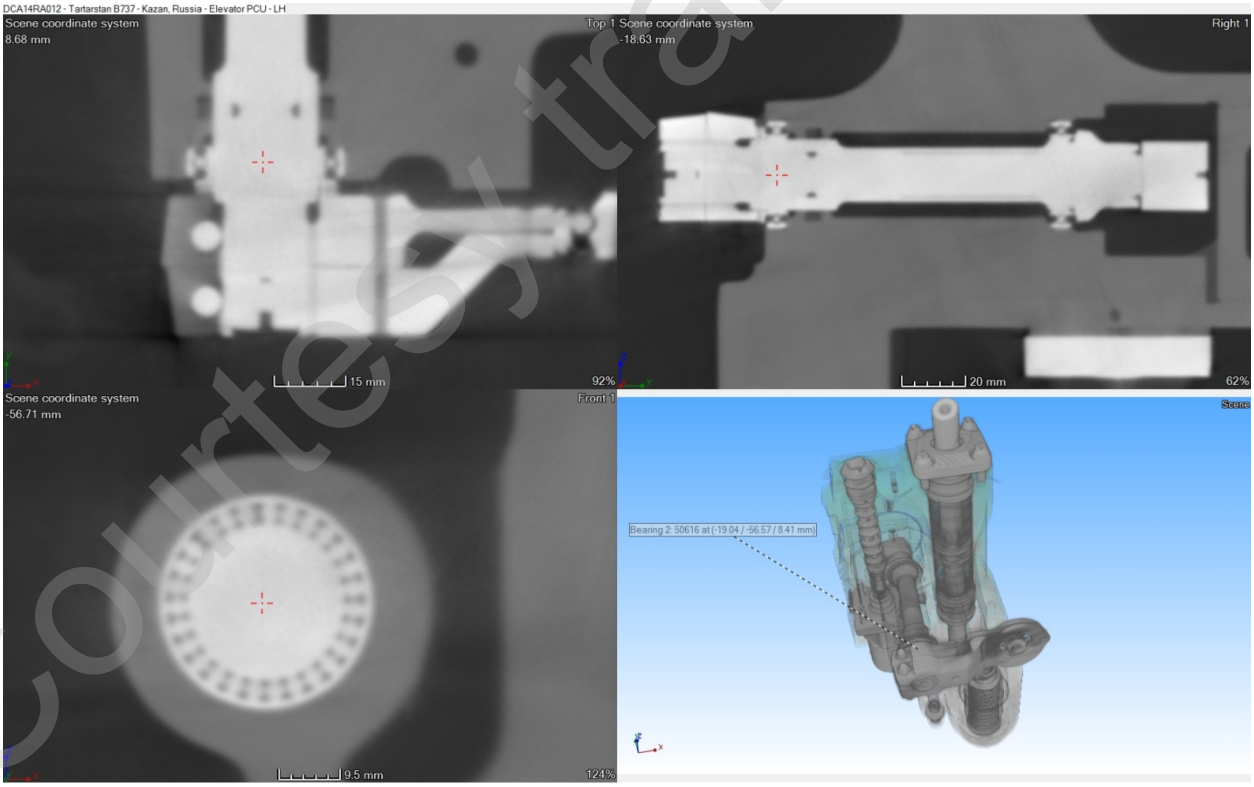


Figure 42 Elevator PCU Left Hand. Bearing 2

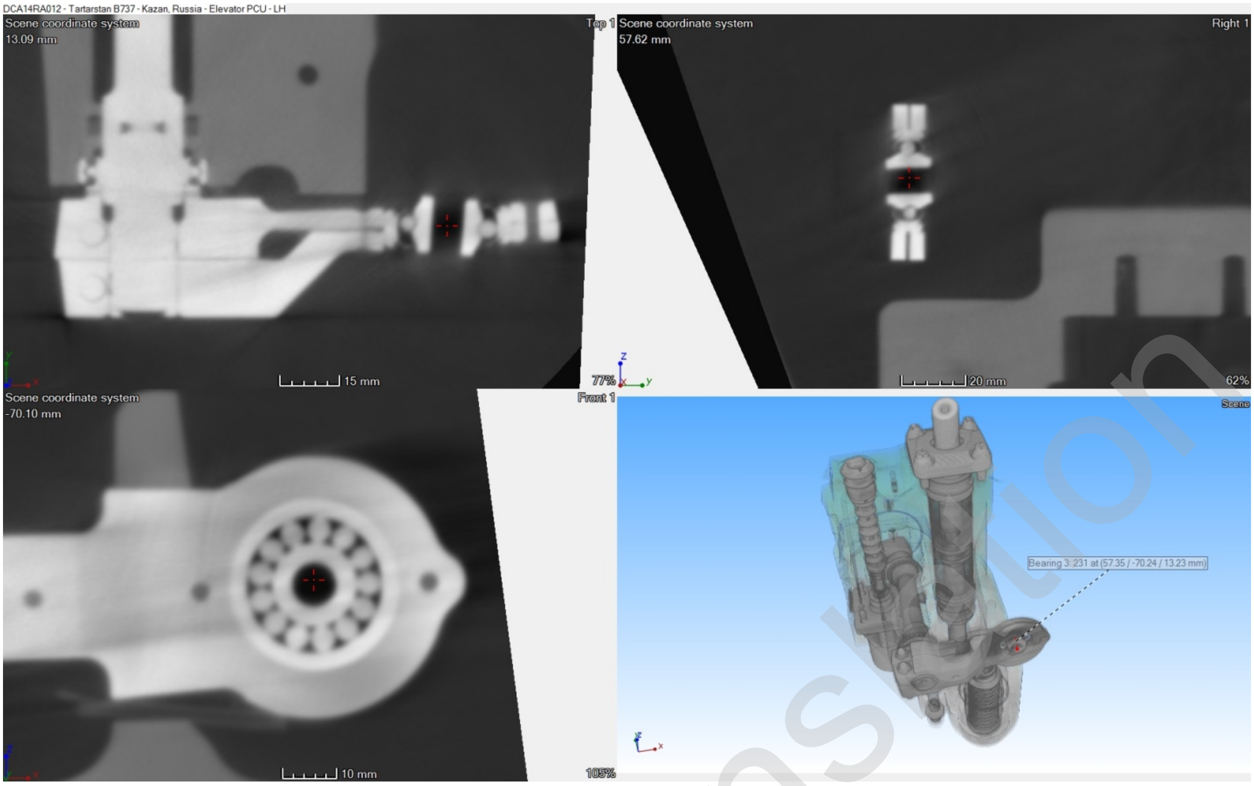


Figure 43 Elevator PCU Left Hand. Bearing 3

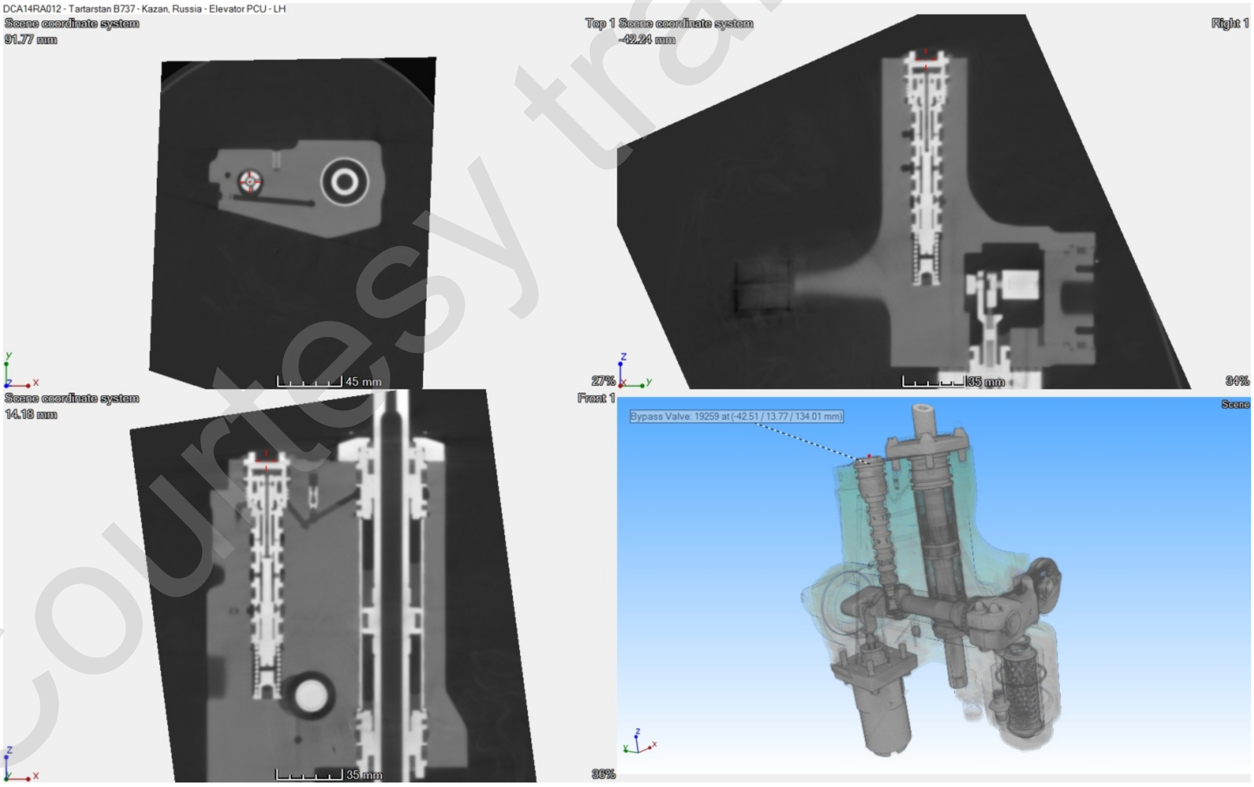


Figure 44 Elevator PCU Left Hand. Bypass Valve

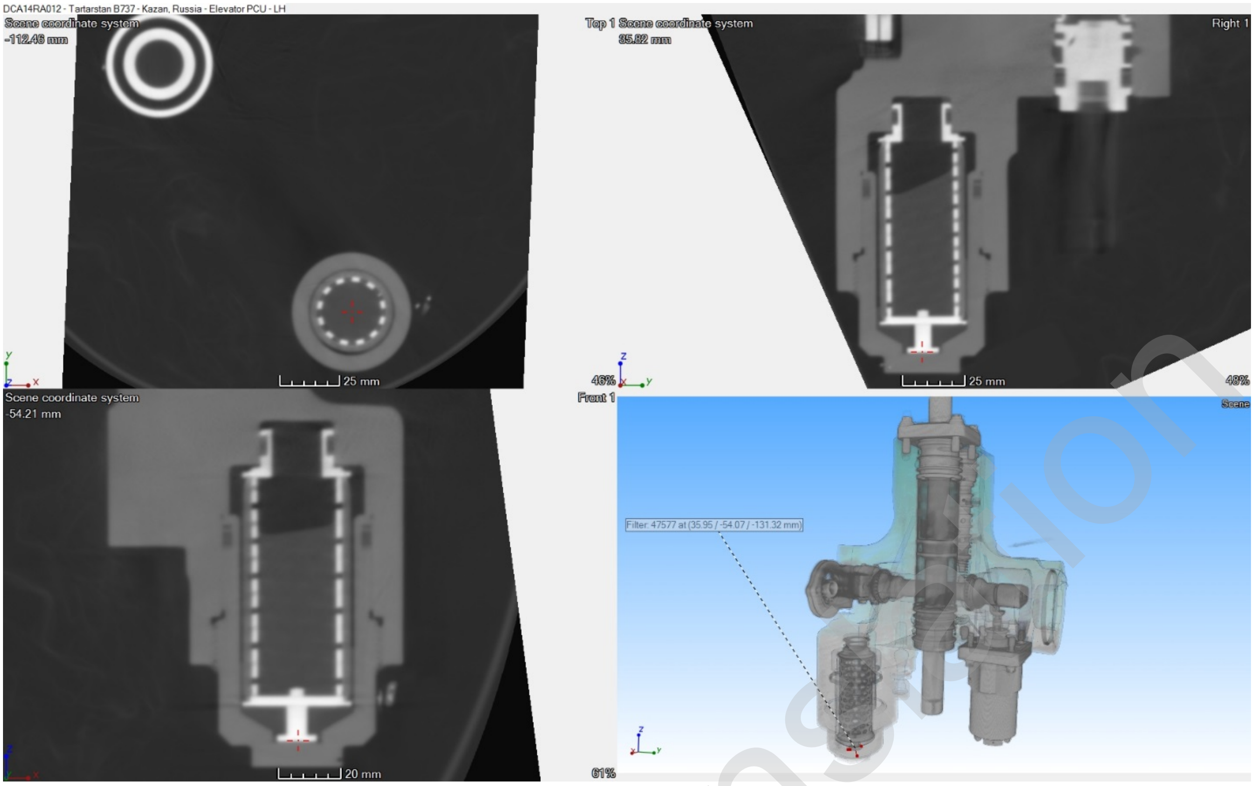


Figure 45 Elevator PCU Left Hand. Filter

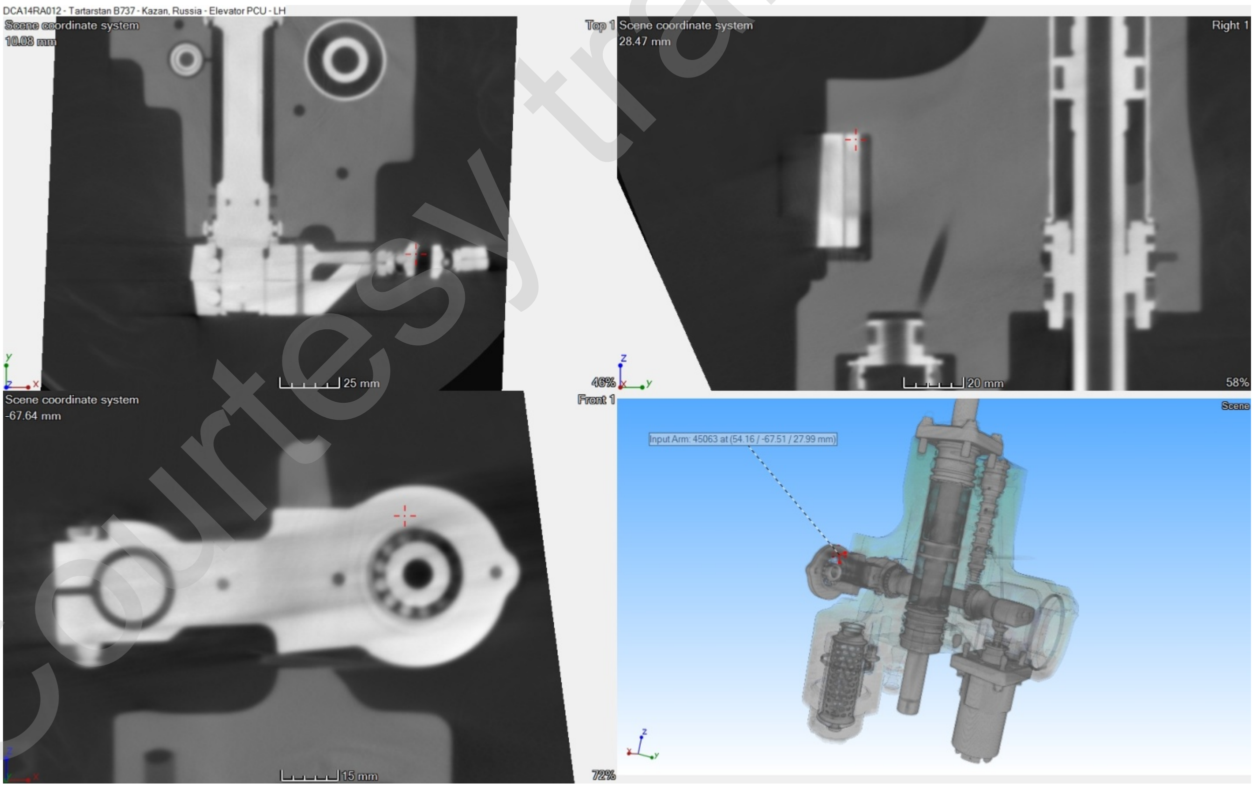


Figure 46 Elevator PCU Left Hand. Input Arm

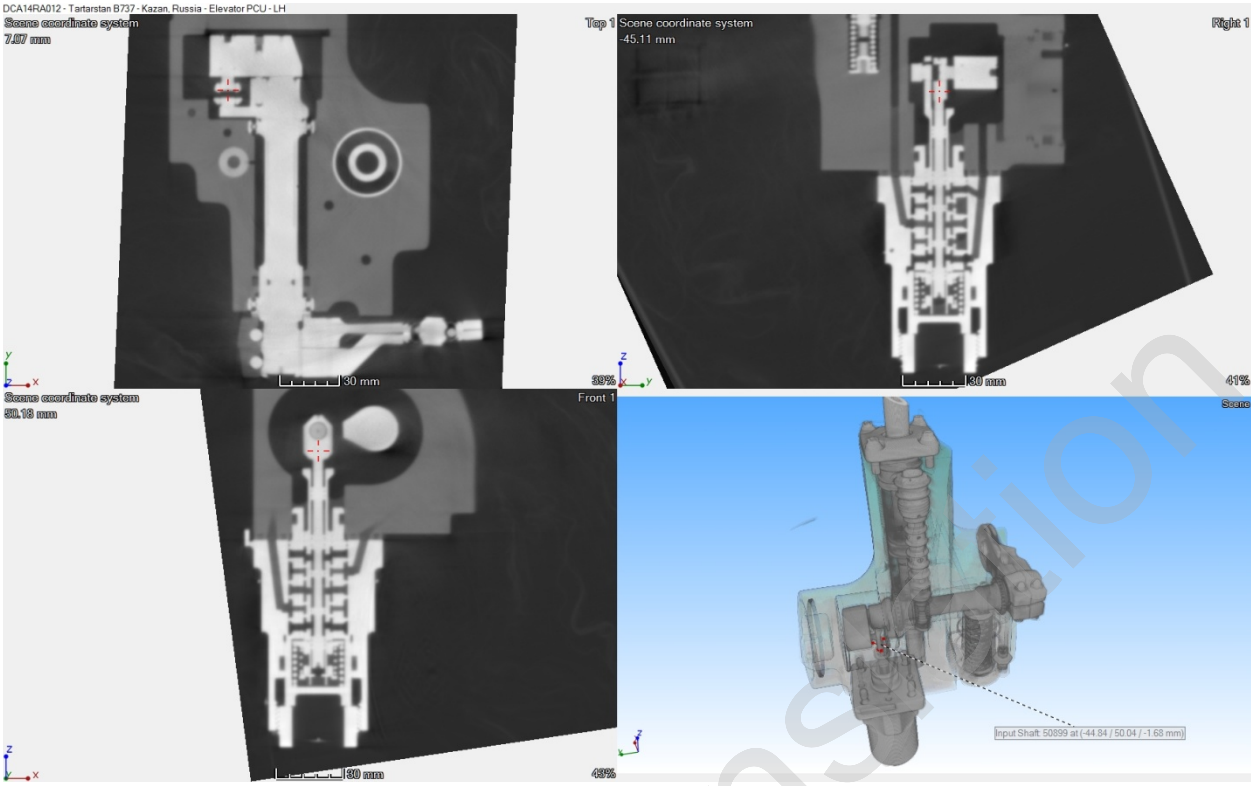


Figure 47 Elevator PCU Left Hand. Input Shaft

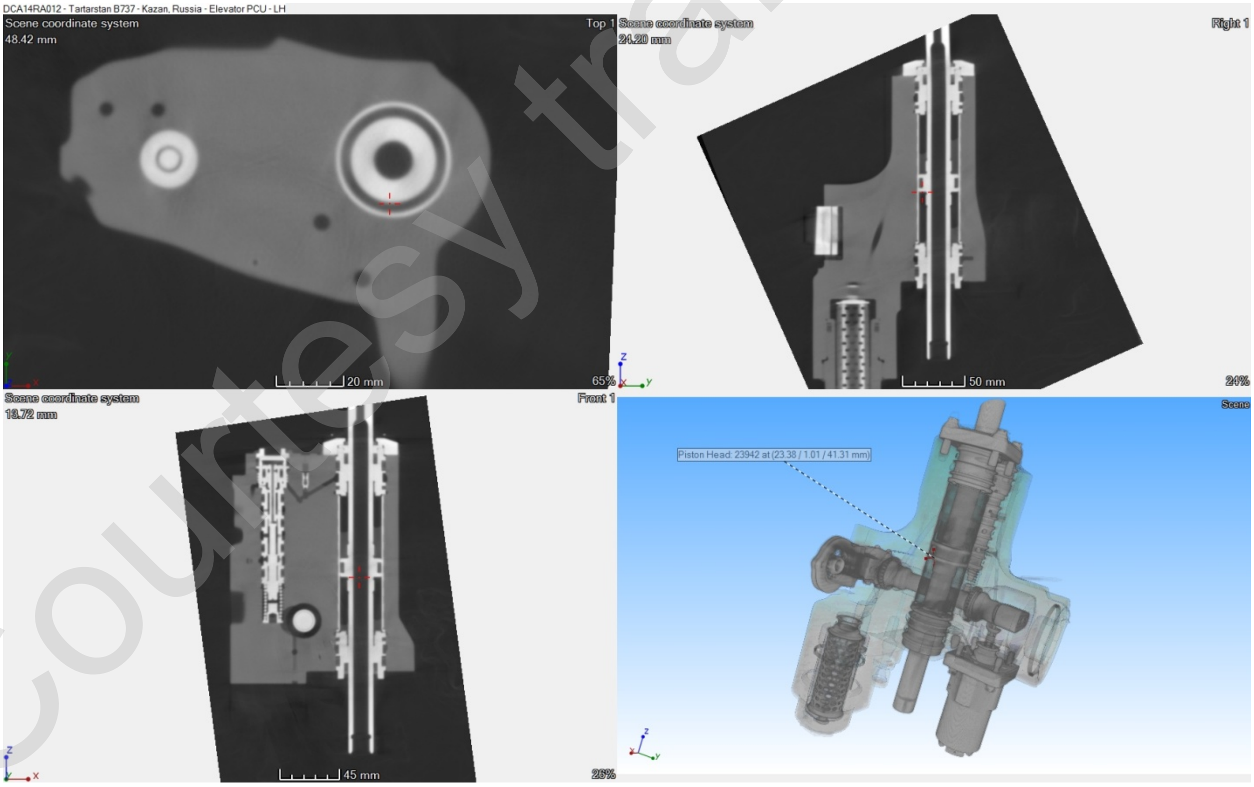


Figure 48 Elevator PCU Left Hand. Piston

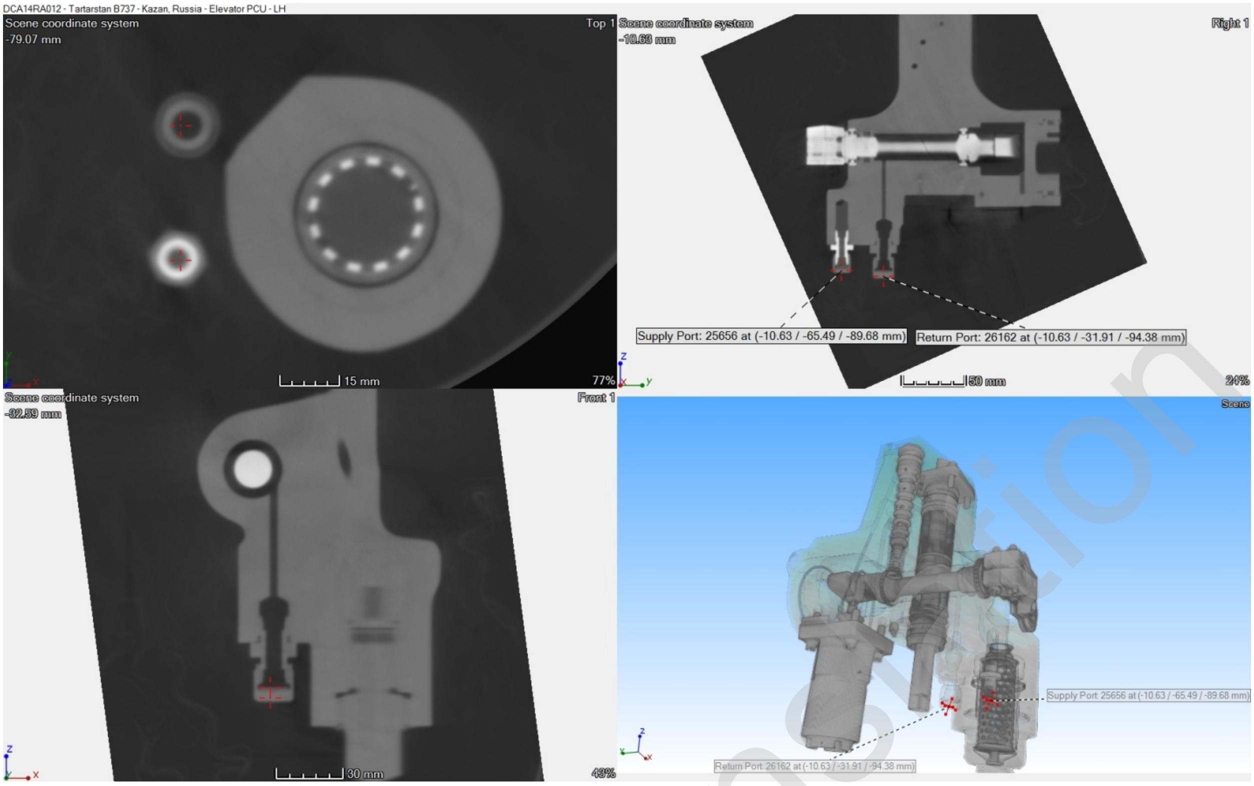


Figure 49 Elevator PCU Left Hand. Supply and Return Ports

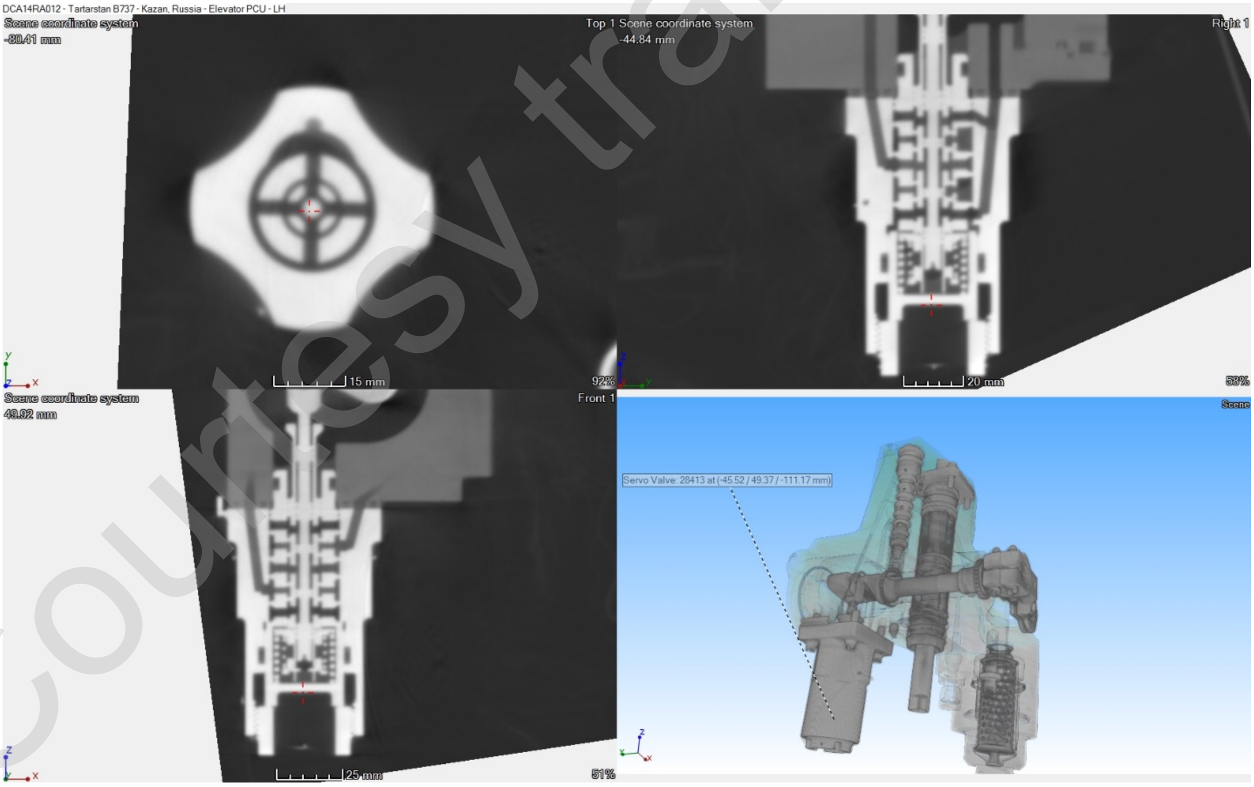


Figure 50 Elevator PCU Left Hand. Control Valve

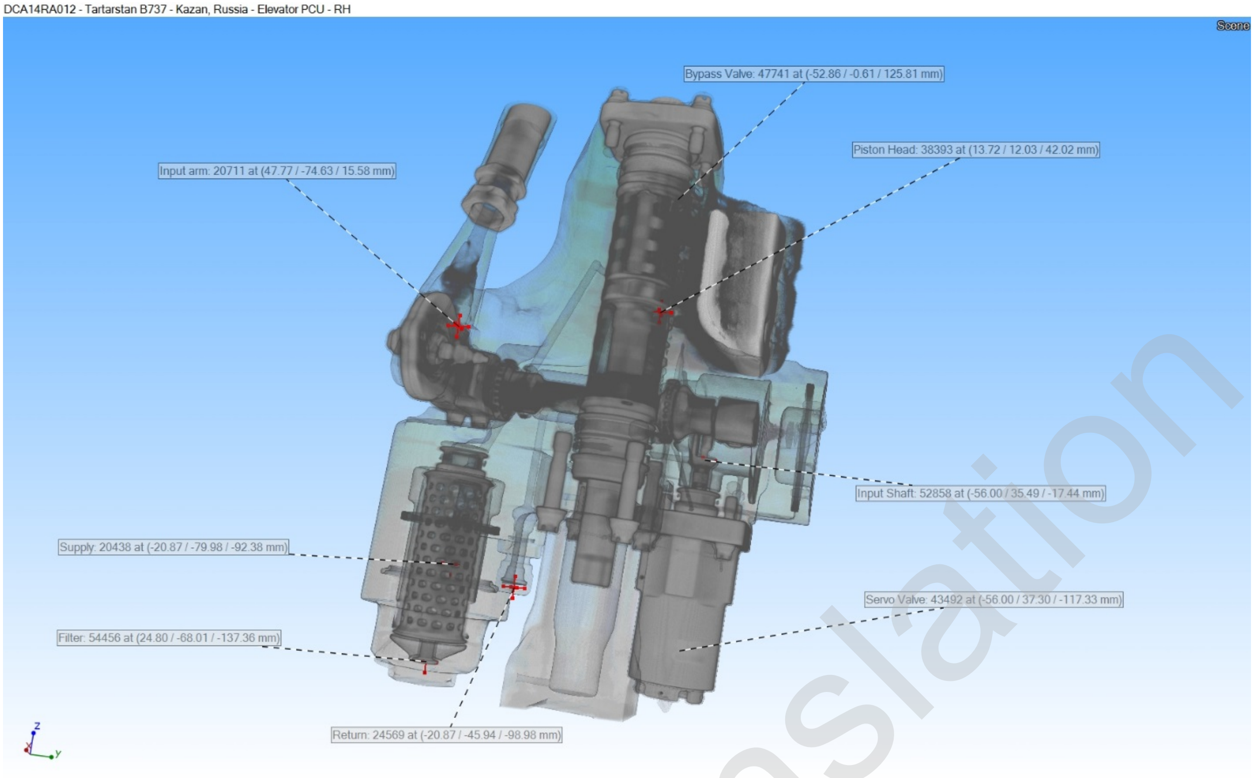


Figure 51 Elevator PCU Right Hand. General view

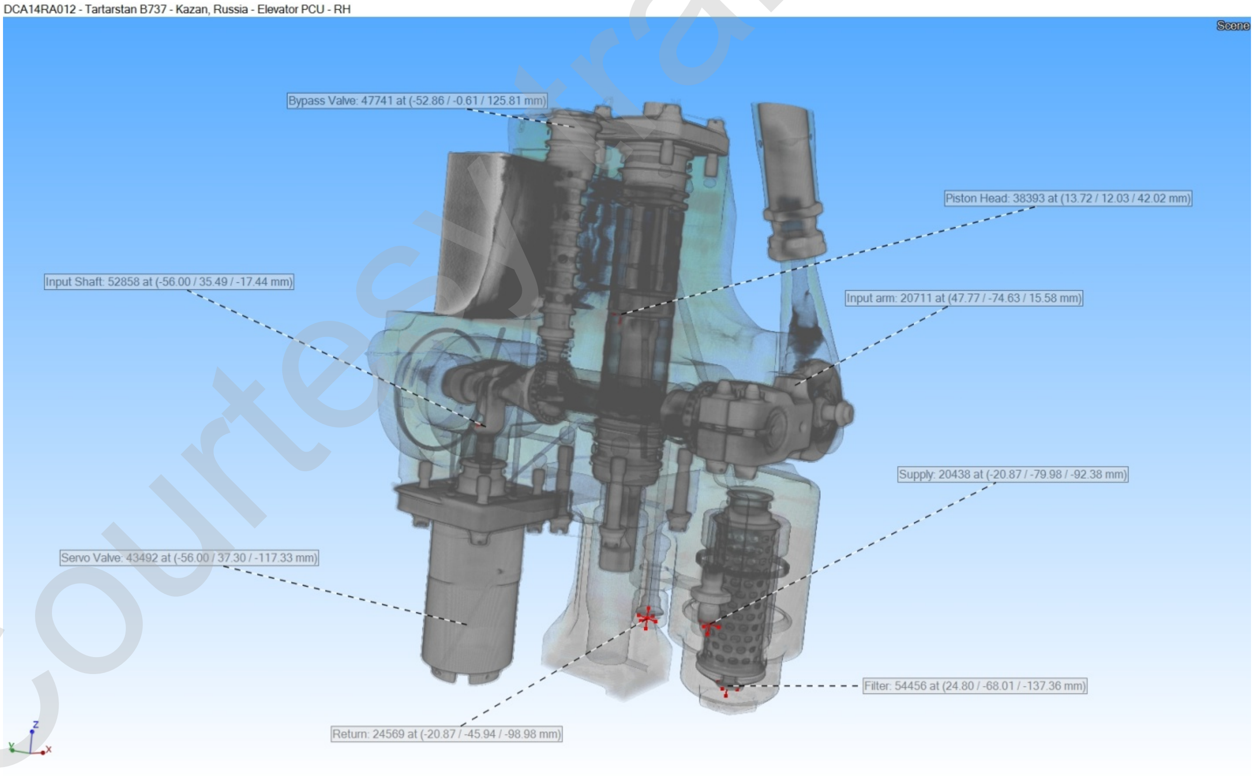


Figure 52 Elevator PCU Right Hand. General view

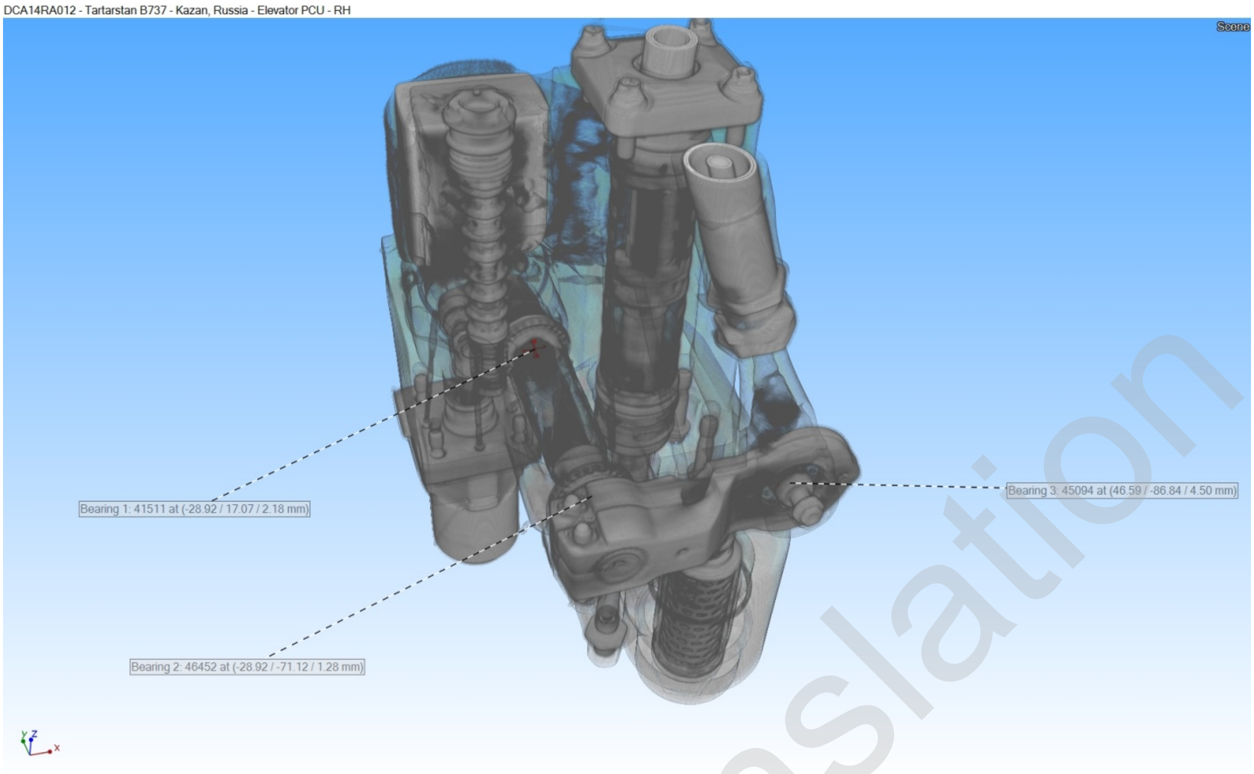


Figure 53 Elevator PCU Right Hand. Bearings

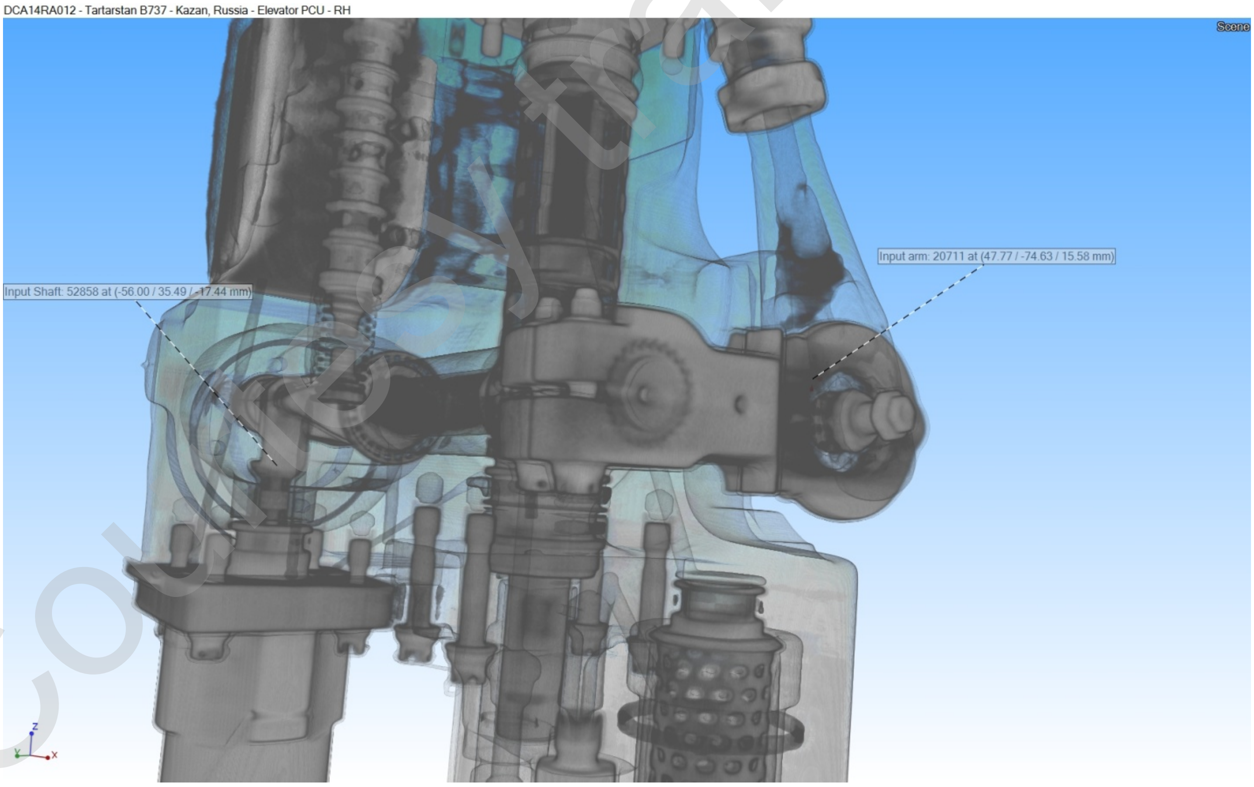


Figure 54 Elevator PCU Left Hand. Input Arm

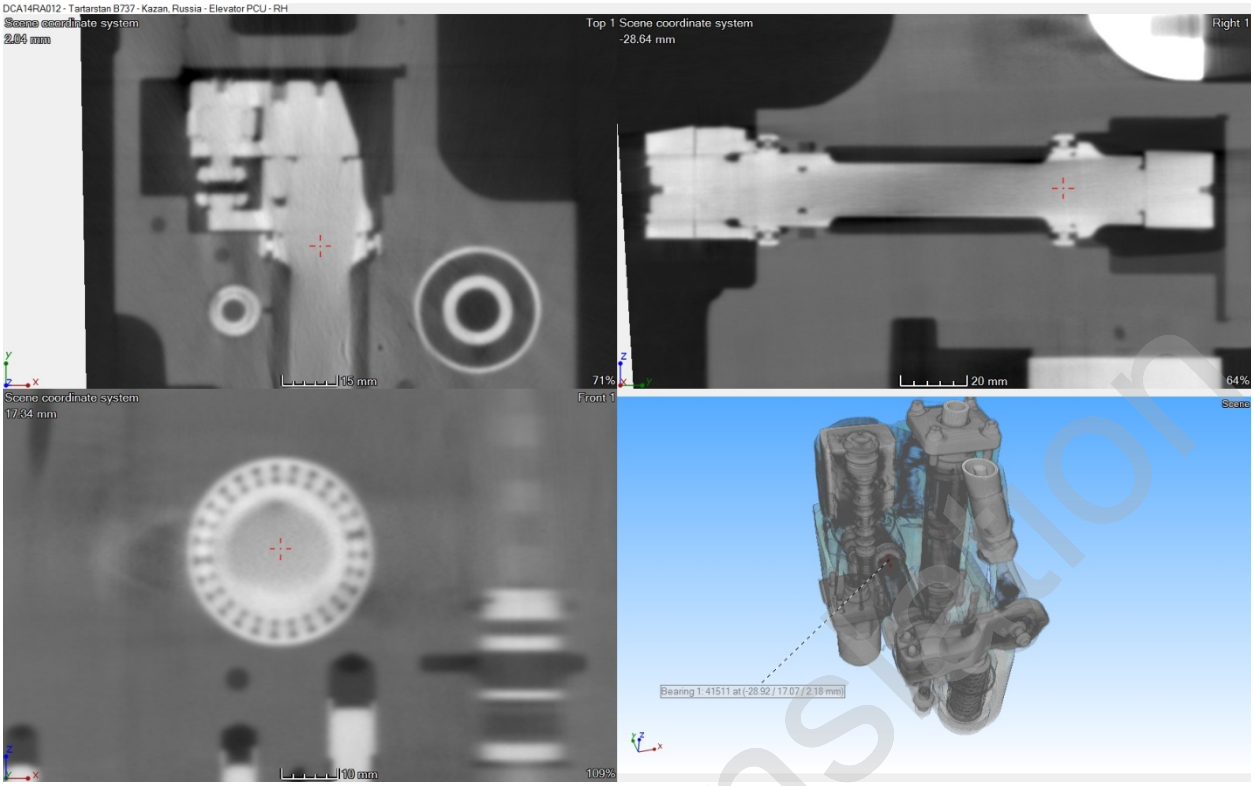


Figure 55 Elevator PCU Right Hand. Bearing 1

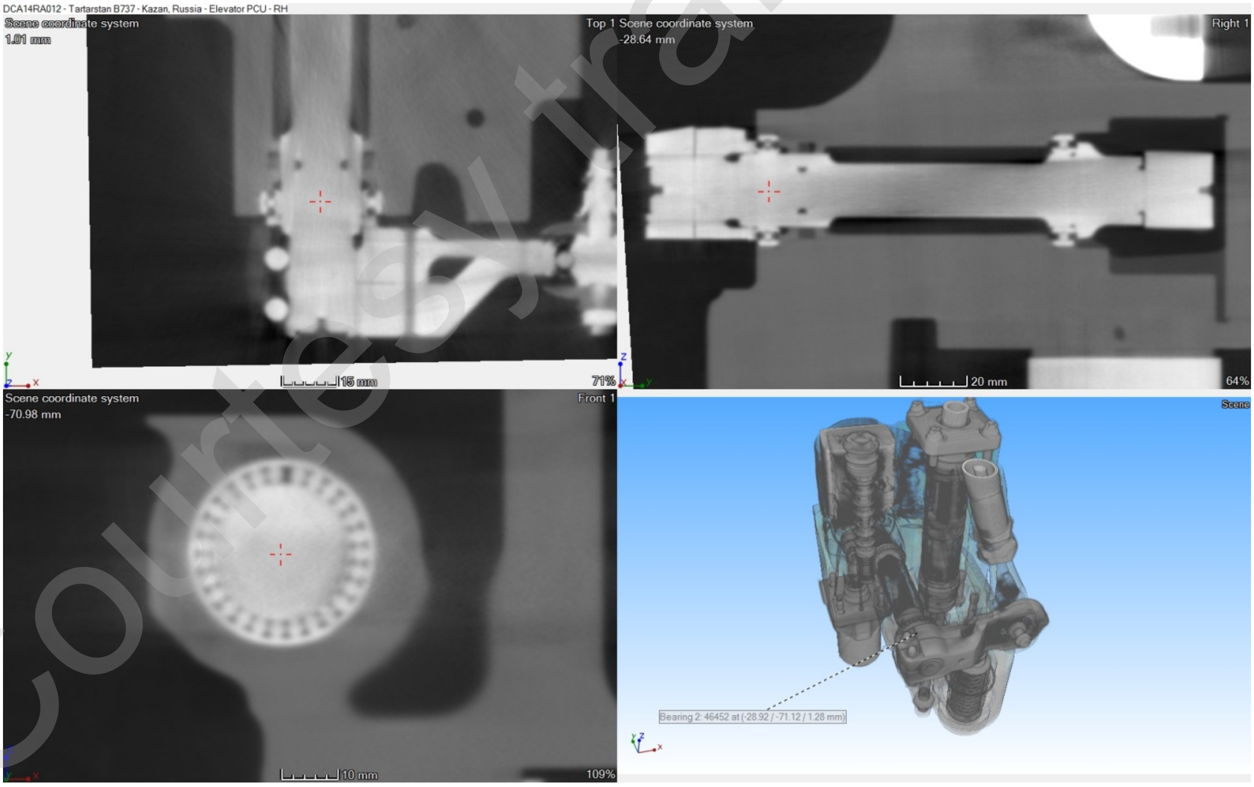


Figure 56 Elevator PCU Right Hand. Bearing 2

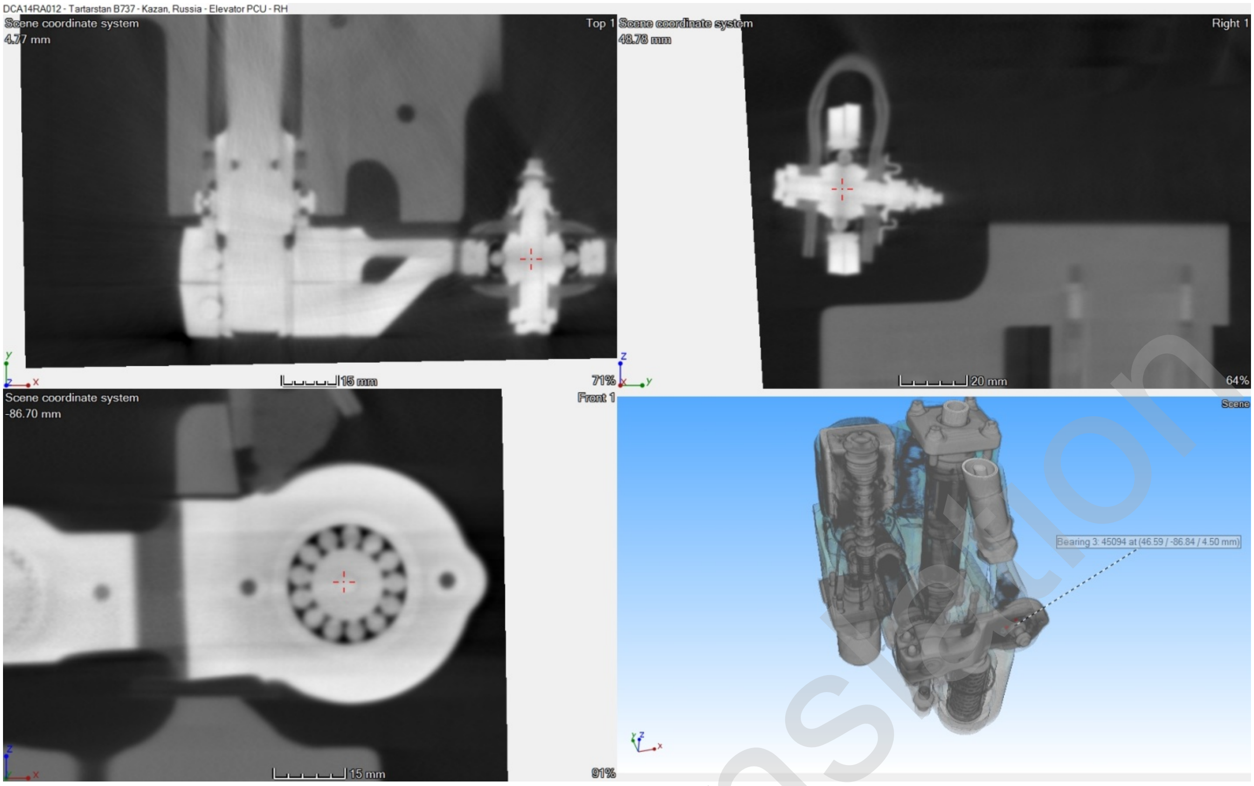


Figure 57 Elevator PCU Right Hand. Bearing 3.

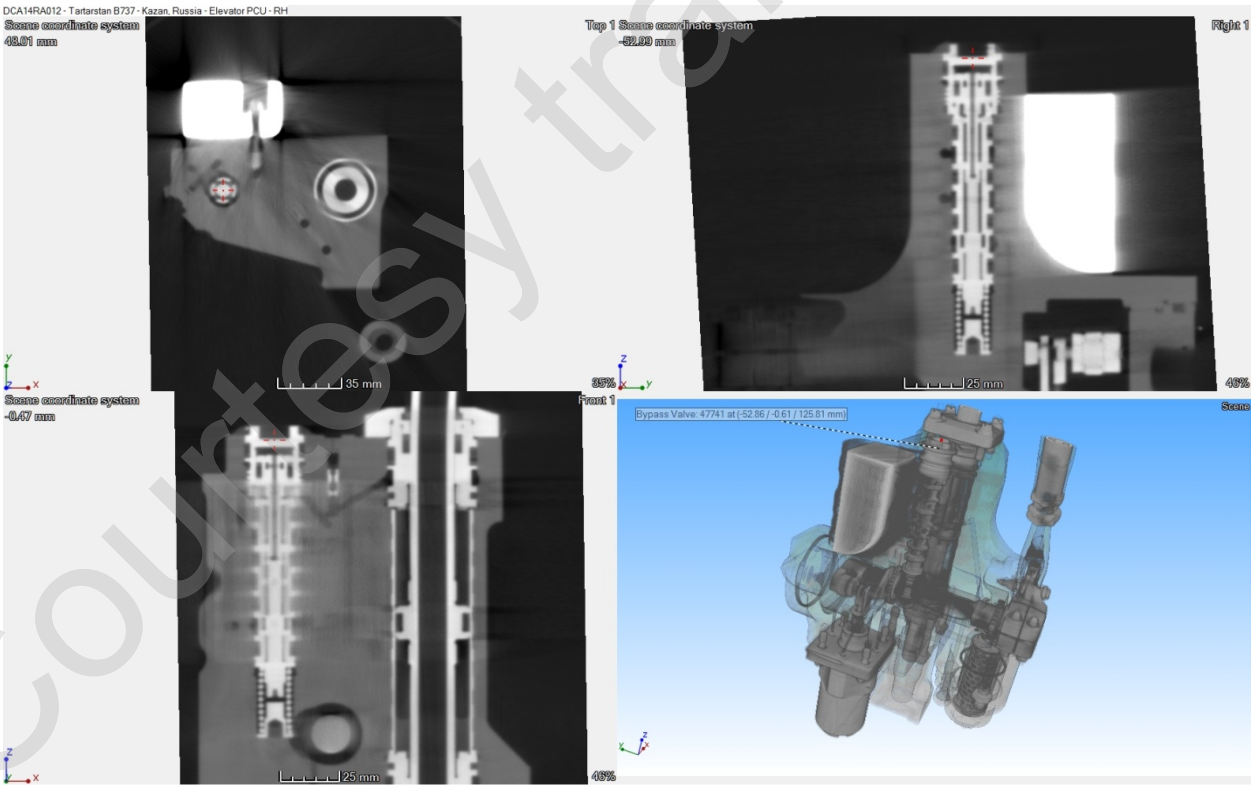


Figure 58 Elevator PCU Right Hand. Bypass Valve

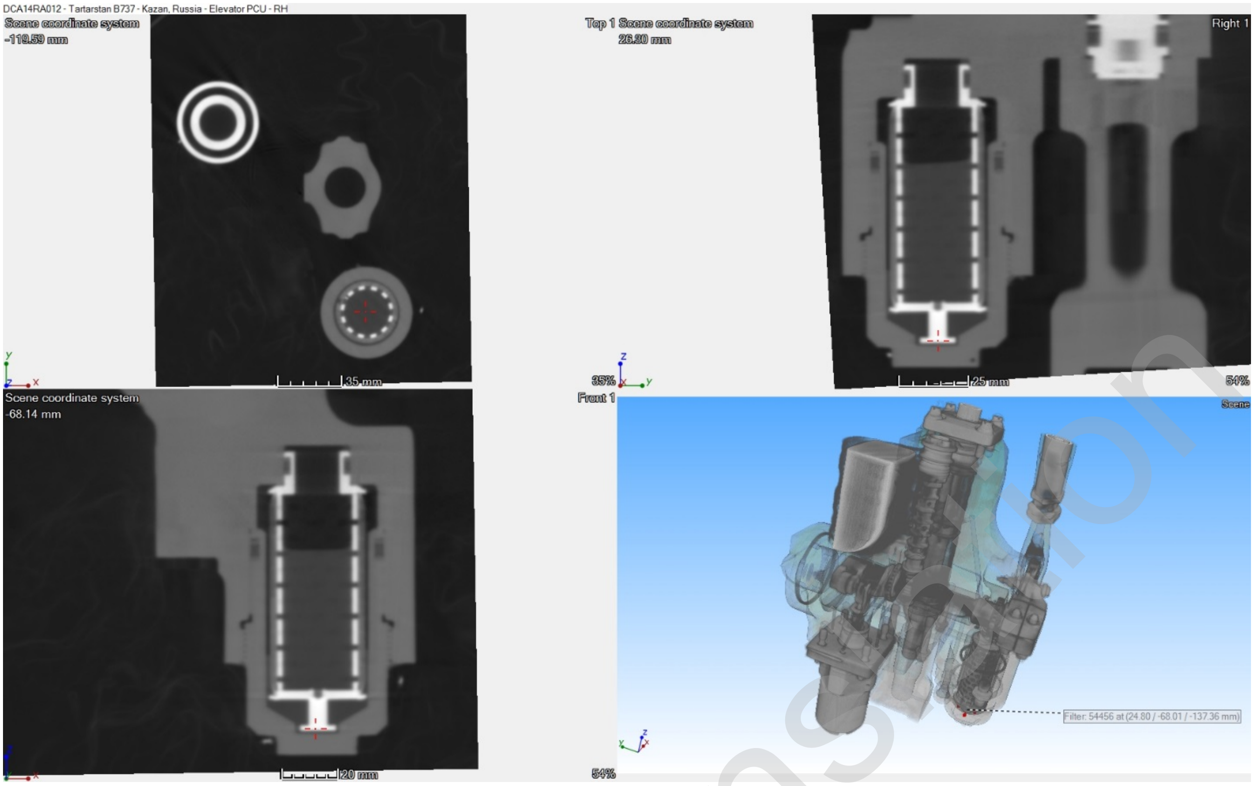


Figure 59 Elevator PCU Right Hand. Filter

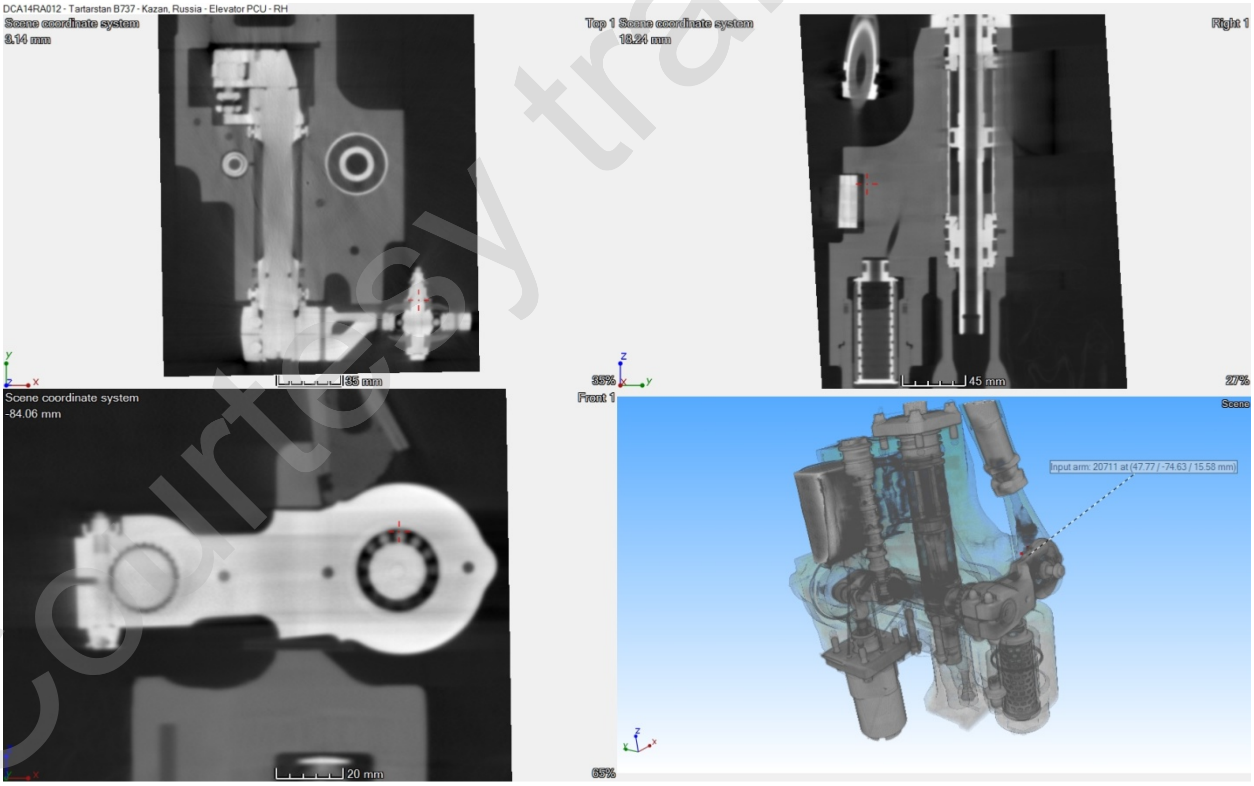


Figure 60 Elevator PCU Right Hand. Input Arm

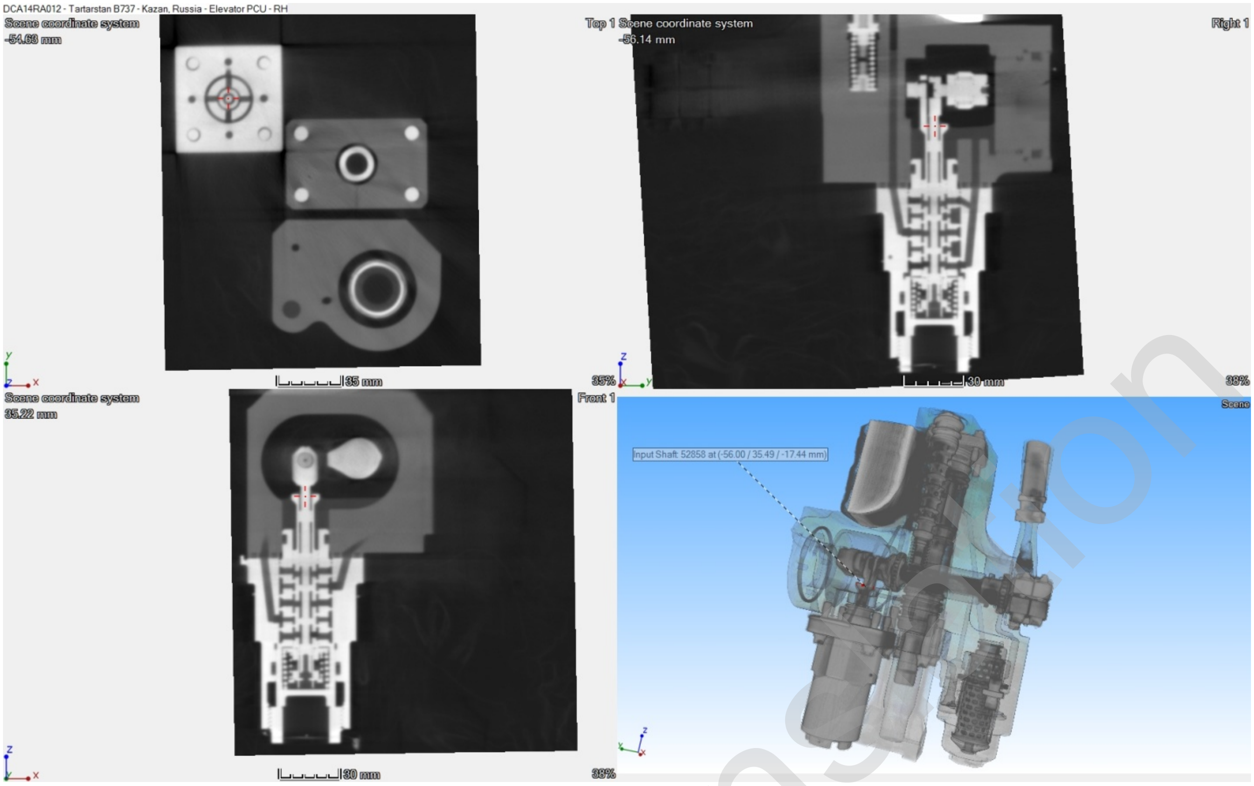


Figure 61 Elevator PCU Right Hand. Input Shaft

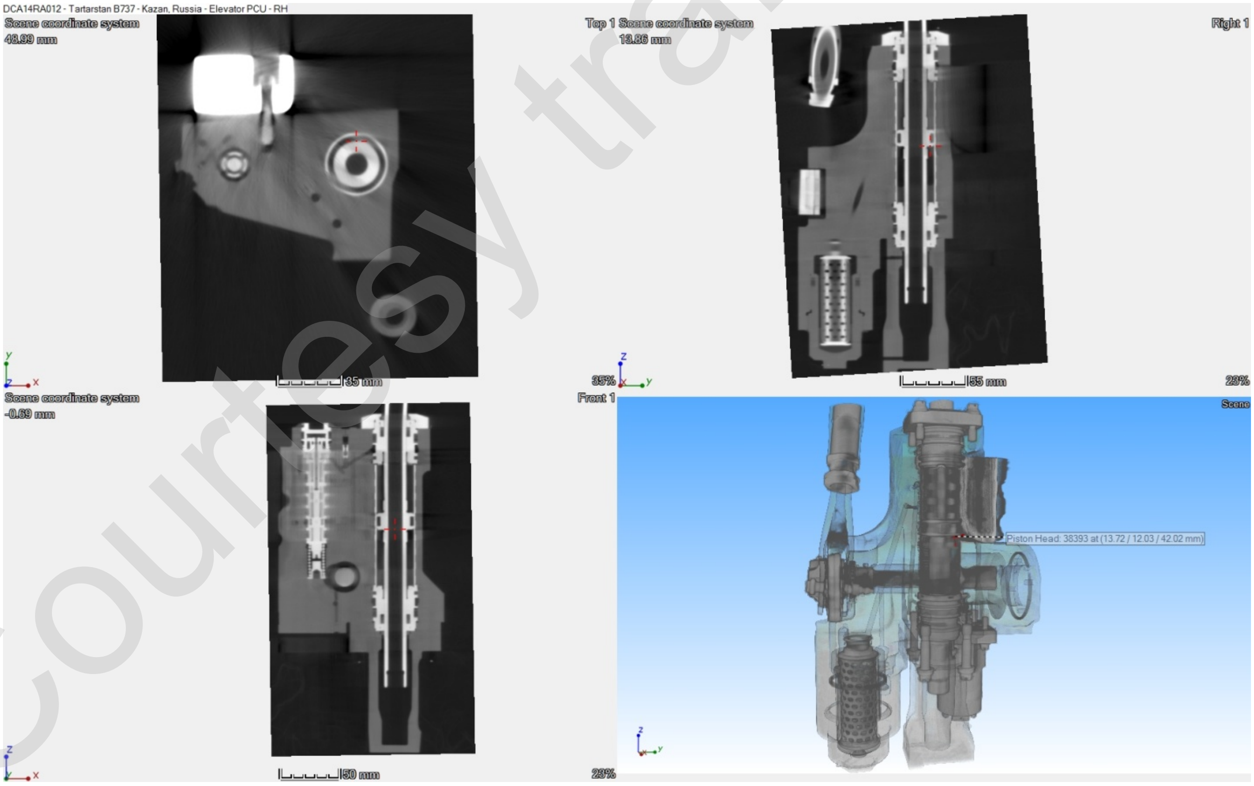


Figure 62 Elevator PCU Right Hand. Piston

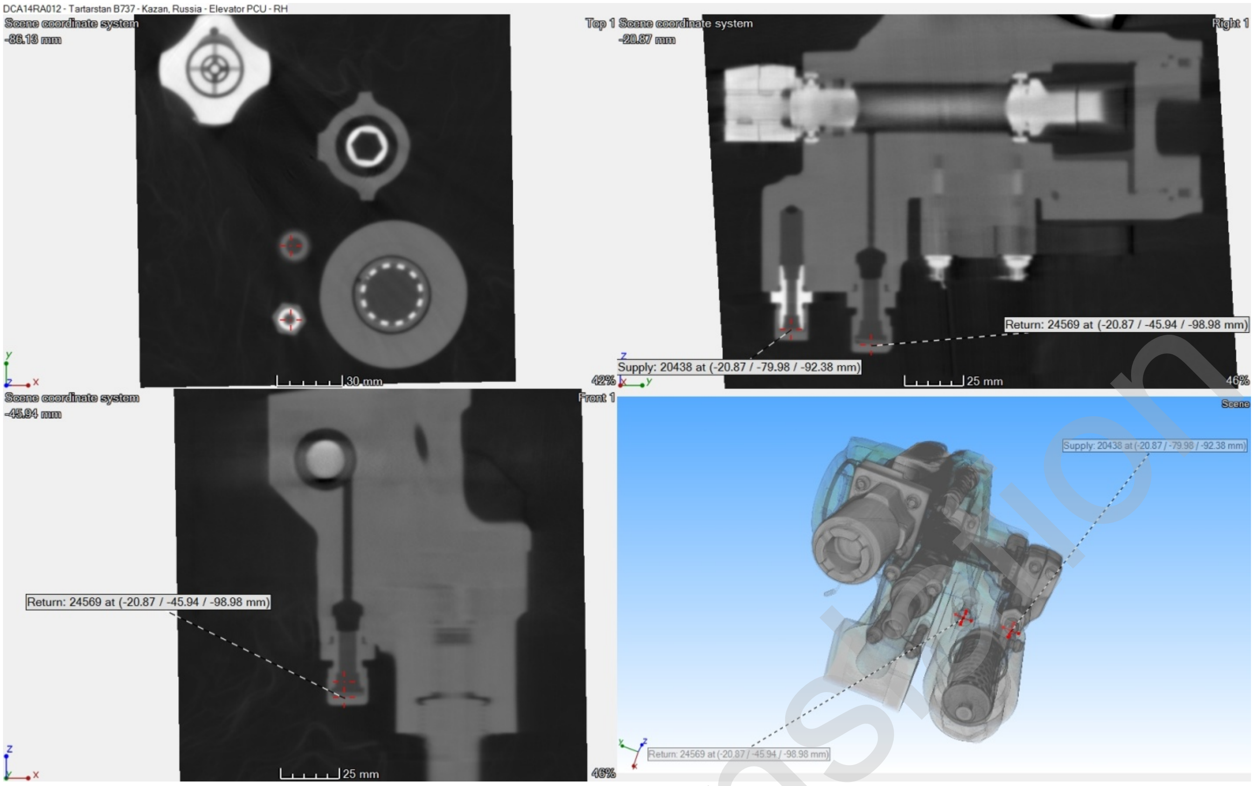


Figure 63 Elevator PCU Right Hand. Supply and Return Ports

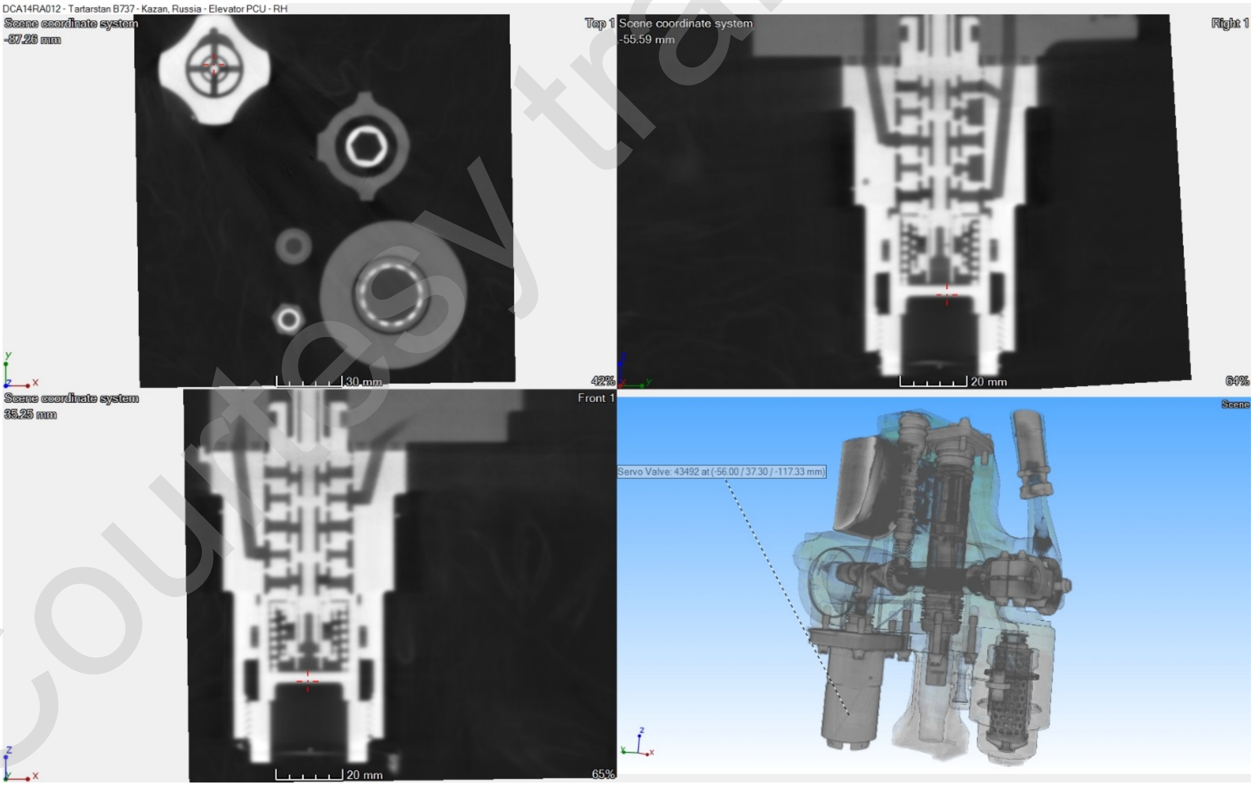


Figure 64 Elevator PCU Right Hand. Control Valve

The scanning analysis showed that:

- the PCU elements were in their normal positions;
- the PCUs' elements were not destroyed;

- there were no foreign objects inside the PCUs.

PCUs Teardown and Elements Condition Analysis

The teardown was conducted at the PCU manufacturer facilities, Parker Aerospace, Irvine, CA, USA. The purpose of the teardown was to evaluate the condition of elements and assemblies of the elevator power control units after the accident.

It was not possible to determine the accurate dates when the PCU were mounted on the aircraft and their operation time based on the available information. According to Parker Aerospace experts, the LH PCU could have been in operation for over 14 years, while the RH PCU for over 20 years. The PCU had no service life limits (were maintained on condition).

After the input arms were removed and the stop surfaces were cleaned from contamination it was determined that there were no FOD marks between the input arms and stops that could have led to the PCU input arm jamming[18].

The disassembly of the control valves, bypass valves and pistons as well as boroscopic examinations of the internal surfaces of the secondary slides and the housing of control valves and bypass valves; the LH control valve[19] and both piston housings revealed no marks of jamming and/or contamination that could have affected the PCU operation. Special attention was paid to control valve elements. The noted marks were consistent with normal wear or burnishing. According to the PCU manufacturer's opinion based on long-term in-service experience the condition of the PCU elements was normal.

No marks of control valve jamming like the ones shown in Figure 65 that were simulated during the tests by Parker Aerospace and might be evidences of the presence in the flow outlets of the foreign objects (chips) with their subsequent shear were noted.

[18] External jamming (with relation to the PCU) is meant here. Section 1.18.7 provides information on the previous in-service jams of this kind.

[19] The LH secondary control valve was sectioned for more thorough examination of the marks found during the boroscopic examination. The sectioning confirmed that the mentioned marks appeared when the control was assembled and did not result from jam or chip shear.

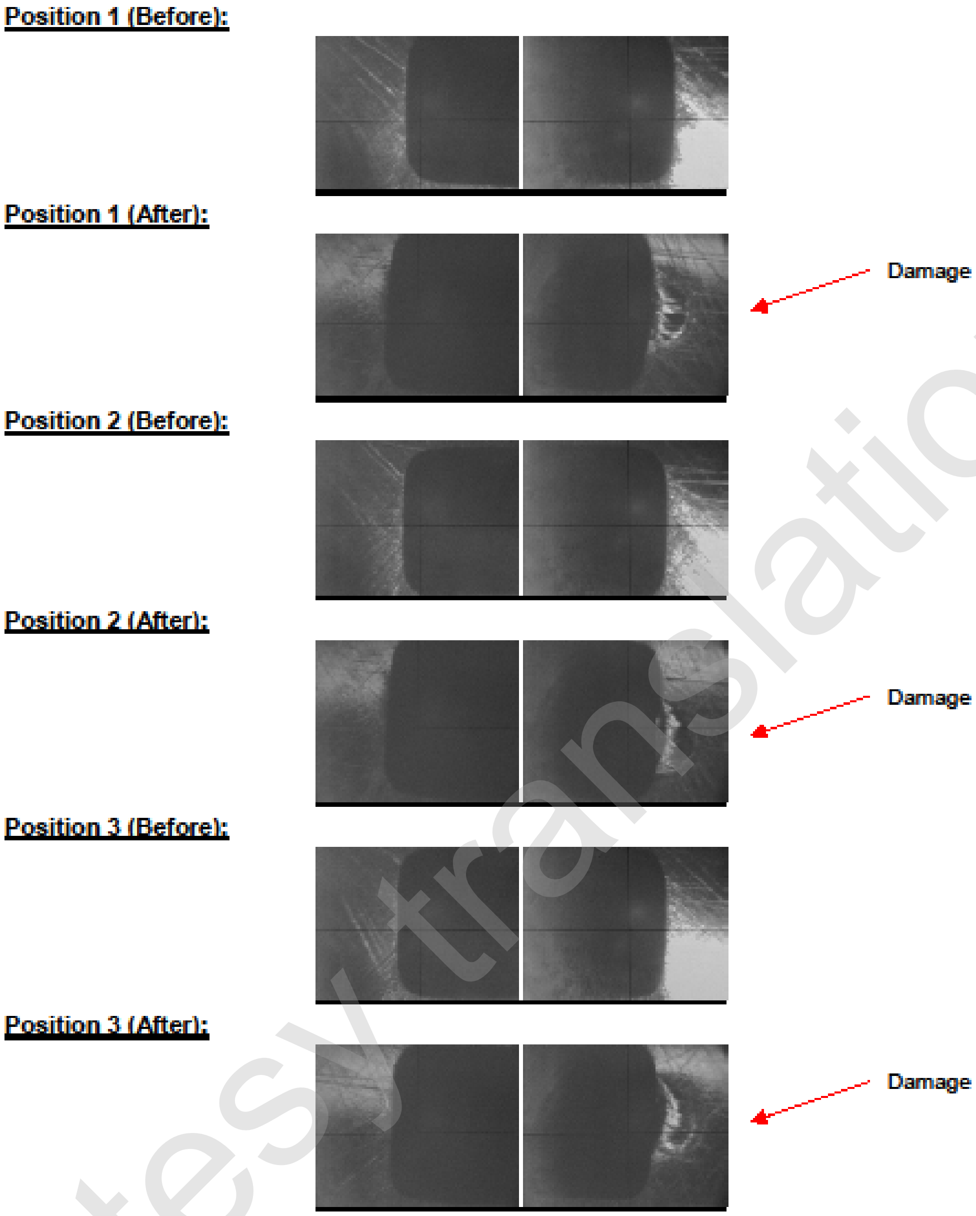


Figure 65 Metering Edge Chip Shear obtained during the examination of test lots

Two following features were revealed in the course of the PCUs teardown.

The first feature is different design of the RH and LH control valve primary slides. Two of the RH control valve primary slide lands have no balance grooves (Figure 66). While the LH control valve primary slide has those balance grooves (Figure 67).

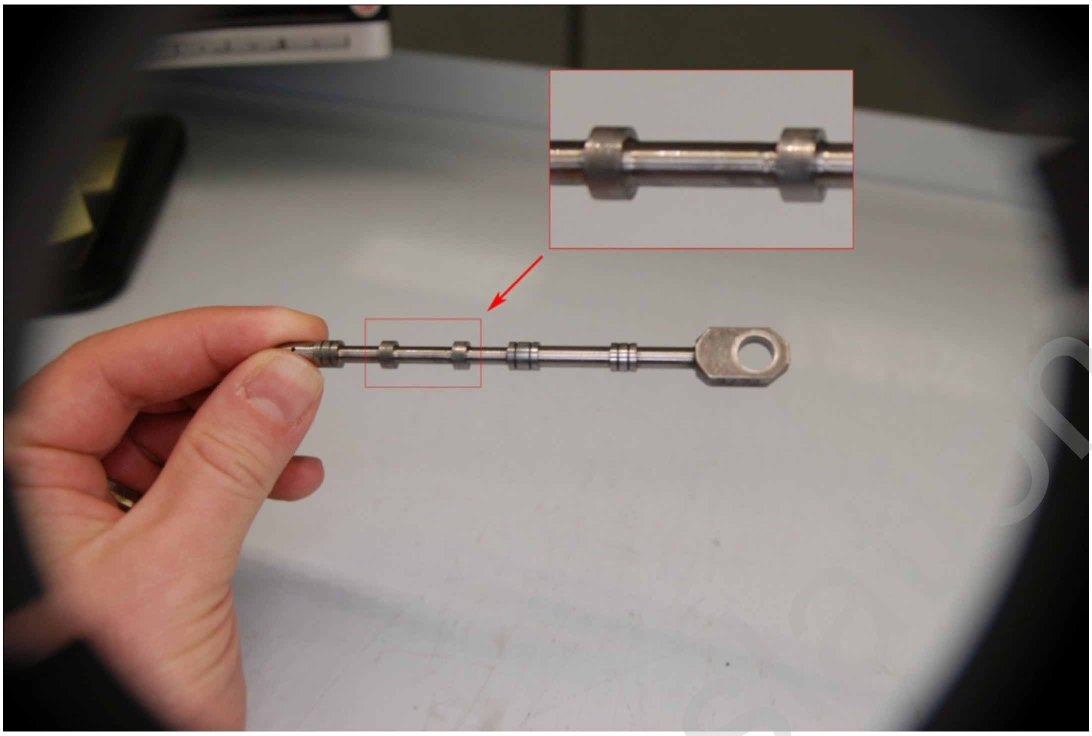


Figure 66 RH control valve primary slide

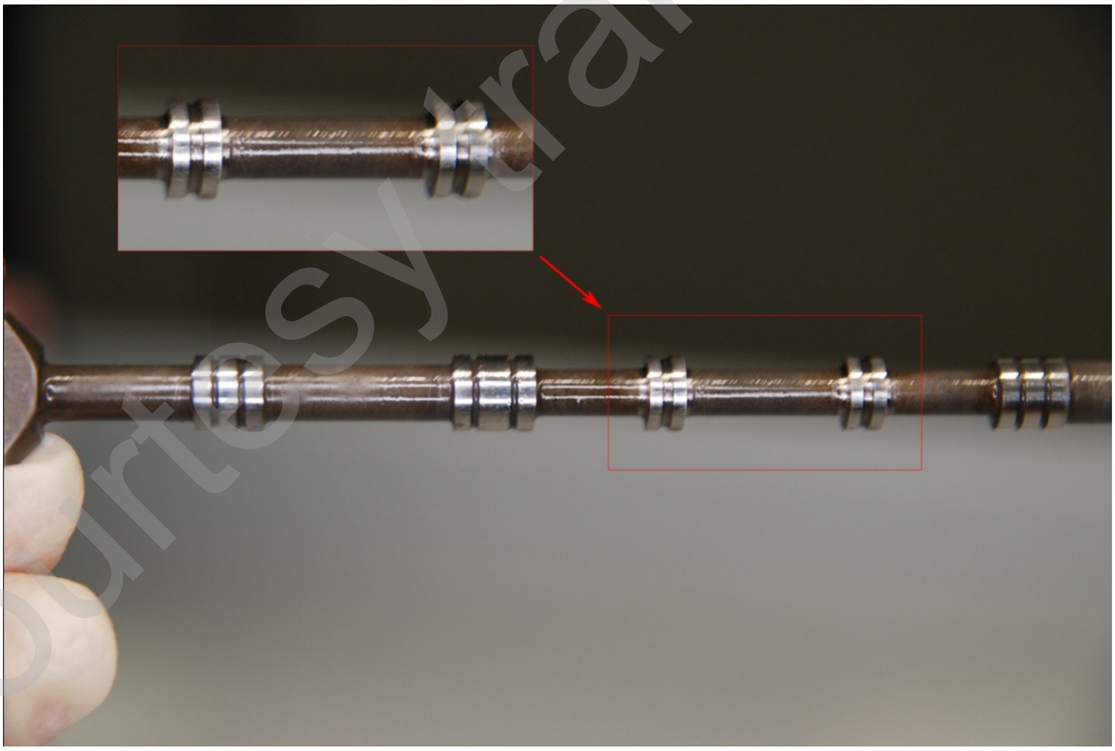


Figure 67 LH control valve primary slide

Similar differences were revealed on the bypass valve slides. The absence of balance grooves may lead to increased friction forces and more extensive wear. According to the designer's explanation both types of slide design are acceptable. This is explained by the fact that balance grooves were added to slide design over time and are now considered the industry standard, though there is no requirement to change PCU's containing the old designs to PCU's with the newer designs.

The second feature is the edges deformation on lands of the RH control valve secondary slide (Figures 68 and 69).

Figure 68 RH control valve secondary slide land edge deformation

Figure 69 RH control valve secondary slide land edge deformation

Such feature is a result of the manufacture of the recessed hole in the secondary slide. The features were measured and were determined to be within the tolerance requirements of the applicable drawing. It was also noted that the side of the land edge that was deformed is non-critical non-metering edge side.

Servo Testing

After the disassembly and condition evaluation of the main servo elements, they were re-assembled to be tested in accordance with the acceptance test procedure (ATP). It should be noted that the ATP specifications are normally used exclusively for the acceptance of newly manufactured hardware. There are no specifications for the used hardware.

The following parameters were tested:

a. Neutral flow;

b. Primary and secondary spool friction

c. Neutral cylinder pressure

d. Cylinder pressure gain (spool shift within ±0.0008 inch from neutral position);

e. Cylinder pressure gain (spool shift within ±0.001 inch from neutral position);

f. Neutral flow and flow gain within the spool shift range;

The LH servo met the ATP specification except those in b). The RH servo met the ATP specification except those in c) and e). According to Parker Aerospace and Boeing, based on the testing above and taking into account that the ATP specifications were designed for the newly manufactured hardware only, there would be no adverse PCU performance impact resulting from the levels of non-compliance noted during the control valve testing. It was noted that measured increase in friction between the primary and secondary slides would result in an additional force on control column of only about 0.1 lbf (0.045 kgf).

Diametric Clearance Measurement

The examination revealed that the clearance values between the primary and secondary slides of the LH control valve were 0.000050 to 0.000080 inches, with the tolerance specifications for a newly manufactured part being 0.000075 to 0.000125 that is the minimum clearance values did not meet the tolerance specifications. As a result of the accident the actuator identifying nameplate (with the serial number) was lost. Because of the identifying nameplate absence the actuator manufacturer was not able to find out any records about clearance just after control valve assembly. Today during acceptance test only a number of actual performance data are checked (flow tests) however clearance measurements are not done.

It was not possible to determine definitely why the clearance value was outside the limitations. The possible causes could be the following:

- slides manufacturing with deviations from the technical drawing;
- insufficient stabilization of slides dimensions in course of manufacturing;
- slides actual condition after the accident, teardown, storage and reassembly could have been rather different from the condition of new parts;
- the small values of measured clearances which may lead to errors even with small deviations from the established measurement procedure.

However, the servo had been in service for quite a long time and the test showed it met almost all the ATP specifications. Thus, the mentioned possible noncompliance with the drawings did not affect the operability of the LH PCU control valve.

PCU Design and In-Service Experience Analysis

According to Parker Aerospace, actuators of this type have totally accumulated 270 millions of flight hours[20]. Not a single event of internal jamming has been recorded. Also contamination testing of this type of PCU (highly contaminated fluids per NAS 1638 Class 9, Class 12 and Class 15 were used during test) did not result in any cases of jamming. In course of these tests control valve parts received significant damages and were subjected to erosion. However in spite of these damages the control valves retained their working capability.

The PCU's design prevents any single control valve jam (primary or secondary slide) from affecting the PCU response to pilot control column input. Jamming can result in the extension of the PCU insensitive area (which leads to deteriorated PCU dynamics and static accuracy of the system) and in the decrease of the speed of the control surface movement in one direction depending on the position in which the primary slide is jammed. The control surface deflection is not affected due to the force developed by the operative PCU.

Double jamming (primary and secondary slides) can be only temporary[21] as the input arm force shears FOD chips (in case of comparable features of chips, such as dimension, hardness) thus preventing any significant effect to the PCU operation. Chip shear capability is explained by the fact that the column force to primary slide force ratio is 12, that is a control input force of 1 kg

[20] Actuators of this type are also installed in aileron control linkage.
[21] This is also true for secondary slide jamming provided the PCU was operating at maximum speeds.

in case of a jam results in 12 kg of force on the primary slide. The level of force that may be applied to the control column strongly exceeded the level of force required to shear the particles during the chip shear testing (Figure 65), which according to Parker Aerospace simulated the worst conditions that could create a jam. The PCU operation is more thoroughly studied in the engineering team report.

Thus, the mentioned examinations (taking into account the engineering simulation in Section 1.16.1) revealed no indications of failure or malfunction of the PCU's in the accident flight.

1.16.7. Pilot's Seats Fragments, Harness System and Flight Deck Door Lock Expertise

The expertise was conducted in the forensic center of the Transport Department for Privolzhsky Federal District of the Russian Ministry of Internal Affairs.

The expertise (Expert conclusion № 56 as of March 03, 2014) as well as the additional expert explanation provided in Committee of Inquiry Letter Ref. № 201/813401-13 as of January 21, 2015 revealed that taking into consideration the molecular genetic expertise[22] the PIC and the FO were apparently harnessed with seat belts: The PIC was seated in the LH seat, and the FO in the RH seat. It was not possible to determine the location of the shoulder straps.

The jump seat was apparently vacant.

At the time of the accident the flight deck door was locked.

1.16.8. Hydraulic fluid examination

The hydraulic fluid samples were taken when the PCU's were dismantled. The examination was conducted at the facilities of the State Research Institute for Civil Aviation (Conclusion № 18-2014/CS GSM-AK).

The examination revealed that:

- according to the tested physical and chemical characteristics as well as the nature of luminescent light and infrared specter, the examined samples could be identified as type HyJet IV-A plus fluids.

[22] In course of the expertise among the other examinations the forensic biological examination was done for to attribute the biological fragments (blood) collected from the cockpit seats to the certain persons.

- the values of relative density, conductivity, acid number, content of natrium, calcium, potassium, chlorine and sulphur are within statistical data for HyJet IV-A plus fluid samples in normal operations;
- both samples revealed high water content, excessive "purity class" value especially within the range of fine-dispersed fractions and the presence of cadmium.

Taking into account the circumstances of the fluid sampling (depressurization, aircraft destruction, fire fighting), most probably the water as well as mechanical additives and cadmium compounds appeared in the hydraulic fluid from the outside after the accident.

The Parker Aerospace also conducted a lab examination of the fluid sampled from the PCU input cavities as the PCU's were disassembled. The results of their examination (LR#241794 of March 07, 2014) are consistent with the conclusions drawn by the State Research Institute for Civil Aviation, FSUE.

Considering the abovementioned and the examination results in Section 1.16.6 the investigation team has concluded that the hydraulic fluid condition did not affect the accident outcome.

1.17. Organizational and Management Information

The owner of the aircraft was AWMS I (postal address: NY 10004, New York, Suite 100-5, One West Street, USA), that leased it to AWAS (Clarendon House, 2 Church Street, Hamilton HM 11, Bermuda). AWAS leased the aircraft to AWAIL (Ireland, Dublin 1, North Wall Quay 25/28), and the latter in its turn subleased it to JSC Bulgaria Air (Sophia Airport, Brussel Boulevard 1540, Sophia, Bulgaria). JSC Bulgaria Air subleased it to JSC Tatarstan Airlines as of December 09, 2008.

Tatarstan Airlines

The airline held an Aircraft Operator Certificate No. 40 issued by the Federal Air Transport Agency, Ministry of Transport of RF as of February 20, 2012. After the accident the AOC was revoked as of December 31, 2013 according to Rosaviatsiya Order No. 845 of December 19, 2013.

Before the revocation the airline operated the following aircraft types: TU-154M, TU-134, YK-42Д, Cessna 208B, Boeing 737-300/400/500, Airbus A319-100 and conducted cargo and passenger transportation.

From August 6, 2012 to August 10, 2012 Tatarstan Airlines underwent an IATA Operational Safety Audit (IOSA) and was granted an IOSA Certificate valid till December 17, 2014.

The operator's address: 420017, Republic of Tatarstan, Kazan, Laishevsky District, Airport.

The oversight of the operator was conducted by Tatar ITO of Rosaviatsyia that was closed after the accident (as per Rosaviatsyia Order No. 167 of March 28, 2014).

On October 8, 2013 the Head of Tatar ITO of Rosaviatsyia approved the Act of base inspection of Tatarstan Airlines with a general conclusion: "The operations of Tatarstan Airlines comply with certification requirements."

AQ ANO S7 Training (ANEO Sibir Airlines Aviation Training Center, ANEO S7 Training)

The aviation training center holds Certificate №53 initially issued as of September 3, 2007 by the Federal Transport Oversight Agency, Russian Ministry of Transport. Further the certificate was extended by the Federal Air Transport Agency and is valid till June 13, 2916. The certificate certifies that the abovementioned aviation training center complies with the Aviation Legislation of the Russian Federation and applicable regulations for civil aviation with regard to the issuance of the abovementioned certificate and is allowed to conduct training for qualifications in the annex to the certificate. The certificate contains 73 names of training courses, simulator training and OJT for various aircraft types including Boeing 737 and its modifications. The training provided is referred to as post-graduate. It includes recurrent training, conversion training to Boeing 737-300/400/500, initial training for international flights, simulator training, etc.

There are similar training programs for cabin attendants, engineering and ground handling staff, flight operation assistants and mechanics.

AQ ANO S7 Training is located at: 142072, Russia, Moscow Region, Domodedovo District, 54 Sanatorium Podmoskovye Settlement.

Tatarstan Airlines Aviation Staff Training Center

The Tatarstan Airlines Aviation Staff Training Center holds Certificate №34 issued as of September 9, 2013 by the Federal Air Transport Agency and is valid till September 8, 2016. The certificate certifies that the abovementioned aviation training center complies with the Aviation Legislation of the Russian Federation and applicable regulations for civil aviation with regard to the issuance of the abovementioned certificate and is able to conduct training for qualifications in the annex to the certificate.

The PIC of the Boeing 737-500 VQ-BBN underwent the following training in the mentioned training center: initial dangerous goods training, recurrent training for international flights, recurrent training for Boeing 737-300/400/500, ICAO English language proficiency testing.

The FO underwent the following training in the mentioned training center: recurrent training for international flights, recurrent training for Boeing 737-300/400/500, Dangerous Goods training, B-RNAV training, English for Flight Crews (radiotelephony phraseology) and ICAO English language proficiency testing.

Tatarstan Airlines Aviation Staff Training Center is located at: 420017, Russia, Kazan, Airport.

1.18. Additional Information

1.18.1. Analysis of State Requirements to Service Providers' Safety Management System and SMS Implementation at Tatarstan Airlines

In accordance with Para 3.1.3 of ICAO Annex 19 the State, within its State Safety Program shall require service providers, including operators, to implement their Safety Management Systems (SMS).

Para 5.5 of FAR-128 specifies that the Operator shall introduce a Safety Management System that:

- includes process for identification of existing and potential safety hazards and assessment of associated risks;
- ensures corrective actions are taken to maintain safety performance at acceptable level;
- ensures continuous monitoring and regular analysis of safety performance indicators;
- ensures constant improvement of mandatory SMS performance indicators.

On December 25, 2012 Federal Law №260 on Amendment to the Air Code of the Russian Federation was issued (effective from September 23, 2013). The amendment therein determines that the State Safety Management ***System*** is implemented in accordance with ICAO SARPs. The Government of the Russian Federation shall establish a procedure for development and implementation of safety management systems. The Civil Aviation Authority shall collects and analyze data on safety hazards and risks according to the procedure established by the Government.

Note: *The Air Code applies the term "State Safety Management **System**" though according to ICAO documents the State shall have a "State Safety **Program** (SSP)" and the service providers shall implement their "Safety Management **Systems**'" within the SSP.*

By the time of the accident no procedure had been established or implemented for the development and implementation of service providers' SMS or for the collection and analysis of safety hazards and risks data.

On May 6, 2008 a State Flight Safety ***Program*** for Civil Aviation Aircraft was approved by the Governmental Resolution of the Russian Federation №641-r. The Program reflects general requirements to the SSP and SMS as of 2008. Appended to the Program is a Roadmap for its implementation including 87 items with implementation deadlines, basically within 2008 and 2009. Most of the actions have not been taken or finished. At present the Program is outdated and it does not clearly define (establish) an acceptable level of safety performance.

Thus, there was actually no integrated (stable) SSP in the Russian Federation at the time of the accident. The basic SSP Components were not determined:

- state safety policy and objectives;
- state safety risk management;
- state safety assurance;
- state safety promotion;
- acceptable safety performance to be achieved.

The mentioned deficiencies of the SSP resulted in SMS deficiencies of certain operators that has been revealed by various accident investigation teams (e. g. Final Reports for ATR72-201 VP-BYZ accident as of April 02, 2012 and TU-204-100B RA-64047 accident as of December 29, 2012).

Similar deficiencies were found when analyzing the SMS of Tatarstan Airlines.

According to the submitted documents the airline started introducing SMS at the end of 2009. At the time of the accident the first edition of the corporate SMM was in force, endorsed by the General Director on November 15, 2009, also approved by the Operational Inspection Office of Rosaviatsyia and accepted by Tatar ITO of Rosaviatsyia. The SMM content analysis revealed that its provisions were on the whole consistent with respective provisions of relative ICAO documents. However, the available SMS documentation was basically a description of theoretical and practical requirements to the development of the SMS taken from ICAO documents, but not the way they are implemented. Some parts of the SMM contain semantic errors (probably resulting from literal translation), e. g. the notions of 'safety' and 'security' are used as synonyms. The airline did not have an SMS implementation plan which is a basic document, that shall determine implementation milestones and assign accountable managers required by ICAO Safety Management Manual (Para 5.4.4 Doc 9859)[23]. The abovementioned confirms that the corporate SMM was produced (actually copied and pasted from various sources) with a formal objective to

[23] The reference above is given to the third edition of ICAO SMM.

meet the relative regulations. The approval and acceptance of the SMM by the aviation authorities was also of a formal nature.

Chapter 2 of the SMM, in the section that determines the basic principles and scope of the SMS, states that the “safety management system is analyzed and improved regularly as well as when changes are introduced to the airline’s operations”. However, the submitted SMM (Edition 1) was dated November 2009 and has not been updated since then, despite significant changes to operations and appearance of new hazards: both qualitative (introduction of Airbus and Cessna aircraft) and quantitative changes to the fleet, high attrition rate, frequent change of top managers (since the summer of 2008 five General Directors were changed) etc.

Note: *Since 2010 22 PIC’s left the airline (13 – Boeing, 9 Airbus) as well as 21 FOs 17 – Boeing, 4 – Airbus) and 14 instructors (10 – Boeing, 4 – Airbus). Among them in 2010 four Boeing instructors left with the same number for 2011 and two for 2012. Meanwhile, since 2011 74 FOs came to the airline and in 2013 18 PIC’s came, including 6 for Airbus and 12 for Cessna. In 2011 and 2012 no PIC came to the airline.*

The airline did not submit any certificates to the investigation team that would have confirmed that any specialist had sufficient SMS competence. A number of certificates shown just confirm that some of the specialists only have general SMS knowledge that explains its applicability, no more. The certificates reveal that the mentioned specialists do not have knowledge on the implementation and operation of the SMS.

Note: *By the time of the accident there were no state requirements in the Russian Federation on SMS training. Furthermore, no aviation training organization had a solid SMS training program. The available SMS training programs included only a small SMS element that gave a general glimpse of the SMS but no explanation on its implementation and functioning.*

The SMS implementation was blocked by lack of competent staff, including top management. This was noted in the Act of Rostransnadzor Inspection as of February 2013.

Note: *Act of Rostransnadzor Inspection № 6.7.1-15 of February 27, 2013:*

Para 12 The airline’s Flight Operations Manual, Para 4, Page A-1-21 and Safety Management Manual, Chapter 5, Para 5.5, Page 5.11 do not assign an accountable manager for the implementation and *operation of the Safety Management System*[24]*. According to the SMS development principle the accountability for its operation shall be assigned to one of the top managers.*

Four months before the accident the airline's Flight Safety Inspection within the framework of an internal investigation of a flight delay defined the following SMS deficiencies in their statement.

Note: *Inspection Statement №46-2013 of July 10, 2013 (prescribed by Head of Flight Safety Inspection)*

The investigation of the flight delay revealed absence of comments in the operational report sheets of TU-154 crew members for the last two years.

This indicates that the SMS has not been implemented yet with regard to hazard identification and mandatory reporting.

This is a violation of ICAO SARPs and FAR-128 requirements.

It should be noted that the text of the statement indicates that the Flight Safety Inspection management mixed up the notions of mandatory and voluntary reports, voluntary reports being treated as mandatory in the airline to be reported via the comment sheet in the technical logbook after each flight. Secondly, hazard as a rule were identified in the airline after they were revealed (reactive approach), but not prevented (proactive and predictive approach) as required by ICAO SMM.

The airline did not have a safety management documentation system. This is evidenced by numerous statements by Rostransnadzor and Deputy General Director for Quality concerning the inconsistency of the airline organizational structure with the FOM, which resulted in the inconsistency of duties and blurred accountability of personnel including management personnel of various levels in charge of safety assurance.

In fact the airline violated Para 5.5 of FAR-128. The airline had neither a documented and implemented process for identification of existing and potential safety hazards nor a process for assessment of associated risks. They did not submit any corrective action plan to achieve and maintain target safety performance indicators that were not determined as well.

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[24] By the time of the accident the corrective action had been taken. Personal accountability for the effectiveness of safety management was assigned to Deputy General Director — Head of Flight Safety Inspection.

Section 4.2.1 “Safety Culture” of the airline SMM contains provisions determining that “one of the main indicators of the management commitment to safety assurance is the adequacy of provided resources. ... provision of required resources shall be consistent with the stated objectives of the organization in terms of safety assurance”.

Meanwhile, since 2011 the airline had encountered financial difficulties, confirmed by Acts of Base Inspections of that period. The Act for 2011 runs that “Tatarstan Airlines still have a possibility to recover financial stability” and the following conclusion is made: “Financial state of the airline complies with certification requirements”.

FAR-11 contain the following provisions on financial soundness of the Operator:

- Para 10. The Applicant (Operator) shall confirm the availability of sufficient financial resources and property for safe operation of aircraft and maintenance of appropriate level of airworthiness, including repair funds, for flight operation and support of declared aircraft, for quality assurance of provided services and for training of aviation staff.

  To assess if the financial resources are sufficient the Operator provides the civil aviation authority with financial and statistical data as per the established of accounting and state statistical reporting.
- Para 25 The Applicant applying for an Aircraft Operator Certificate shall develop a business plan containing a justification of their ability to complete the planned flight program within 24 months and assurance of defrayal of pertinent expenses without any income within 3 months since the start of operations.

  The Operator applying for the introduction of changes into their operations including new aircraft types, start of international flights, changes to the base airport, attaches to the application pertinent changes and additions to the business plan.

Thus, the only quantitative criterion of the “sufficient financial resources” is the assurance of defrayal of pertinent expenses without any income ***within 3 months since the start of operations.*** None of the paragraphs directly limits financial indicators for the declared operations. On October 8, 2013 (right before the accident) the Head of Tatar ITO of Rosaviatsyia approved the Act of base inspection of Tatarstan Airlines with a general conclusion: “The operations of the Operator comply with certification requirements.” Meanwhile, Section “Financial status” of the Act characterizes the Operator as having an excessively high level of credit indebtedness at the end of the accounting period. The value of the indebtedness matches an average monthly cost price of the Operator, which indicates financial crisis of the Operator and an existing insolvency risk. The airline’s operations are unprofitable. Current solvency is unstable, with significant deficiency of long-term financial sources of current operations assurance or a significant level of debt load, the Operator is in crisis; as the deficiency in resources and debt load increase, the risk of insolvency and bankruptcy gets higher.

Taking into account the abovementioned as well as other materials available to the investigation team, it can be concluded that for a long period of time the airline did not and could not (due to its financial status) allocate sufficient resources for safety assurance, including simulator training (see Section 1.5.2). Despite the repeated deficiencies (remarks) during regular checks concerning a number of the pilots (including PIC's and FOs) none of the line pilots underwent extra simulator sessions and none was suspended from flights after simulator training due to low knowledge or flying skills.

Thus, the investigation team concludes that the implementation of the SMS in the airline was at the initial level. In fact the SMS did not reach its objectives.

1.18.2. Analysis of Training Organizations Certification and Licensing Requirements and their implementation at ANEO S7 Training.

According to Para 1.2 and 1.3, Chapter 3, FAR-23 all civil aviation training centers shall undergo mandatory certification by the applicable aviation authority. According to Para 1.10 the aviation training center acquire the right to conduct professional training as per the declared programs since the certificate is issued.

Meanwhile, at the time the accident crew members underwent conversion training for Boeing 737 effective were the Law on Education of the Russian Federation № 3266-1 of July 10, 1992 with pertinent revisions (expired on September 1, 2013) and the Provision on Educational Activity Licensing approved by Governmental Resolution №277 of March 31, 2009 (superseded by Governmental Resolution №174 of March 16, 2011 "On Approving Provision on Educational Activity Licensing"). In accordance with Para 6, Article 33 of the Law on Education an educational organization acquired the right to conduct educational activities since it was granted a license (permit).

According to Para 1 of the Provision on Educational Activity Licensing the licensing was conducted based on the graduate and (or) post-graduate education programs, as well as professional training programs.

According to Para 1, Article 33 of the Law on Education educational organizations, in accordance with their license, issued documents certifying completion of relative education and (or) receiving relative qualification as mentioned in the license to persons that passed graduation tests.

Educational organizations issued the following documents to those who successfully completed the training course (according to Para 7 and 28 of the Provision on Educational Organization of Post-graduate Professional Education):

- certificate on refresher training for persons that underwent short-term training of 72 to 100 hours;
- certificate on advanced training for persons that underwent training of more than 100 hours;
- diploma on professional conversion training for persons that underwent training of more than 500 hours;
- diploma on qualification for persons that underwent training of more than 1000 hours.

Thus, matching of the FAR-23 provisions and educational regulations reveals that professional conversion training of the accident crew for Boeing 737 should have been conducted on the basis of a certificate (FAR-23) and a license (Law on Education) in accordance with the approved training programs for more than 500 hours.

At the time of conversion training of the PIC and FO the Certificate of Compliance №52/258 issued on September 3, 2007 by the FATA to the ANEO Sibir Airlines Aviation Training Center was effective. Appended to the mentioned Certificate are training programs that the training center was allowed to apply, including conversion training of flight crews for Boeing 737.

The program “Conversion training of flight crews for Boeing 737-300/400/500” was approved by the Head of Flight Operations Oversight Department of FATA as of April 9, 2008 and included 136 hours of ground training, 15 hours of testing and 84 hours of simulator training (total of 235 hours). The PIC underwent training in accordance with that program.

The FO underwent training in accordance with the “Program of Conversion Training of Flight Crews for Boeing 737-300,400,500/600,700,800” approved by the Head of Flight Operations Department of Rosaviatsyia as of October 6, 2009. The mentioned program included 120 hours of ground training, 16 academic hours of emergency procedures training and 84 hours of simulator training (total of 220 hours).

At the time the PIC’s conversion training started, ANEO Sibir Airlines Aviation Training Center was licensed by the Ministry for Education of Moscow Region License for Educational Activity Series A, Form Number 321662, registry № 62999 as of February 6, 2009, valid till October 12, 2009. The following license was issued on November 26, 2009, Series A, Form Number 337405, registry №63929. This license was replaced on February 5, 2010 due to the change in the licensee’s name to ANEO S7 Training, License Series A, Form Number 345034, registry №64216 (valid till June 29, 2014). The conversion training programs underwent by the

PIC and the FO are not listed in the Appendices to the mentioned licenses. It should be also mentioned that the training programs underwent by the PIC and the FO could not be classified as professional conversion training programs according to the Ministry of Education criteria due to their duration (less than 500 hours). Furthermore, while the PIC was under training (from October 1, 2009 to March 28, 2010) for a period of time (October 12, 2009 to November 26, 2009) ANEO Sibir Airlines Aviation Training Center did not have a valid license of the Ministry for Education of Moscow Region.

Within 2009 to 2013 the activities of ANEO Sibir Airlines Aviation Training Center (ANEO S7 Training) was checked 9 times by commissions of Rosaviatsyia and three times by commissions of the Ministry for Education, but none of their inspection acts indicated the non-compliance of the educational activity with the established criteria.

1.18.3. Analysis of Aviation Personnel Training and Conversion Training System (based on the example of ANEO S7 Training)

The procedures for certification of aviation training centers in the Russian Federation is determined by FAR-23. The objective of FAR-23 provisions implementation is further improvement of civil aviation personnel training in aviation training centers of the Russian Federation. The abovementioned document establishes the way accredited aviation authorities shall interact with aviation training centers in the course of certification of the latter.

It should be noted that the mentioned document was enforced in January 1999 and has not changed since then, despite the publication of ICAO Manual on the Approval of Training Organization (First Edition in 2006 and Second in 2012), significant changes introduced to Russian Civil Aviation, as well as numerous complaints about the operation of training centers including findings of accident investigations.

FAR-23 includes of the following definitions:

Professional training – an accelerated acquisition of skills required to perform certain work.

Theoretical training – a stage in professional training of aviation personnel that aims at acquisition of specific knowledge, their maintenance and improvement in compliance with the established requirements.

Simulator training – a stage in professional training of aviation personnel that aims at acquisition, maintenance and improvement of specific practical abilities and skills with various training devices.

Flight training – a stage in professional training of aviation personnel that aims at elaborating practical skills and abilities in real flight conditions.

Conversion (transition) training – a stage in professional training of aviation personnel that aims at acquisition of type rating for other aircraft types.

Para 3.1.1 of FAR-23 (Section 3 Aviation training Centers. General Requirements and Main Objectives) determines that all kinds of training shall be conducted with mandatory accountability of a specific aviation training center for the quality of training of each individual trainee, i.e. for the certificate issued after a successful completion of the training course certifying the acquired knowledge and skills. This provision shall be complied with even when freelance teachers and flight instructors are utilized.

To fulfil the set objectives an aviation training center shall have, above others (FAR-23, Section I, Para 3.2.1):

- staff teachers and instructors;
- FFS for the applicable aircraft types;
- a possibility to use an aircraft and an aerodrome to conduct a flight training.

To meet the mentioned requirements a training center shall have, as a minimum, a flight methodical squadron, either owned or leased aircraft, and use an aerodrome that would lead to payments for the takeoffs and landings, fuels and fluids and navigation service. To conduct flights it is also required to hold an AOC. This can lead to the increased price of the training and can make a training center noncompetitive.

Most aviation training centers use a different scheme, relaying a significant workload on freelance teachers and flight instructors who are employed by airlines. This possibility is provided by Para 4.1 and 4.2, Section II of FAR-23. Meanwhile, there is certain inconsistency between provisions of Para 3.2.1 (staff teachers and instructors) and Para 4.1 (flight training may be conducted with use of sufficient number of instructors and aircraft of an operator as required). It should be also noted that Para 4.1 could lead to a conclusion that FAR-23 provides for a possibility of using instructors (and aircraft) of a specific operator (who has sent their pilots for training), but not any freelance instructors.

FAR-23 has no recommendations as to how the invited instructors from airlines shall be employed. The employment procedure is not regulated. Currently instructors are employed in the following ways:

- as per an agreement with an airline, the airline accounting the instructors' working hours and paying for their work;
- as per an agreement with a physical person of conducting one-time job within the period they are free from the main job.

The investigation team draws attention to the issue of accounting work and rest time of the used instructors which is irregular in the second case.

It should be noted that currently flight training (as defined by FAR-23) is almost never used for foreign types of aircraft. Instead FFS training is applied. FAR-23 does not specify qualification requirements for teachers and instructors that are authorized to conduct this type of training. Para 3.3 stipulates that specific requirements to the organization of simulator training according to the declared programs as well as its duration and regularity shall be determined by departmental regulations. Similar provisions are contained in Para 2.3 with regard to theoretical training and in Para 4.5 with respect to flight training. Meanwhile, there is no unified regulating document that would determine the mentioned requirements to theoretical, simulator and flight training. The same is true with respect to Section 5 “General Requirements to Training Programs (Courses)” of FAR-23. Some requirements are present in various Federal Aviation Rules (e. g. FAR-147 determines criteria for the acquisition of instructor rating) but there is no solid regulatory basis that would regulate the operation of aviation training centers and type rating procedure. The mentioned deficiencies as well as the absence of regulatory basis in the Russian Federation with respect to the implementation of SMS in training organizations (the requirement to implement SMS in training organizations is now specified in ICAO Annex 19, and before it was regulated by ICAO Annex I Personnel Licensing) do not ensure a unified state policy of aviation personnel training and do not allow training organizations to implement effective SMS, which results in the quality of aviation personnel training. In the current circumstances the quality of training cannot be warranted by the existing system (regulatory basis), but mostly depends on the decisions taken by an individual training center as to how to deal with specific training issues not regulated by the authority.

Neither FAR-23 nor other regulations or guidance documentation contain any provisions that would regulate the organization of instructor’s work, trainee group formation or determine the number of instructors required to conduct the training. These issues are neither determined by the aviation training center’s documents, which leads to the lack of methodology and non-compliance with the basic principles of flight training. As there are no applicable requirements, the training center does not have to provide methodological guidance to the instructors or elaborate training methods and techniques for the modern aircraft types, therefore all accountability for the methodological training of instructors is relayed to the operator whose instructors are used, though the training center is accountable for the quality of training provided.

As instructors are occupied with work for their airline, the training center invites free instructors on “leftovers” principle. As a result a new instructor can be invited to each training event, who as a rule does not have required information on the level of training achieved by the trainees, their weak points and issues of concern. Every invited instructor conducts training in their own way, which can have a negative effect on the acquisition of knowledge and skills.

Thus, the regulatory basis that regulates the operation of aviation training centers requires significant improvement with consideration of ICAO Annex 1 and Annex 19 provisions as well as ICAO Doc 9859 “Safety Management Manual” and Doc 9841 “Manual on the Approval of Training Organizations”.

The abovementioned deficiencies became totally apparent during the PIC and FO’s training at ANEO S7 Training and are detailed in Section 2.3.

1.18.4. Analysis of Flight Time, Flight Duty and Rest Planning and Tracking at Tatarstan Airlines

The accountability for tracking flight crews' cumulative duty time and rest time is stipulated by Order №139. The same requirements are reflected in Appendix 1 to the Collective Agreement of Tatarstan Airlines with the same name as Order №139: Provision on Flight Time, Duty Time and Rest Time of Flight Crews (further referred to as Appendix 1 to the Collective Agreement).

All local airline documents shall comply with the state requirements in Order №139.

Note: ***Order №139, Section 1, General***

Para 3 The regulations of the present Provision are mandatory for use when developing operators’ Flight Operations Manuals, drawing duty schedules for flight crews and aircraft flight schedules.

The tracking of flight crews' duty time shall be conducted by cumulating the duration of various kinds of work performed by flight crews. The tracking procedure and kinds of work to be tracked are determined by Order №139.

Note: ***Order №139 and Appendix 1 to the Collective Agreement***

Para 66 The employer shall ensure maintenance of flight crews flight time, duty time and rest time records in the following way:

a) flight time is recorded in the flight task and individual pilot logs;

b) flight shift duration is recorded in the flight task;

c) duty time, rest time and overtime are recorded in the work time roster.

Para 5 of Order №139 determines that the flight crew duty time consists of the flight shift time, ground time between flight shifts and time spent for transferring a non-operating crew member at the behest of the employer. According to Para 14 of Order №139 the ground time between flight shifts includes:

“a) time for preflight preparation, debriefings, professional training, simulator training, tests, filling in flight and service documents as well as study of documentation regulating the organization, support and conduct of flights.

b) time being in reserve;

c) time for staying in an off-base airport at the behest of the employer in order to continue the flight task (further referred to as awaiting departure time at off-base airports between flight shifts), as long as specified in Para 27 of the present Provision.

c) time of aircraft embarkation and disembarkation;

d) time for other duties not related to the flight task.

The start and end of ground work as specified in a) and d) above are established by the Collective Agreement or organization’s work arrangements”.

The obligatory nature of medical certification for flight crews is regulated by: The Labour Code of the Russian Federation (further referred to as RF Labour Code), Order №139 and FAR MA CA. Para 51 of Order №139 determines that the Employer shall provide flight crews with the following time periods to undergo mandatory medical certification and medical examinations (as prescribed by the doctor)

a) a quarterly medical certification - two calendar days;

b) a semiannual medical certification - four calendar days.

Passing the mandatory medical certification is the responsibility of the Employee. According to the Collective Agreement the Employee is paid average wages for the period of mandatory medical certification. Thus, time spent on the medical certification is part of the duty time and shall be taken into account when tracking the duty time.

The person in charge of the flight crew duty planning at Tatarstan Airlines was Expert for Flight Operations Planning and Arrangement (further referred to as FOPA Expert). In accordance with Para 3.2 of the Provision on Flight Detachment of Tatarstan Airlines (further referred to as Provision on FD) the mentioned expert worked for the Flight Detachment.

Note: ***Provision on Flight Detachment of Tatarstan Airlines. Section 3. Flight Detachment Structure***

Para 3.2 Based on its main functions the FD includes: FD commander, his deputy and assistant, doctor, operations engineer, chief navigator, chief flight engineer, flight squadrons, FOPA experts and flight crews.

When performing his duties the FOPA expert used the Provision on FD and his job description (further referred to as JD). According to JD Para 1.2, 2.1, 2.17 the mentioned expert was in charge of tracking flight and duty time that fell under flight operations.

Note: ***FOPA Expert JD Section 1. General***

Para 1.2. The main tasks of the FOPA Expert are:

arrangement and conduct of planning duty and rest time of flight crews in the FD within the time when flights are conducted in compliance with the RF Labour Code requirements and the Collective Agreement of Tatarstan Airlines.

ensuring that flights are filled with a required number of flight crews according to the norms and the Provision on flight and rest time of flight crews.

Section 2. Duties:

The FOPA Expert JD is obliged to:

Para 2.1 Perform flight planning in compliance with the requirements of:

the AOC;

applicable state regulatory documents;

Provision on Flight Detachment.

IOSA Standards and Recommended Practices and GOST R ISO "Quality Management System. Requirements";

corporate standards for quality and safety.

Para 2.17 Track flight and duty time of flight personnel for each 10 days, each month.

In accordance with Para 4.7 the FOPA expert is only accountable for exceeding monthly and yearly flight time limitations, however this Para does not mention the accountability for compliance with duty time norms.

The airline did not have any form to be filled by the FOPA expert. Completing such a form would have been an evidence of flight and duty time control. Meanwhile, neither the job description nor the Provision on FD contained a procedure for coordination between various departments that would have explained where, when and to whom the FOPA experts were to transfer the available information on duty time spent for flight operations. If such a procedure had existed, it could have allowed to track the cumulative duty time for the flight operations period and the ground time period between the flight shifts. This is required for total duty time control for fatigue management.

Para 64, Chapter XX “Requirements for Duty and Rest Time Planning and Tracking” of Order №139 determines that provided there are working shifts and tracking of cumulative duty time, a flight crew member shall work for an established duty time duration in accordance with duty rosters”. Duty rosters are compiled by the Employer considering the opinion of Employees’ representatives for a period of no less than one month and presented to personnel no later than one month before they enter into force. In case of operational need rosters can be changed with consideration of the opinion of Employees’ representatives and the changes shall be presented to personnel no later than five days before they enter into force.

It should be noted that according to Para 65 of Order №139 the Employer shall ensure accurate tracking of overtime work. Chapter 7 (Section 7.4), Part A of the FOM of Tatarstan Airlines contains a provision on the necessity to track overtime work, however in fact such tracking was not performed.

In accordance with the Collective Agreement (Para 3.1.4) the airline applied quarterly tracking of cumulative duty time, which complies with Para 7 of Order №139.

For cumulative duty time tracking purposes the FOM, Appendix 5 “Provision on planning and tracking records maintenance” to Chapter 2 “Flight Operations Control and Oversight” of Part A prescribes a procedure for duty time planning and tracking as well as the way the duty roster is to be filled.

Note: ***FOM, Part A, Chapter 2, Appendix 5 Provision on planning and tracking records maintenance”***

Section VI. The following symbols are used for duty and rest time planning:

- *Flight – flight number;*
- *Day off – capital «В»;*
- *Standby – capital «Р»;*
- *Simulator training – capital «Т»;*
- *Days when a pilot is not engaged in flights, but due to operational need shall be available for flight duty – capital «Д»;*
- *Training – capital «У»;*
- *Flight and Engineering Conference – capital «ЛТК»;*
- *Debriefing «Разб»;*
- *Preflight preparation – «Пр»;*
- *Medical certification – «ВЛЭК»;*

– Besides symbols *«Отпуск» (Vacation) and «Болен» (Sick leave) are used.*

The duty rosters in the airline were not published to the flight crews. This makes it impossible to compare the initially planned roster and the actual amount of work and assess the crew planning quality. According to the FOPA expert the planning was conducted for a period of up to 15 days, which is inconsistent with Para 64 of Order №139 (planning shall be performed for one month's period). However, even the existing roster was almost never complied with (due to aircraft replacement, interline with another airline and untimely return of flight crews to the base airport). Flights were conducted on the "just-in-time" principle.

The rosters were filled in pencil, which made them possible to be changed. Instead of airport standby the airline made use of standby at home. However, such standby activity was not always rostered, could sometimes be rostered as days off duty and were not identified in any way in the duty time tracking roster. This makes control of cumulative duty time of flight crews impossible. The duty time rosters also revealed evidence of inconsistency with the actual production activity. This enabled the airline to hold back (diminish) the actual flight crews duty time.

For example, according to the available data, on September 17, 2013 the PIC underwent the semiannual medical certification. He consulted three doctors: a surgeon, an urologist and the FD doctor who authorized him for flights. However, passing the medical certification was not rostered, according to the duty time roster the PIC had a day off duty on that day. Meanwhile, all pilots who were not engaged in flights underwent seasonal training on that day, while the PIC, though he had just come back from the vacation (the vacation lasted from September 2 to September 16, 2013), was rostered as having a day off instead of the seasonal training. On the next day, September 18, there was a debriefing in the Flight Detachment and, according to the airline personnel's statements, the PIC attended it while he was rostered again as having a day off duty. On September 24 the PIC was rostered again as having a day off though seasonal training was conducted at the air squadron. Most probably the mentioned days off duty were rostered to satisfy the requirements of Para 63 of Order №139 concerning the weekly uninterrupted rest period (after six duty days in a row). The same was true with regard to the FO.

The FOM (Item II, Para 3.1 "General" of Appendix 5 "Provision on planning and tracking records maintenance" to Chapter 2 "Flight Operations Control and Oversight" of Part A) prescribes that compiling the duty and rest time roster for flight crews shall be the responsibility of the flight group commander or flight group instructor, but not of a FOPA expert. Changes to the roster can be introduced by the flight group commander or flight group instructor, while the duty and rest time tracking is conducted by the air squadron commander assistant. There was no Provision on the flight group or air squadron as Flight Detachment structural units, which makes it impossible to understand the functions of these structural units in flight operations management processes or assess the coordination of their personnel. This flight operations organization deficiency was reflected in Flight Operations Observations 1 and 2 of the Act of Base Inspection of Tatarstan Airlines approved by Head of the Tatar ITO of Rosaviatsyia as of October 8, 2013.

However, the job description of the air squadron commander assistant did not prescribe his responsibility for flight crew duty time tracking. The responsibility of the air squadron commander assistant to track duty time was not regulated by any local regulations of the airline. Meanwhile, the roster filled by them was often inconsistent with either the actual duty hours spent on the ground or days of the month when the crews had ground duties between flight duty shifts. Just like with the FOPA expert there was no department coordination procedure that would establish where, when and to whom the air squadron commander assistant was to transfer the duty time roster reflecting duty periods between flight duty shifts.

In accordance with the Provision on the FD, the Flight Service doctor was responsible for compliance with the duty and rest norms. However, the job description of the Flight Service doctor did not contain a clear description of this responsibility or any accountability for compliance with the norms.

It should be specifically noted that Appendix 1 to the Collective Agreement on the duty time and rest periods of flight personnel, Para 7 of Section II prescribes that “duty time tracking is made by the Employer with consideration of the opinion of the Employees’ representatives”. However, there was no procedure in the airline to consider the opinion of the trade union.

As mentioned before, the cumulative duty time was tracked on the quarterly basis[25]. Order №139 and Appendix 1 to the Collective Agreement have similar interpretation of duty time norms as to the number of standby and split flight shifts within the accounting period. The provisions of Order №139 as to split flight shifts are consistent with Article 105 of the RF Labour Code.

Note:	***RF Labour Code. Article 105. Split Shift***
	At jobs where it is required due to special nature of work, or when conducting jobs with irregular intensity during the work day (shift) the work day may be split into parts so that the overall duration of the duty time should not exceed the established daily duty time

[25] However, Chapter 7 of the FOM contains norms for standby shifts that specify that the duty time accounting period is one month, which is inconsistent with the Collective Agreement.

duration. Such a split is made by the Employer based on a local regulation accepted with consideration of the opinion of a selective labour union.

Order №139

Para 25 A crew member can be assigned for standby no more than four times within the accounting period. The duration of standby shall not exceed 12 hours within the successive 24 hours.

Section X. Duration of duty time and rest period during split shift when conducting transportation flights

Para 29 When conducting flights with a minimum flight crew number the flight time of a flight crew member can be split into two parts upon their consent.

The break between the two part of the split shift is not counted for the purpose of cumulative flight time.

Shift split is made by the Employer based on a local regulation accepted with consideration of the opinion of a selective labour union.

Para 30 It is allowed to split no more than two shifts within the accounting period for duty time and no more than two successive flight shifts.

Para 31 The total duration of the split shift shall not exceed the duration of a flight shift as established by Para 16 and 17 of the present Provision.

Para 32 It is not allowed to split flight shifts when the airplane is operated by augmented crew.

Para 33 After two successive split shifts a flight crew shall have a minimum of 48-hour rest at the base airport.

As becomes apparent from the abovementioned documents, in order to conduct split shift flights the airline shall have a local regulatory document accepted with consideration of the opinion of a selective trade union of the organization and a consent of the flight crew to work split shifts. However, the airline did not have any local regulatory document that would have been accepted with respect to the trade union opinion, or any consent of flight crew members to conduct split shifts.

The Act of Rostransnadzor Inspection № 6.7.1-15 as of February 27, 2013 revealed the following violations of duty time limitations and rest periods. In particular, some of the flight personnel were not provided with weekly days off duty, and the time spent on debriefings, training, medical certification, etc. was not completely counted for cumulative duty hours. It was noted that the available rosters did not reflect the actual duration of flight crew duty time. Rostransnadzor made a statement on the violation of the requirements of Para 5.23 of FAR 128, and Para 51, 61, 63-66 of Order №139.

The internal investigation on compliance with duty time limitations and rest period requirements in the Cabin Attendant Department conducted by the Tatar ITO of Rosaviatsyia in July 2013 based on reports made by several cabin crew members also revealed violations in the provisions of days off duty by the airline and the necessity to revise Order №139.

The unsatisfactory duty time tracking in the airline resulted in the violation of duty time limitations and rest periods by the PIC and the FO.

Analysis of compliance with the duty time limitations and rest periods was conducted on the basis of individual flight logs, duty time rosters, daily flight schedules, flight tasks, accounting data on the payments for the actual flights and the cumulative duty time roster. The analysis was made with respect to the provision of the RF Labour Code, Order of the Russian Ministry for Health and Social Development №588н as of August 13, 2009 (further referred to as Order №588н) on the accounting duty time norms for specific calendar periods (month, quarter, year) depending on the established weekly duty time, Order №139, Collective Agreement, FOM of Tatarstan Airlines and the 2013 occupational calendar.

It should be noted that flight time is part of duty time. The duty time norms are formed on the basis of an order on duty time norms calculating procedure and the occupational calendar. The absence of an employee within an accounting period for a valid reason (e. g. for a vacation) reduces the flight and duty time norm for the respective value, which complies with Article 104 of the RF Labour Code.

Note:	***RF Labour Code , Article 104, Cumulative Duty Time*** *When the production environment of a private entrepreneur, an organization, on the whole or for some of the jobs, cannot comply with the daily or weekly norms established for a specific employee category, it is allowed to apply cumulative duty hours tracking so*

that the duration of duty time for an accounting period (month, quarter and other periods) did not exceed the normal amount of duty hours. The accounting period cannot exceed one year.

The normal amount of duty hours for an accounting period is determined on the basis of the weekly duty time duration of specific employee categories. For employees working part-time day and (or) part-time week the normal amount of duty hours is reduced respectively.

The procedure for cumulative duty time accounting is established by corporate work arrangements.

As mentioned before, the airline did not have a procedure for cumulative duty time tracking.

Analysis of the PIC's Duty Time and Rest Period Within the Last Month[26] Before the Accident

Within the period of October 17 to November 16, 2013 the PIC had 36 flight hours[27], which did not exceed the calculated flight time norm of 69 hours. However, having a norm for that month of 21 work days with 3 days off duty, the PIC had only one day off according to the available documents, and he spent 8 days flying and 16 days performing ground duties, 2 of which were officially during his vacation (from November 1 to November 7). The recalling from vacation was not officially recorded. The duty time norm for that period was 126 hours, whereas in fact he worked for 198 hours (according to the available documentation).

Analysis of the PIC's Duty Time and Rest Period within the Third Calendar Quarter of 2013

Such analysis is required as the accounting period for the cumulative duty time at Tatarstan Airlines was one quarter.

Within that quarter, consisting of 79 work days and 13 days off, the duty time norm was 475 hours. The analysis of the PIC's working time within July, August and September revealed that despite the working norm of 79 work days he worked for 55 days only, as he was on vacation for 24 work days. For the PIC's 55 work days he should have had 9 days off, with the duty time norm of 332 hours. However, in fact he had only one day off and he worked for 585 hours, which

[26] Hereinafter the investigation team assumes that with regard to crew fatigue management there is no difference between a calendar month and any 30 successive days.
[27] Hereinafter within this section flight hours are rounded to the nearest whole number.

exceeds by 23% even the total duty time norm (disregarding the time for vacation) for the third quarter of 2013. The established norm was exceeded by 253 hours or 76%.

The flight time analysis also reveals that the norm was exceeded. Taking into account the 55 work days of the PIC his personal norm was 186 flight hours, while his actual flight time was 223 hours.

Analysis of the PIC's Duty Time and Rest Period within the Last Three Calendar Months Before the Accident

Within that period, consisting of 79 work days and 13 days off, the duty time norm was 475 hours. The analysis of the PIC's working time within August, September and October revealed that despite the working norm of 79 work days he worked for 57 days only, as he was on vacation for 22 work days. For the PIC's 57 work days he should have had 9 days off, with the duty time norm of 344 hours. However, in fact did not have any day off and he worked for 594 hours, which exceeds by 25% even the total duty time norm (disregarding the time for vacation). The established norm was exceeded by 250 hours or 73%.

The flight time analysis also reveals that the norm was exceeded. Taking into account the 57 work days of the PIC his personal norm was 193 flight hours, while his actual flight time was 213 hours.

Other PIC's Duty Time and Rest Period Violations

Within 6 months before the accident (from May to October 2013) the PIC conducted split shift flights on May 3, May 14, June 2, August 28, September 16 and September 25. As was mentioned before, such flights were conducted in the airline in violation of Order №139 provisions: without a local regulatory document and without consent of crew members.

Within the third quarter of 2013 and within the successive three months[28] before the accident the PIC had three split flight shifts instead of the permitted 2.

Within the third quarter of 2013 the PIC was on standby 6 times with a norm of no more than 4.

Within the consecutive 3 months before the accident the PIC was on standby 12 times.

[28] Hereinafter the investigation team assumes that with regard to a crew fatigue management there is no difference between a calendar quarter and any 3 successive months.

Analysis of the FO's Duty Time and Rest Period Within the Last Month Before the Accident

Within the period of October 17 to November 16, 2013 the FO had 43 flight hours, which did not exceed the calculated flight time norm of 90 hours. However, having a norm for that period of 26 work days with 5 days off duty, the FO had only one day off according to the available documents. He spent 9 days flying and 21 days performing ground duties, furthermore having a duty time norm of 160 hours for the 26 work days he actually worked for 244 hours according to the available documents.

Analysis of the FO's Duty Time and Rest Period within the Third Calendar Quarter of 2013

Within that quarter, consisting of 79 work days and 13 days off, the duty time norm was 475 hours. The analysis of the FO's working time within July, August and September revealed that despite the working norm of 79 work days he worked for 59 days only, as he was on vacation for 20 work days. For the FO's 59 work days he should have had 9 days off, with the duty time norm of 355 hours. However, in fact he had only one day off and he worked for 633 hours, which exceeds by 33% even the total duty time norm for the third quarter of 2013. The established norm was exceeded by 278 hours or 78%.

The flight time analysis also reveals that the norm was exceeded. Taking into account the 59 work days of the PIC his personal norm was 199 flight hours, while his actual flight time was 209 hours.

Analysis of the FO's Duty Time and Rest Period Within the Last Three Months Before the Accident

Within that period, consisting of 79 work days and 13 days off, the duty time norm was 475 hours. The analysis of the FO's working time within August, September and October revealed that despite the working norm of 79 work days he worked for 59 days only, as he was on vacation for 20 work days. For the FO's 59 work days he should have had 9 days off, with the duty time norm of 355 hours. However, in fact did not have any day off and he worked for 639 hours, which exceeds by 35% even the total duty time norm. The established norm was exceeded by 284 hours or 80%.

The flight time analysis reveals that the FO did not exceed the flight time limitations. Taking into account the 59 work days of the PIC his personal norm was 199 flight hours, while his actual flight time was 192 hours.

Other FO's Duty Time and Rest Period Violations

Within 6 months before the accident (from May to October 2013) the FO conducted split shift flights on May 12, July 9, July 16, July 23, August 12, August 19, September 21, October 6 and October 15.

Within the third quarter of 2013 (July, August and September) the FO had five split flight shifts instead of the permitted 2. Within the successive three months before the accident the FO had 4 split flight shifts instead of 2.

Within the third quarter of 2013 the FO was on standby 7 times with a norm of no more than 4.

Within the consecutive 3 months before the accident the FO was on standby 10 times. In October the FO was on standby 7 times: on October 3, October 11, October 13, October 18, October 20, October 26 and October 27.

Exceeding Flight Time Norms

The flight time norms of the flight crew were exceeded by way of replacing a pilot's actual flight time by shorter flight time recorded in the individual flight logs.

Thus, in May 2013 the FO had actual 92 hours and 05 minutes of flight time, only 82 hours and 05 minutes are recorded in his individual log. In August 2013 the FO had actual 93.15 hours, while only 90.00 hours are recorded.

The airline was well aware of the exceedance of flight time norms established by Order №139. The available evidence includes an inspector statement № 18 of May, 2, 2011 prescribed on the basis of an internal inspection conducted by the Flight Safety Inspection addressed to Deputy General Director for Flight Operations Flight Service Director. The statement reveals a violation of the monthly flight time norms for 5 pilots including the PIC.

According to Act № T/12-26 of inspection conducted from November 12, 2012 by the Tatar Regional Office of Rostransnadzor, there were flight operations violations related to the extension of the monthly flight time norm up to 90 hours without a written consent of the pilots. The airline neglected the Rostransnadzor finding stating that it was prohibited to conduct flights with an exceeded flight time norm (up to 90 hours) without complying to legal regulations. The pilots signed their consent to fly with an extended flight time norm for the period of May to December 2013. However, in January and February 2013 the FO had already flown for over 80 hours each.

The Act of Base Inspection of Tatarstan Airlines approved by Head of Tatar ITO of Rosaviatsyia as of October 8, 2013 contains the following statement (Flight Operations Findings, Para 5): “there is a deficiency in flight personnel comparing to the required number...”. This finding confirms the impossibility of Tatarstan Airlines to conduct the declared number of flights without exceeding duty time limitations.

The above situation was inconsistent with Para 21 of FAR-11 running: “The Applicant (Operator) shall employ, in compliance with the legislation of the Russian Federation, flight personnel to form flight crews of a sufficient number to conduct the declared flight program of the Operator.”

Analysis of Leave Planning at Tatarstan Airlines

Article 123 of the RF Labour Code determines that “the regularity of paid leave provision is established annually in accordance with the leave schedule approved by the Employer with consideration of the opinion of a selective trade union no later than two weeks before the start of a new calendar year according to a procedure established by Article 372 of the present Code for local regulatory documents approval.” The leave schedule is mandatory for both the Employer and the Employee. The Employee shall be notified of the leave start with written acknowledgment no later than two weeks before it starts.”

Para 3.11.13 of the Collective Agreement prescribes the same provisions for leave management as in the RF Labour Code.

However, the airline actually did not notify personnel on their scheduled leaves with their written acknowledgement, while the employees’ applications for leaves either do not have a date of application or are dated later than the start of the actual leave. This is confirmed by the available leave applications of the PIC (available in investigation documentation).

In addition to the mentioned violations, the available leave schedule for the Flight Detachment did not have an approval date and was approved without consideration of the opinion of the selective trade union. Furthermore the schedule was not consistent with the actual leaves, did not contain the actual scheduled leave dates and was filled in pencil which gives ground for its correction as desired. Thus, according to the schedule the PIC was to be on leave in January 2013, while in fact he was on leave for 7 days at the end of February. In March he took another leave of 7 days which is not reflected in the schedule. The same was true with regard to the FO. The FO was to be on leave in January to February and in June to July, while in fact he was on leave in April and September. It should be noted that the permission to full the leave schedule in pencil is documented in Section 5 of Appendix 5 to Chapter 2, Part A of the FOM.

The analysis revealed that the airline personnel did not make use of the complete leave time.

Analysis of PIC's Leaves

In accordance with the available reference of the PIC's unutilized leave, it was 111 days. The analysis of the PIC's work for the last half year before the accident revealed that there was a great amount of overtime work without enough rest time to counteract the accumulated fatigue. The unutilized leave time could have also resulted in extra fatigue accumulation.

While being on leaves, the airline pilots were called out to duty. Thus, according to a corporate order on November 1 to 7, 2013 the PIC had to be on leave, which is reflected in the leave schedule. However, he was engaged in some ground activities without being officially recalled from the leave. In accordance with the flight schedule for November 1, 2013 he was to attend the Flight Detachment debriefing meeting which he did attend. In accordance with the flight schedule for November 2, 2013 he was on standby duty from 05:00 to 19:00. Additionally, on November 4 and 6 he was scheduled for the daily flight schedule, but did not actually fly.

This was not just a single case. For example, while being on leave from September 2 to 16, 2013 the PIC underwent medical certification on September 11 and 16, meaning he spent part of the leave time to prepare for the certification instead of having a rest. On September 16 the PIC was on a split flight duty. His flight duty time started at 2:45 and finished only at 20:30. On that day he made two return flights from Kazan to Moscow. This indicates that on September 16, 2013 ***within the same day*** the PIC was on leave, conducted flights and underwent medical certification, while according to the Duty Roster the PIC was engaged in seasonal training on September 16.

Analysis of FO's Leaves

In accordance with the available reference of the FO's unutilized leave, it was 275 days. Just with the PIC, a great amount of overtime work within the last 6 months before the accident without enough rest time as well as unutilized leave days could have resulted in accumulated fatigue.

Similar to the PIC, the FO, while being on official leave (from August 8, 2013 to September 22, 2013) flew to Prague on September 21, and to Moscow on September 22 without being officially called out from the leave. He was paid both for the leave and for the flights on these days.

Analysis of PIC's Business Trips

Business trips in the airline were not always used as appropriate. For example, according to business trip confirmation №777 of June 28, 2013 the PIC was to be in Moscow on July 3 to 5, 2013 for simulator training. However, on July 5, 2013 he was scheduled for and operated a return flight from Kazan to Dushanbe.

Such violations were reflected in the Act of Rostransnadzor Inspection №6.7.1-15 as of February 27, 2013.

Note: ***Act of Rostransnadzor Inspection № 6.7.1-15 of February 27, 2013***

Para 15: *there is no evidence of the actual training completed by a TU-154 PIC (Surname and Initials) who, according to the available tasks, was simultaneously undergoing recurrent training from January 20, 2012 to February 4, 2012 at Kazan and simulator training on February 2, 2012 at Ulyanovsk.*

1.18.5. Flight Crew English Language Proficiency

According to the information available to the investigation team the PIC was granted ICAO ELP Level 3 based on the Minutes of Qualification Test №52 as of April 27, 2009 (before the start of conversion training for Boeing 737) of Tatarstan Airlines Aviation Staff Training Center[29]. By the time of the accident the PIC was granted ICAO Level 4 (Minutes of Qualification Test №151 as of February 8, 2011).

By the time of conversion training the FO had only passed initial English language course for flight mechanics (according to the Application for conversion training to be a commercial pilot). The FO was granted ICAO Level 3 based on the Minutes of Qualification Test №194 as of May 26, 2011 and then ICAO Level 4 based on the Minutes of Qualification Test №254 as of November 9, 2012.

Both pilots were authorized for international flights (the PIC since August 25, 2010, the FO since July 3, 2012), meaning they were subject to the provisions of FAR "Requirements to Civil Aviation Flight Crews of the Russian Federation when Preparing for International Flights" approved by Order №90 of the Russian Ministry for Transport as of July 9, 2007(hereinafter referred to as FAR-90). According to FAR-90 flight crew members "shall demonstrate proficiency

[29] Other qualification test minutes referred to in this Section were also completed by Tatarstan Airlines Aviation Staff Training Center.

in General and Aviation English no lower than ICAO ELP Operational Level 4 and comply with listed in Addendum 1 and Supplement A to Para 1.2.9.4 of ICAO Annex 1.

FAR-148 effective at the time the flight crew underwent conversion training for Boeing 737 determined that “applicants sent for conversion training for other (new) types of civil aircraft if the aircraft documentation is presented in the English language, shall demonstrate English language proficiency at a level sufficient to understand the documentation and conduct operational procedures.” It should be noted that neither FAR-148 nor any other Russian regulations for civil aviation determine the criteria to assess a sufficient level of the English language in the specified context. The safety recommendation[30] given by the investigation team for the Boeing 737 VP-BKO accident that occurred on September 13, 2008 was not followed.

Note: *FAR-90 and FAR-148 were revoked by Order № 453 of the Russian Ministry for Transport as of December 27, 2012 “On Introducing Changes to Some Regulations of the Russian Ministry for Transport” (registered in the Russian Ministry of Justice on February 18, 2013 and officially published in The Rossiyskaya Gazeta newspaper on February 27, 2013 and enforced 90 days after the official publication. The requirements for flight crews engaged in international flights to demonstrate sufficient proficiency in the English language were introduced to FAR-147. However, after FAR-148 was revoked, there has been no requirement in any Russian civil aviation regulatory documents that flight crews being trained to fly foreign made aircraft with documentation presented only in the English language, shall demonstrate English language proficiency.*

Taking into account that all mandatory (AFM, FCOM, etc.) manuals and most guidance for Boeing 737 are only presented in the English language, the investigation team deemed it necessary to conduct an evaluation of the flight crew language proficiency level with participation of independent experts[31]. The evaluation was made on the basis of audio files containing records of the PIC and FO’s qualification tests provided by Tatarstan Airlines Aviation Staff Training Center.

The raters were asked to answer the following questions:

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[30] The recommendation was as follows: “develop and implement qualification requirements for English language proficiency for flight personnel operating aircraft with operational and technical documentation in English, as well as for maintenance personnel who conduct maintenance of the mentioned aircraft.

[31] The evaluation of the actual pilots’ ELP level was made by two independent experts ICAO ELP raters who had undergone special training and were registered in the List of Accredited Raters of Rosaviatsyia.

- What is the actual PIC's ELP level?
- What is the actual FO's ELP level?
- Was the actual ELP level sufficient for reading and understanding of texts in operational manuals and documentation in the English language?

The following documents and resources were used for the evaluation purposes:

- Annex 1 to Convention on International Civil Aviation *Personnel Licensing;*
- Annex 10, Volume II to Convention on International Civil Aviation *Communication Procedures;*
- ICAO Doc 4444, ATM/501 *Air Traffic Management/Procedures for Air Navigation Services;*
- ICAO Doc 9835 *Manual on the Implementation of ICAO Language Proficiency Requirements;*
- ICAO Cir 318 *Language Testing Criteria for Global Harmonization*;
- *The ICAO Language Proficiency Rating Scale: Indicative Reference Levels for Training Purposes , E. Mathews, P. Shawcross, 2005*;
- Materials from websites of international organizations engaged in language proficiency testing:

  http://www.govtilr.org

  http://www.actfl.org/sites/default/files/pdfs/public/ACTFLProficiencyGuidelines2012_FINAL.pdf,
  http://www.eui.eu/Documents/ServicesAdmin/LanguageCentre/CEF.pdf,
  http://theenglishacademy.ie/english-courses/alte.html,
  https://www.ielts.org/institutions/test_format_and_results/ielts_band_scores.aspx,
  http://www.examenglish.com/TOEIC/.

The records were rated against six ICAO language proficiency skills Pronunciation, Structure, Vocabulary, Fluency, Comprehension and Interaction. The evaluation of both pilots showed some of the skills being at Pre-operational Level 3 of the Rating Scale. However, the conclusion was made by both experts that both pilots demonstrated the general level of ELP at ICAO Elementary Level 2.

To answer the third question it had to be taken into account that currently there are no ICAO SARPs that would specify requirements to the understanding of written texts applicable to non-native speakers of English when trained to fly a certain aircraft type. Therefore two methods below were used to answer the question:

- correlation of the test evaluation results for Structure and Vocabulary to the available documents used for Boeing 737 conversion training in the English language;
- extrapolation of the ICAO Rating Scale to other English language proficiency rating scales that include Reading as one of the determinable elements of language proficiency.

The analysis of manufacturer's documents used for conversion training, the correlation of their contents to the PIC and FO's test results as to Structure and Vocabulary and the extrapolation of ICAO scale to other scales including Reading as one of the language proficiency skills, revealed that the PIC and FO's English language proficiency was insufficient for the Boeing 737 conversion training.

Note: *The Final Report on the ATR-72 VP-BYZ accident that occurred on April 2, 2012 at Tyumen airport reveals that even ICAO Operational Level 4 does not guarantee clear understanding of operational manuals and guidance in English.*

The experts also noted a number of deficiencies in the testing process arrangement. The test used for ELP assessment could not be considered valid, as its format was not consistent with the ICAO scale. Specifically selected and trained interlocutors have to be used for the test. The interlocutors' low language proficiency level, misunderstanding of objectives and methodology of the testing (or their intentional violation), direct assistance and hints provided to the test-takers reveal unsatisfactory level of the interlocutors' competence.

1.18.6. Aeroplane State Awareness During Go-Around Safety Study

Note: *The present chapter was included to the Final Report with aim to invite attention of aviation administrations, ATC units, aircraft manufacturers, airlines, and aviation training centers to the issue of losing aeroplane state awareness while conducting a go-around, as well as to support FR SR 5.2.36. The general information about the issue was included into the present chapter and it doesn't relate to the specific aircraft type and/or the operator. Regardless of the fact that not all hazards were shown up in the accident flight, the Investigation Team believes it is necessary to* *include into the FR all of them. The factors that had been shown up during the accident flight are discussed in Part ANALYSIS.*

In August 2013 the BEA published the results of a specific safety study relating to “aeroplane state awareness during go-around” (ASAGA)[32].

According to statistical data of the study between 1985 and 2010 15 ASAGA accidents occurred with a total number of fatalities being 954 persons. There were also a number of occurrences that did not end up as accidents.

Within the framework of the study, 16 accident or incidents characteristic of ASAGA events were studied. The BEA undertook a series of simulator sessions and a survey was circulated amongst flight crews.

The study determined that ASAGA-type events are due to a combination of the following:

- time pressure and a high workload;
- the inadequate monitoring of primary flight parameters during go-arounds, especially with a startle effect;
- the difficulty in applying CRM principles in a startle situation;
- inadequate monitoring by the PNF;
- the low number of go-arounds with all engines operating performed by crews, both in flight and in the simulator;
- inadequate fidelity on flight simulators;
- the non-detection of the position of nose-up trim by the crew during go-arounds;
- interference from ATC;
- the mismatch between the design of procedures for go-arounds and the performance characteristics of modern public transport aeroplanes;
- aircrew learning teamwork on unrepresentative aeroplanes before a first transport aircraft;

[32] Complete survey is published at: **http://www.bea.aero/etudes/asaga/asaga.php.**

– somatogravic illusions related to excessive thrust on aeroplanes; The lack of evaluation of visual scan during the go-around;

– the channelized attention of a crew member;

– the difficulty of reading and understanding FMA modes;

– excessive time spent by the PNF on manipulating the FCU/MCP.

The investigation team notes similar results received during the simulator experiment within the framework of this investigation (Section 1.16.5).

Based on the safety study, the BEA worked out a number of safety recommendations[33]:

FLIGHT CREW TRAINING

Monitoring primary flight parameters

Analysis of accidents or serious incidents due to go-arounds shows that crews are often no longer aware of the basic parameters – pitch, thrust – and their correlation with changes in calibrated airspeed and vertical speed. Performing the go-around requires a high number of actions. Crews may have difficulty in identifying priorities for their actions and may not continuously monitor these parameters.

The BEA recommends that:

– **EASA in coordination with manufacturers, operators and major non-European aviation authorities ensure that go-around training integrates instruction explaining the methodology for monitoring primary flight parameters, in particular pitch, thrust then speed.**

Assessment of the role of the PM

The performance of the monitoring function is essential but insufficient during the go-around. During performance of the go-around studied, the PM’s attention was focused on the actions to take and not on their monitoring. It is therefore necessary to focus on this issue in particular during initial training in MCC and then assess the results during on-going and recurrent training.

The BEA recommends that:

– **EASA, in cooperation with the national civil aviation authorities and major non-European aviation authorities, ensure that during recurrent and periodic training,**

[33] The present Report contains a translation of the safety recommendations into the Russian language.

training organizations and operators give greater importance to the assessment and maintenance of the monitoring capabilities of public transport pilots.

Recommendations on CRM

The ASAGA study highlighted the difficulties of maintaining a good level of CRM throughout a go-around. The priorities of the PF and PM are different. Their respective workloads limit their interaction and mutual monitoring of actions. Although fundamental, current CRM alone cannot constitute a reliable safety barrier in the case of disruptive elements. In general, whatever the type of recent accident, investigative findings often point to shortcomings in CRM.

The BEA recommends that:

– **EASA study the additional technical and regulatory means required to mitigate the shortcomings of CRM in high workload and/or unusual conditions.**

Flight crew training

Today, a go-around is considered as a normal procedure. Nevertheless, the study showed that its rarity, gestures and complexity in terms of workload make the procedure a singular one. A go-around does not often occur during operations – especially on long haul flights – and is one of the maneuvers that are poorly represented by simulators, in particular due to the absence of a realistic ATC environment. For this reason, in practice, the go-around procedure is not a normal procedure but a specific one.

The study showed that pilot training did not correlate with the scenarios of accidents and serious incidents due to go-arounds, especially during recurrent simulator checks. The number of go-arounds with all engines operating is insufficient and the scenarios used are often predictable. PANS training (PANS-TNG) does not include realistic scenarios during the go-around.

The BEA recommends that:

– **ICAO enhance the PANS-TNG by including realistic detailed training scenarios based on current technology and risks.**
– **ICAO modify the relevant annexes to make mandatory the performance in an aircraft of a go-around with all engines operating for the issuance of the first CS-25 type rating.**
– **EASA review the regulatory requirements for initial and periodic training in order to ensure that go-arounds with all engines operating are performed sufficiently frequently during training.**
– **EASA review the regulatory requirements for the first CS-25 type rating in order to make mandatory the performance of a go-around on an aircraft with all engines operating.**

Recommendations on video recordings

During the study, use of video was essential to carry out a proper analysis of simulator sessions. In addition to the non-verbal communications, the video recordings made it possible to have access to all the information presented to the crew. A video recording of the pilots' workspace is a major improvement. Installed in a simulator, it would be a source of additional information of use during crew debriefing.

The BEA recommends that:

- **ICAO make mandatory the installation of an image recorder in all full flight simulators intended for public transport and used in the context of training.**

ERGONOMICS AND CERTIFICATION

Limitations on available thrust

When full thrust is used during a go-around, an excessive climb speed can be reached very quickly, and make it difficult to undertake the actions in the go-around procedure. It can, firstly, be incompatible with the time required to perform the go-around and, secondly, be a source of the somatogravic illusions that have led crews to make inappropriate nose-down inputs. Certain manufacturers have already implemented a system limiting the thrust. The main objective is to give flight crews time, to limit excessive sensory illusions and excessive pitch attitudes.

The BEA recommends that:

- **EASA, in coordination with major non-European aviation authorities, amend the CS-25 provisions so that aircraft manufacturers add devices to limit thrust during a go-around and to adapt it to the flight conditions.**
- **EASA examine, according to type certificate, the possibility of retroactively extending this measure in the context of PART 26/CS-26, to the most high-performance aircraft that have already been certified.**

Error in go-around engagement modes

The study showed, however, that there is a conflict between the application of maximum thrust and an operating environment that rarely, if ever, requires it. On Airbus aircraft, the thrust lever is primarily a mode selector and is generally not moved, except during take-off and flare. In a phase of flight with a high workload, qualified pilots make mode selection mistakes in go-arounds both when advancing the thrust lever to stop and/or when moving it back to the CLIMB detent. Errors in mode engagement, such as confusion between an input on the palm switch and the AT disconnect button, have been highlighted on Boeing aircraft and have also led to serious incidents.

The BEA recommends that:

- **Airbus and Boeing re-evaluate the possibilities of errors linked to the engagement of go-around modes**
- **Aircraft manufacturers study the means required to detect and correct erroneous mode selection during a go-around.**

Management of aircraft configuration

The PM's management of the aircraft configuration is time-consuming during the go-around and is undertaken to the detriment of monitoring the primary flight parameters.

The BEA recommends that:

- **Aircraft manufacturers study the feasibility of simplifying the management of the aircraft configuration, during a go-around, in order to increase the PM's monitoring availability.**

Study of visual scan to develop go-around procedures by manufacturer

The assessment of visual scan is fundamental in developing a procedure. Some devices, such as oculometric systems, exist today so that a detailed study can be made. At present, analysis of visual scan is not formalized, despite the fact that it alone can be used to analyze teamwork shortcomings in detail.

The BEA recommends that:

- **Aircraft manufacturers and operators study pilots' visual scan in order to improve and validate their procedures, particularly with regard to go-arounds**
- **EASA, in cooperation with the international certification authorities, introduce certification criteria to make mandatory the study of pilots' visual scan in developing procedures defined by manufacturers.**

Simulated representation of external references

Most ASAGA-type events have occurred at night and/or without visibility. The loss of external visual references certainly contributed to the loss of situational awareness during the go-around. The possibility of seeing or having a representation of the outside environment would probably make it possible to reduce the risks associated with somatogravic illusions. Today, there are systems available that represent the outside environment in 3D.

The BEA recommends that:

- **EASA and manufacturers study the implementation of means to allow flight crew to have access to a virtual representation of the outside environment in IMC conditions.**

TRAINING AND ERGONOMICS

Channelized attention and dispersion to the detriment of the primary parameters

The study showed the vital importance of monitoring by the PM during the go-around. PM can have great difficulty in monitoring all the parameters required by the procedure. The PM's visual scan during a go-around is not homogeneous for a given procedure. It even reveals a significant dispersion of attention. Training does not adequately address this problem. Phenomena such as channelized attention or attentional tunnelling may well occur during a go-around.

The BEA recommends that:

- **EASA, in cooperation with the national civil aviation authorities and major non-European aviation authorities, ensure that the risks associated with dispersion and/or channelized attention during the go-around, to the detriment of the primary flight parameters, be taught to crews.**
- **In the long term, main civil aviation authorities, in coordination with aircraft manufacturers and operators, define means to counter channelized attention phenomena.**
- **EASA, in coordination with manufacturers, operators and major non-European aviation authorities, study whether to extend these measures to other procedures requiring a high workload in a short time frame.**

Engagement of automated systems – monitoring modes displayed on the FMA

The study showed that the number of changes in FMA modes during the go-around can be high. This makes it difficult for crew members to detect and read all these changes. Go-around procedures cannot be evaluated based solely on the assumption that FMA mode changes have been comprehensively read and understood. In addition, the selection of a proper guidance mode, displayed on the FMA, does not in itself guarantee correct tracking of the path. Go-around procedures are not evaluated in a realistic operational context.

The BEA recommends that:

- **EASA ensure that national civil aviation authorities check, during in-flight and simulator checks, that monitoring of the engagement modes of automated systems by pilots is correctly executed.**
- **EASA, in coordination with the major non-European certification authorities, ensure that aircraft manufacturers modify ergonomics so as to simplify the interpretation of FMA modes, and facilitate detection of any changes to them.**

– **EASA, in coordination with the major non-European certification authorities, ensure that go-around procedures designed by manufacturers and taken up by operators are evaluated in a realistic operational environment.**

Manipulating the FCU/MCP

During a go-around, the attention given to manipulating the FCU/MCP can take a long time, during which the flight path is no longer monitored. Most crews manipulate the FCU/MCP without observing the result on the EFIS, despite the fact that this does not correspond to recommended practices.

The BEA recommends that:

– **EASA in coordination with national civil aviation authorities ensure that airlines under its oversight once again insist during training on the best practices for manipulating the FCU/MCP**
– **EASA ensure that aircraft manufacturers improve for new aircraft, the design of the FCU/MCP and decrease the time required for its use during a go-around, while evaluating the impact of the time it is used during other phases of flight with high workloads.**

Go-around and position of pitch trim

A go-around performed at low speed with an unusual nose-up trim position can lead to a stall and a loss of control. Before the go-around, the speed drops and the aircraft systems compensate for this loss of speed by pitching up the stabilizer more and more. Consequently, aircraft manufacturers should develop means to prevent this type of excessive trim from occurring and/or to prevent the aircraft stabilizer from being kept in an unusual attitude during a go-around. Crews pay less and less attention to the position of the trim during flight. They should thus be informed as early as possible of an excessive drop in speed so that they avoid applying full thrust with an unusual position of the pitch-up trim.

In the event of an excessive nose-up pitch position that is uncontrolled, few pilots know the upset recovery procedure which consists of reducing the thrust and/or modifying the trim position.

The BEA recommends that:

– **EASA, in cooperation with the national civil aviation authorities, major non-European certification authorities and manufacturers, ensure pilots have practical knowledge of the conduct required during a go-around at low speed with pitch trim in an unusual nose-up position, and that they make a competence assessment.**

– **EASA, in cooperation with the major non-European certification authorities, make mandatory the implementation of means to make crews aware of a low speed value and, where necessary, prevent an unusual nose-up trim position from occurring or being maintained.**

SIMULATORS

Fidelity of simulators and somatogravic illusions

Simulators do not correctly represent the phenomenon of somatogravic illusion during a go-around. The pitch and accelerations present in the simulator are not those felt during a real go-around. There is no objective standard for evaluation of qualification of simulator motion. It appears, however, technically possible to improve simulator fidelity in this respect. In addition, experienced pilots rarely carry out real go-arounds and it is statutorily possible that recently qualified FOs have never been subject to somatogravic illusions prior to carrying out scheduled flights during line-oriented flight training. During the investigation into the accident involving A330 F-GZCP on 1 June 2009, the BEA had already recommended to EASA that it

– **Modify the basis of the regulations in order to ensure better fidelity for simulators in reproducing realistic scenarios of abnormal situations.**

Consequently, the BEA completes this recommendation in the context of this study and recommends that:

– **ICAO ensure that manufacturers of simulators in cooperation with aircraft manufacturers improve simulator fidelity with respect to the phenomena of somatogravic illusions, especially during go-arounds.**

AIR TRAFFIC MANAGEMENT (ATM)

Modification of go-around flight paths by ATM

ATC can modify the published missed-approach procedure during the go-around manoeuver. Crews can then be surprised, or even upset, to have to change their plan of action during a go-around. The consequences of these changes can be significant, particularly when they prevent the use of certain automated systems and increase the time pressure. In a flight phase where the workload is already high, additional actions further disrupt teamwork, and monitoring by the PM in particular.

The BEA recommends that:

- **ICAO define standards and recommended practices (SARPS) or procedures for air navigation services (PANS) so that air traffic controllers, except where necessary for safety reasons, do not give instructions that are in contradiction with the published**

missed-approach procedure; and that, when necessary, the instructions are announced to crews as early as possible during the approach.

- **EASA, without waiting for possible ICAO actions, in coordination with Eurocontrol and national civil aviation authorities, implement regulatory measures limiting modifications to published missed-approach procedures.**

Controller training and radiotelephone communications from ATC

The study showed that ATC exchanges between controller and crew during a go-around disrupt the crew and that some dialogues could be delayed. In paragraph 5.2.1.7.3.1.1 of Annex 10, ICAO provides that during certain phases of flight no transmission must be made to an aircraft. This is not the case for missed approaches.

The BEA recommends that:

- **ICAO extend the provisions of Annex 10 to include the go-around phase by requiring that, unless required for imperative safety reasons, no transmissions are made to an aircraft during a missed approach manoeuver, as long as the crew have not indicated that they are available again.**
- **EASA, in coordination with Eurocontrol and national civil aviation authorities, ensure that the risks associated with the transmission of messages and modifications in the flight path during go-arounds are taken into account by ATM training organizations or air navigation service providers during initial and recurrent training of air traffic controllers.**

Design of missed approach procedures

Among the various possibilities for designing a missed approach, a straight-ahead missed approach is not given priority, although it could facilitate the control and use of automated systems on aircraft. Furthermore, at present the published go-around altitude is not related to aircraft performance. The rate of climb of most modern aircraft is high and even has to be limited for some. Thus, the BEA has documented cases in which the published go-around altitude does not give crews enough time – about a minute – to carry out the scheduled actions before interception. Yet the study showed that the time available during the go-around was a decisive factor for its success.

The BEA recommends that:

- **ICAO indicate, during the design of a missed approach procedure, that a straight-ahead missed approach flight path must be given preference when that is possible.**
- **ICAO introduce, in SARPS or PANS during the design of a missed approach procedure, that the first vertical constraint be as high as possible, taking into account the high performance of public transport aircraft, to carry out a standard go-**

around; EASA, without waiting, in coordination with Eurocontrol, take the necessary steps to propagate the safety benefits from the above recommendations.

1.18.7. Elevator PCU Abnormal Operation Events on Other Boeing 737 Aircraft

On June 14, 2009 a Boeing 737-400 (737), registration number TC-TLA[34], experienced an uncommanded pitch-up event at 20 feet above the ground during approach to Diyarbakir Airport (DIY), Turkey. The flight crew performed a go-around maneuver and controlled the airplane's pitch with significant column force, full nose-down stabilizer trim, and thrust. During the second approach, the flight crew controlled the airplane and landed safely. Both crewmembers sustained injuries as they were inputting very forceful control column inputs to maintain pitch control. None of the passengers or cabin crewmembers reported injuries.

The incident investigation was conducted by the NTSB. The NTSB's investigation found that the incident was caused by an uncommanded elevator deflection as a result of a left elevator power control unit (PCU) input arm assembly jam due to foreign object debris (FOD). The FOD was a metal roller element (about 0.2 inches long and 0.14 inches in diameter) from an elevator bearing. As a result, the PCU would be commanded to move the elevator to a position that would pitch the aircraft nose up.

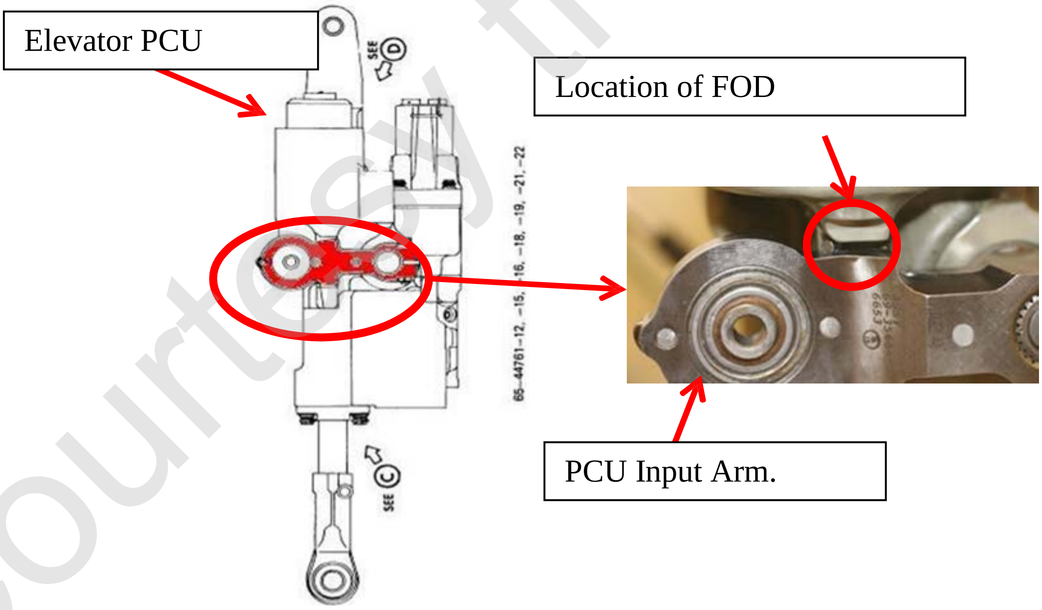

Figure 70 Location of FOD

[34] Additional information can be reached at: http://ntsb.gov/_layouts/ntsb.aviation/Results.aspx?queryId=638accf8-73f9-40a4-aebd-41d7138a8bff.

The FDR record analysis (Figure 71) revealed that the significant column input forces applied by the crew led to control linkage extension. This is revealed by comparing the column and elevator positions before and after the jam. The same column position corresponds to different elevator deflection angles.

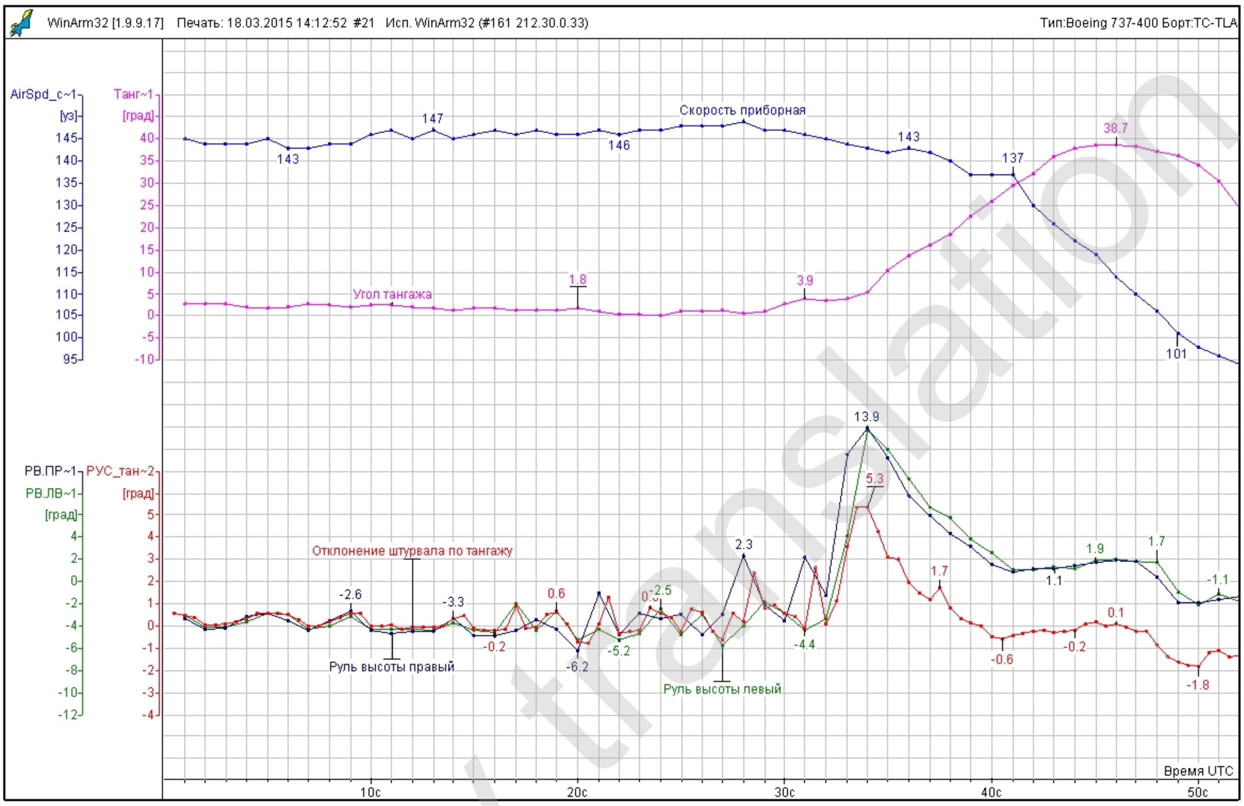

Figure 71 Boeing 737-400 TC-TLA Flight Parameters

The NTSB investigation materials show that FAA's service difficulty report database contained four additional events involving binding or jamming of the elevator control system. None of the events resulted in an accident. In two of the events the source of the jam could not be identified. During the third event the binding was caused by a large piece of Velcro lodged between an elevator cable elements. During the fourth event the jamming was caused by the elevator balance weight lodged between the lower surface of the elevator and the stabilizer. During the first three events the crews had to exert excessive forces on control columns, the fourth event occurred during the takeoff roll and the takeoff was aborted.

On 26 December 2012 Norwegian Air Shuttle Boeing 737-800 was involved in a serious incident while approaching to land at Kittilä Airport (EFKT) in Finland[35]. When the aircraft was

[35] The investigation was conducted by the AIBN (Norway) assisted by NTSB (USA) and SAIF (Finland). The extracts from the FR are included into the present chapter. The FR can be seen at http://www.aibn.no/Aviation/Published-reports/2015-01-eng?ref=1713.

positioned to intercept the glide slope with configuration: Flaps 5, gear up, autopilot channel A in use, Autothrottle engaged, there was the stabilizer nose up deflection recorded. On the Boeing 737, it is normal for the stabiliser trim to engage for a few seconds in such a phase, but this time the trim continued for 12 seconds in the nose-up direction. The electric trim changes the position of the entire horizontal stabiliser (accompanied by the typical sound). As a result of the new trim setting, the aircraft's nose rose considerably.

This caused the airspeed to rapidly decline, thus engaging the aircraft's autothrottle system at full engine power. Full engine power caused the aircraft's nose to rise further, with associated further loss of airspeed.

When the aircraft's nose position passed +12°, both pilots started to push the control column, in an attempt to lower the aircraft's high nose angle. At this time, the aircraft was in clouds (IMC). In this case no attempt was made to disengage the aircraft's autopilot, autothrottle system or manually run the electric stabiliser trim in the nose-down direction. Neither was the engine power reduced. According to the PIC's subsequent statement, he believed that the autopilot had disengaged in an early phase when the aircraft's nose started to rise.

The maximum nose angle of +38.5° occurred two seconds after the pilots had achieved full force forward on the control column until the mechanical stop. The Flight Data Recorder (FDR) shows that the pilots used a total force of 174 lb (~79 kg). The pilots manually used the electric trim, which resulted the autopilot to automatically disengage. The aircraft's nose angle rose unintentionally from +1.5° to +38.5° over a period of 20 seconds. At the same time, the airspeed dropped to an alarmingly low speed of 118 kt (CAS). The pilots were eventually able to slowly lower the nose position.

Calculations made by Boeing indicate that the elevator was extremely slow in responding. With only 0.2°/second, compared with the normal 50°/second. This indicates a rate of 1:250 compared with the normal response.

While control was being regained, when the nose angle passed +10°, the pilots quickly pulled the control column back with a force of approximately 100 lb (44 kg). The angle of attack had then reached about 25° AOA and caused the “Stick Shaker” and stall warning to activate for four seconds.

After nearly half-an-hour in a holding pattern a new approach was carried out. The second approach and landing was uneventful.

The FDR analysis indicated that minimum three of the aircraft's total of four Input cranks on PCUs eventually became blocked. AIBN's investigation cannot exclude that the volume of de-icing fluid and snow better facilitated the formation of ice on the PCU Input cranks.

AIBN finds it likely that the blockage consisted of ice particles in the gap on the Input cranks and that the ice particles were eventually crushed when the pilots exerted their full force on the elevator control column.

1.18.8. Analysis of PIC’s Previous Approaches

The investigation team analyzed a number of previous approaches to RWY 29 of Kazan Airport conducted by the PIC. The approach flight paths are shown on Figures 72-77 (the actual flight path is marked in red, the recorded flight path is marked in green).

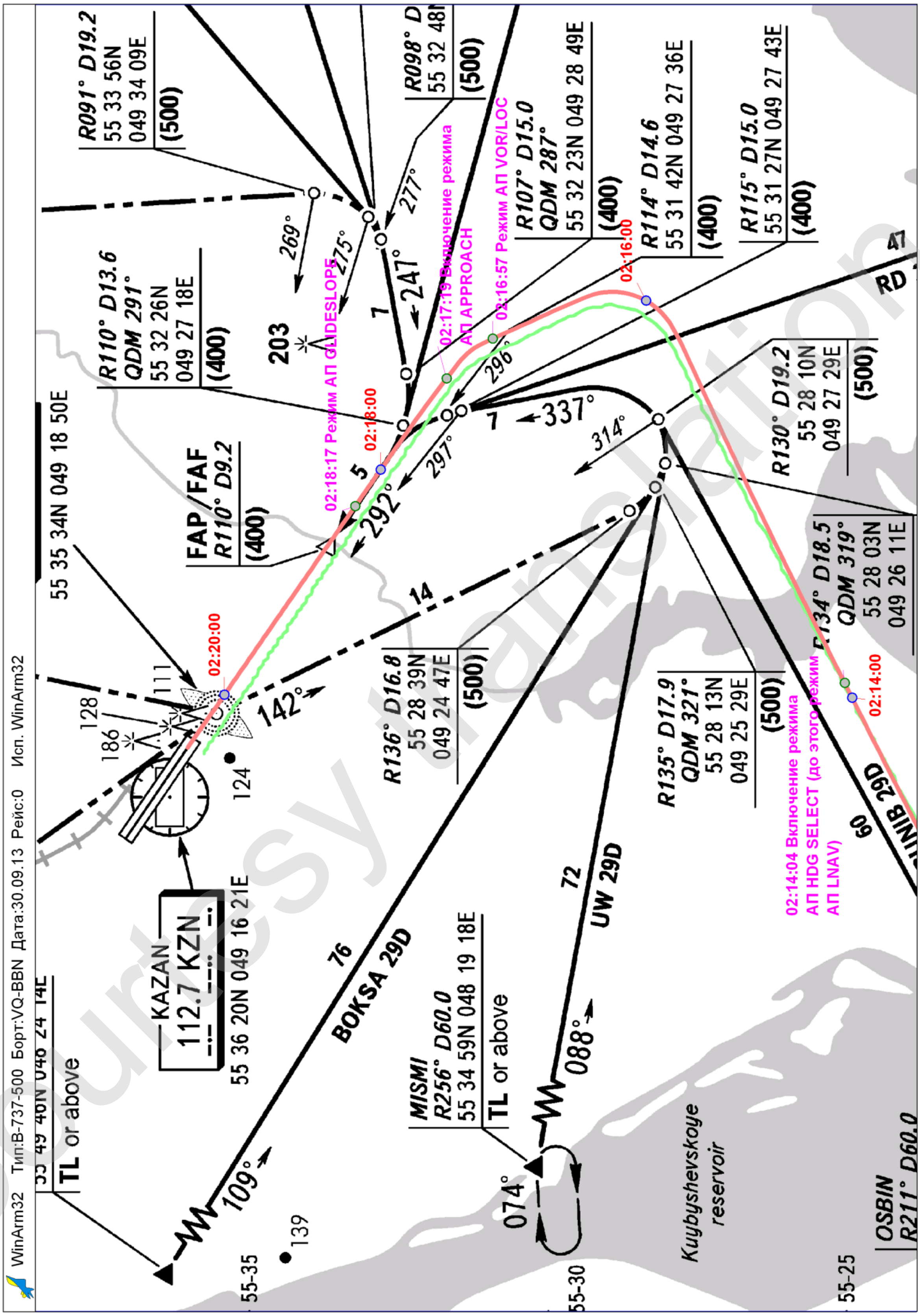

Figure 72 Boeing 737-500 VQ-BBN Flight Parameters, September 30, 2013

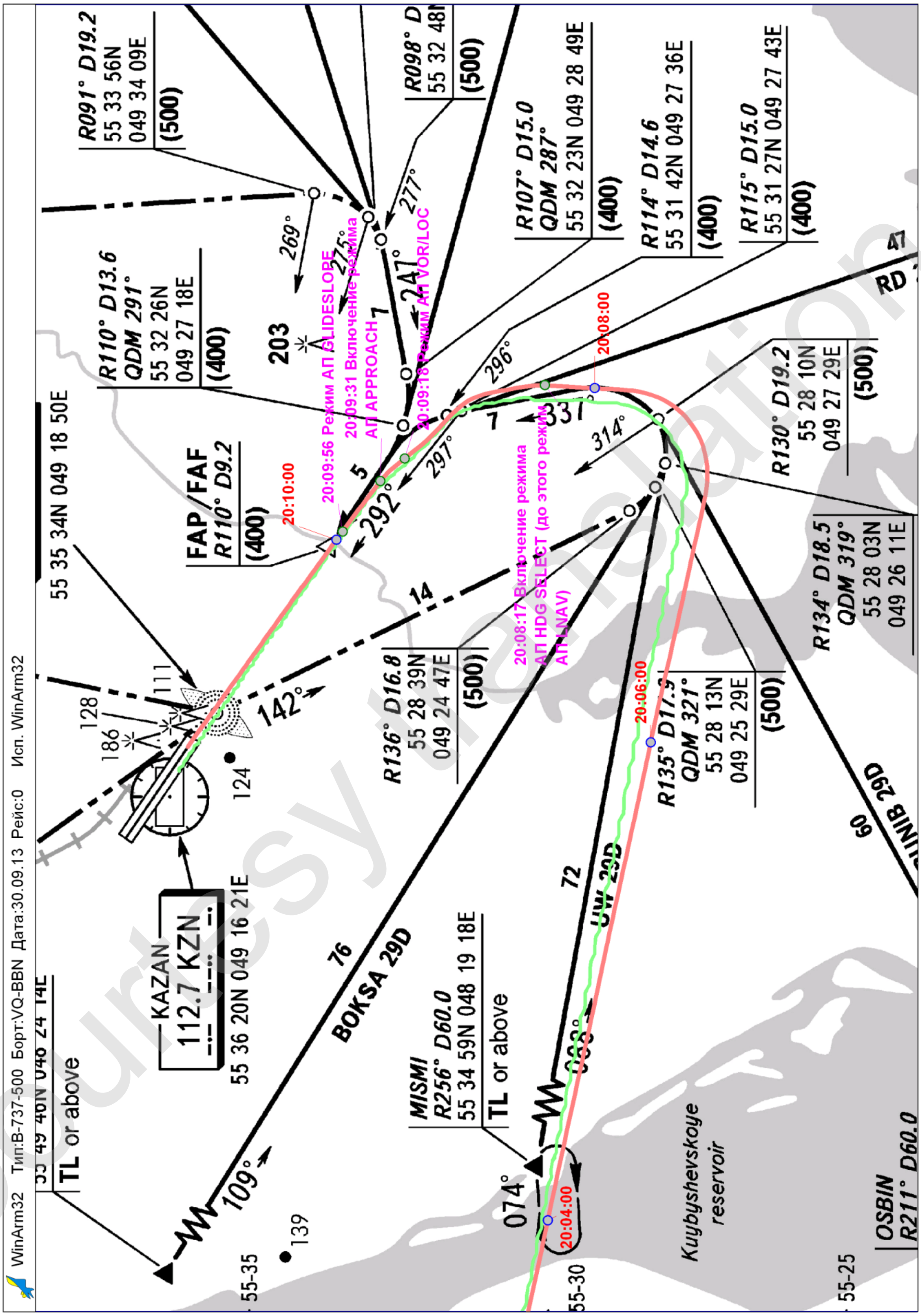

Figure 73 Boeing 737-500 VQ-BBN Flight Parameters, September 30, 2013

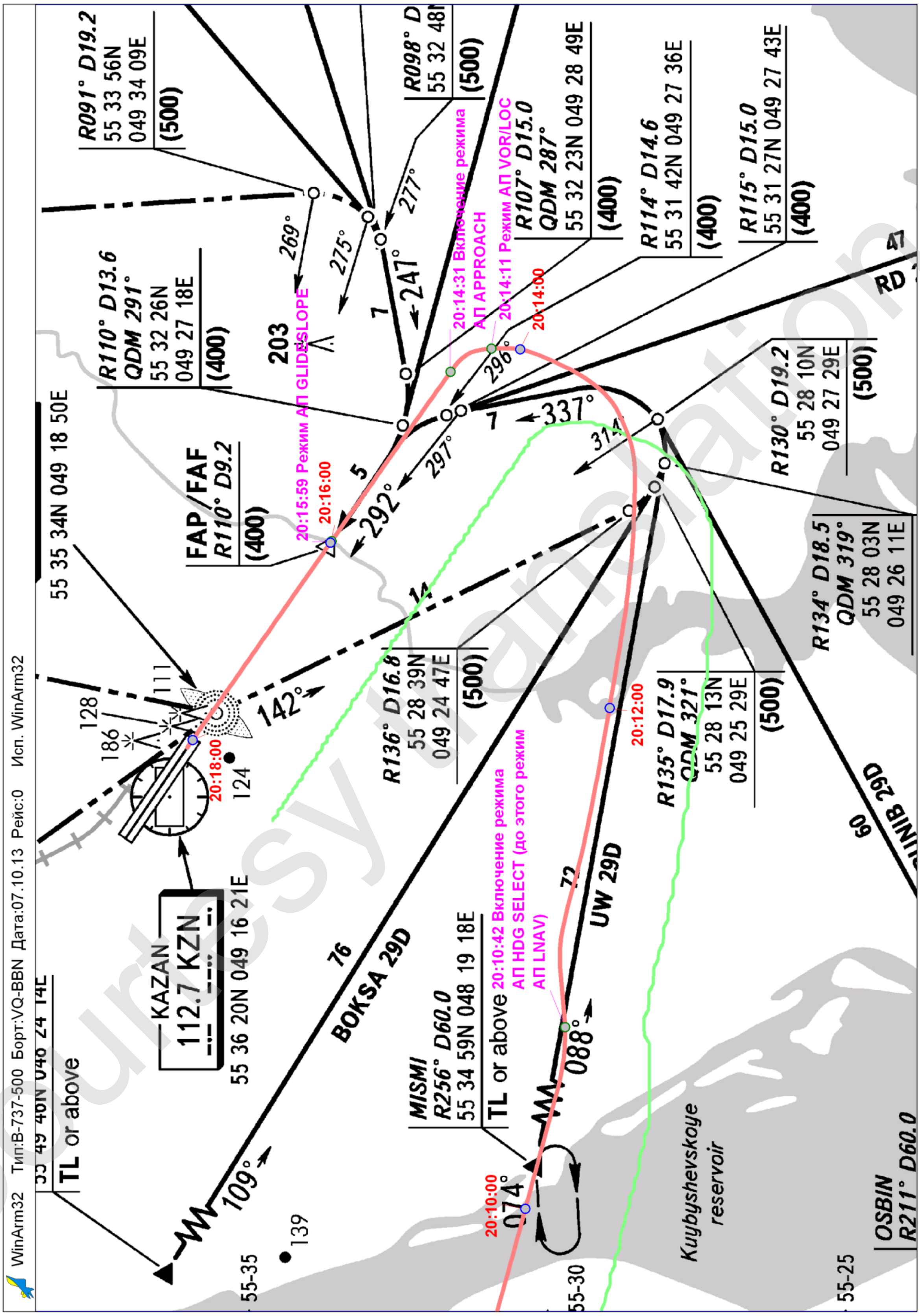

Figure 74 Boeing 737-500 VQ-BBN Flight Parameters, October 7, 2013

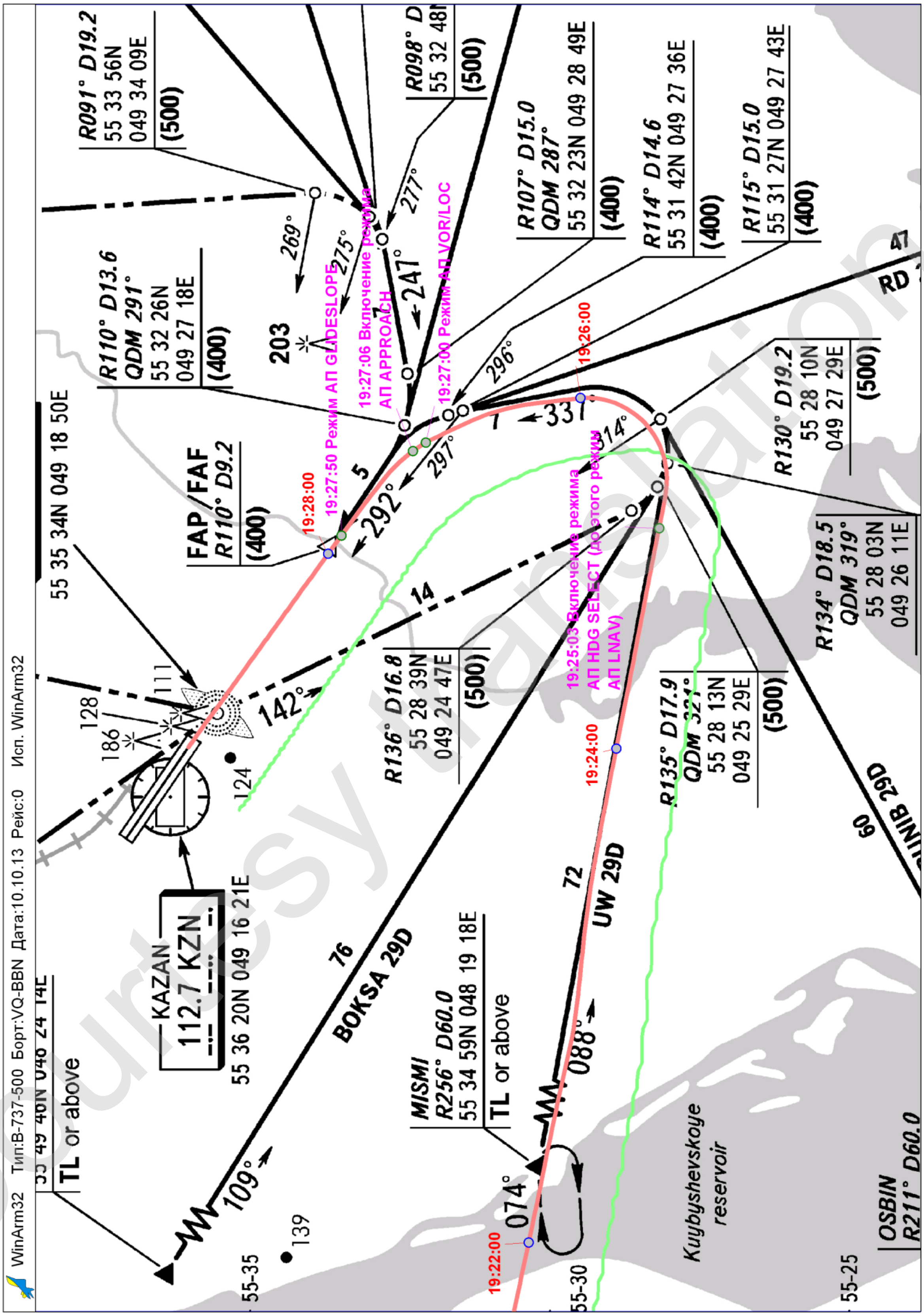

Figure 75 Boeing 737-500 VQ-BBN Flight Parameters, October 10, 2013

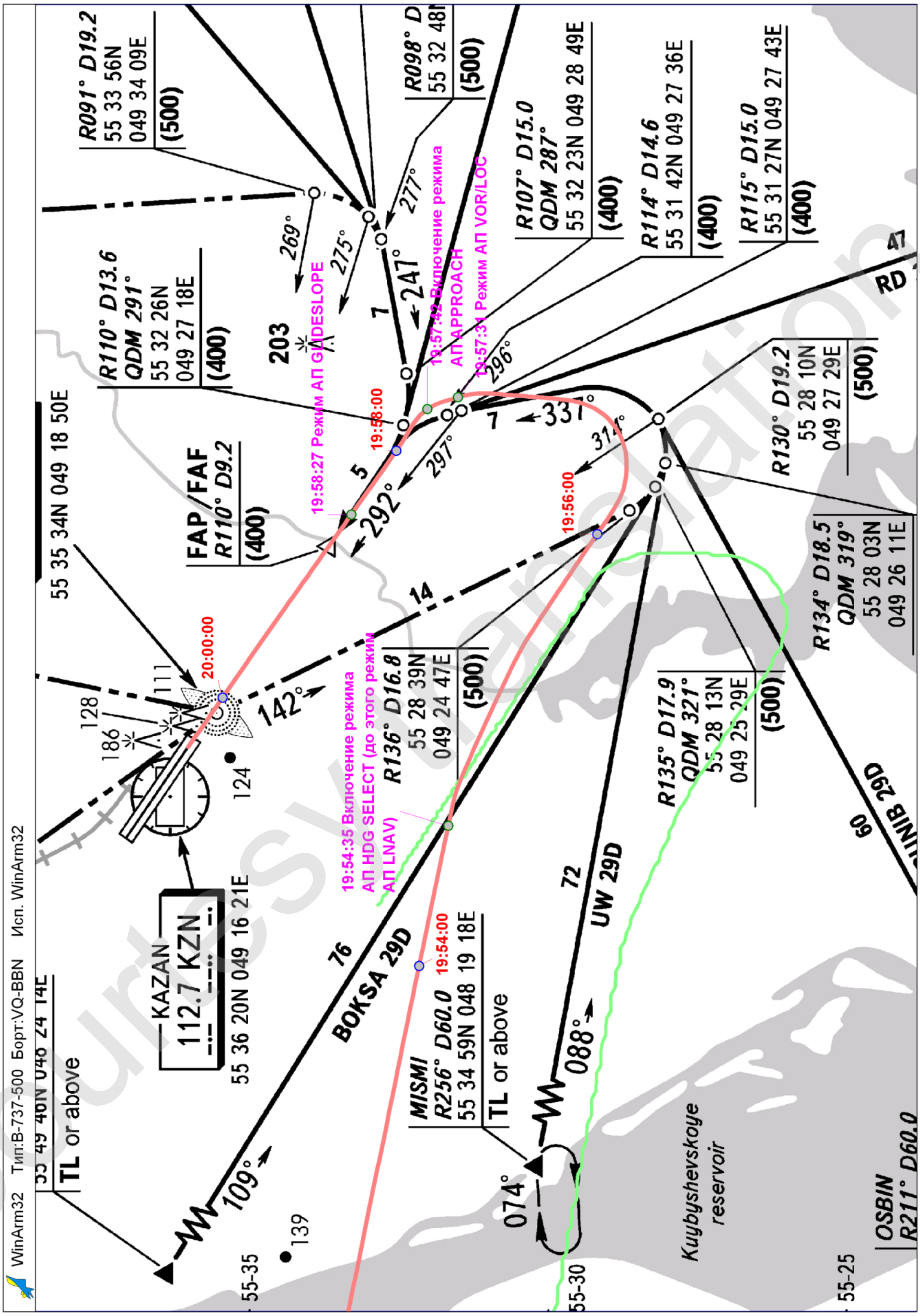

Figure 76 Boeing 737-500 VQ-BBN Flight Parameters, October 17, 2013

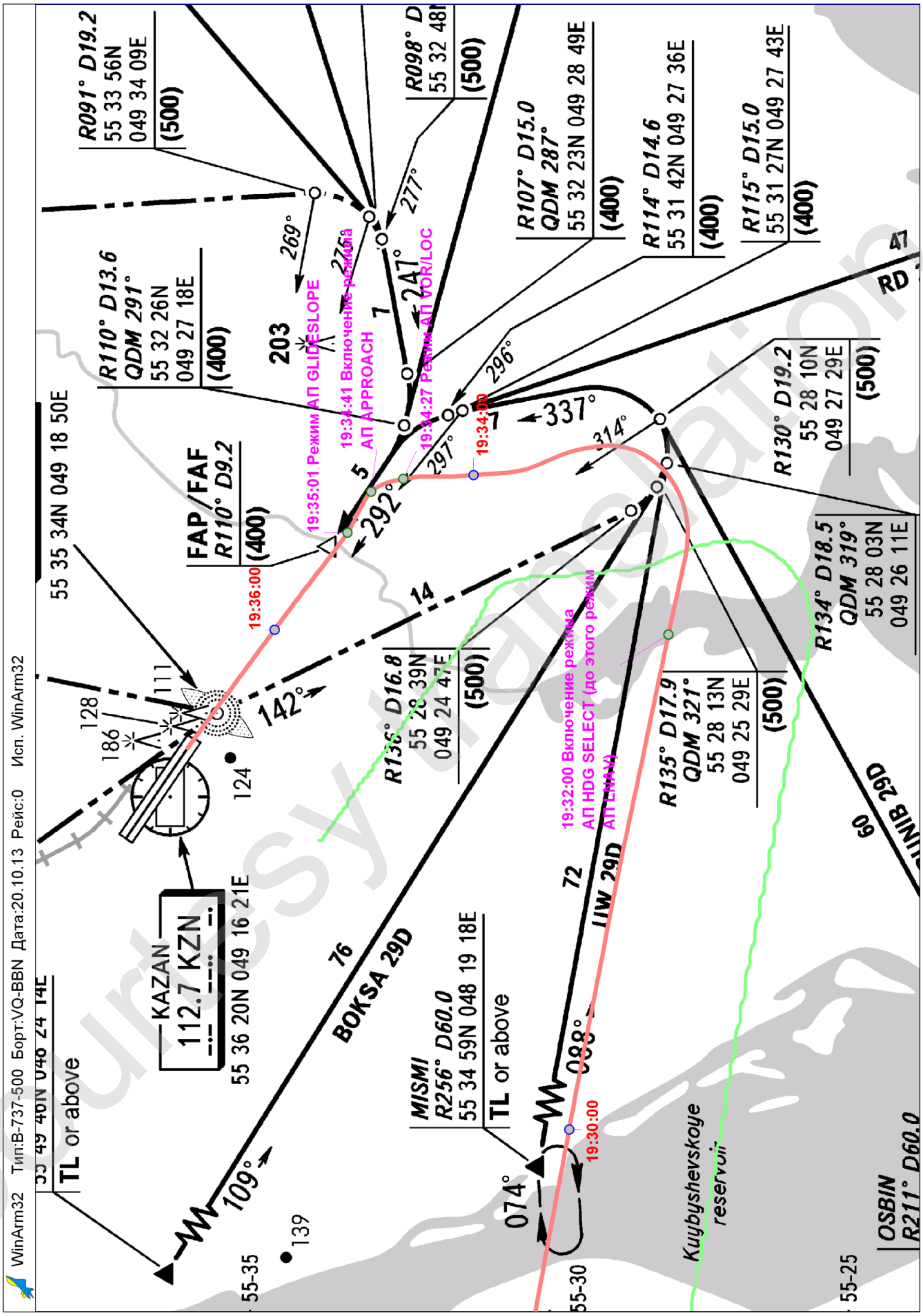

Figure 77 Boeing 737-500 VQ-BBN Flight Parameters, October 20, 2013

As the FDR records aircraft position taken from the left-hand IRS and there are not CVR records for the mentioned flights, it was not possible to determine the instrument indications viewed by the crew (whether the current position was updated with reference to Kazan Airport VOR/DME signals). However, in view of the data above, the following can be concluded:

– during the previous approaches there were instances when IRS current position errors reached significant values that could be compared with the error remarked in the accident flight. The start of the base turn during all approaches was matched the approach pattern with an acceptable accuracy.

– in all cases when there was significant deviation of the actual flight path from that calculated by the IRS, the crew deactivated L-NAV mode well in advance and entered the base turn point with HDG SEL mode engaged.

– during all approaches the crew engaged the VOR/LOC in due time, which ensured the aircraft intercepted the localizer in automatic mode;

– the flight path in Figure 76 is similar to the accident flight path from the MISMI waypoint to the disengagement of the L-NAV mode. After the L-NAV mode was disengaged and the HDG SEL mode activated the crew made a corrective turn right to intercept the base turn entry point with acceptable accuracy.

1.18.9. Failure to Monitor Flight Parameters During Go-Arounds

On the 22nd of January 2002 a Boeing 757-208, TF-FIO, operated by Iceland Air (Iceland)[36] was involved in a serious incident during a missed approach to Oslo airport Gardermoen (Norway).

The approach was conducted in IMC with a strong tailwind and was unstabilized. As the PIC (PF) tried to manually capture the glide path from above, he disconnected both A/P's and the auto throttle. As the aircraft was flown manually, the PIC noticed that raw data information of the ILS on his instruments were lost. On the FO's instruments all indications were normal, but the crew did not consider a change of controls at that time. At an altitude of approx. 580 feet AAL the PIC decided to initiate a missed approach and announced his decision to the FO (according to the SOP such decision shall be taken at an altitude of 1000 feet during an unstabilized approach).

The aircraft was above the glide path, and the SOP calls for the go-around altitude to be set when stabilized on GP, therefore the go-around altitude was not set on the MCP. Flaps were not

[36] For more information see: http://www.aibn.no/Aviation/Reports/2003-07

in landing configuration, set at 20°. The lowest altitude AAL indicated on the FDR was approx. 460 feet (1100 feet QNH).

Upon initiating the go-around, the A/T automatically engaged and increased the thrust to the EPR (Engine Pressure Ratio) limit of 97%. The pitch-up column input and the application of the under wing engine power resulted in gradual increase of nose-up pitch angle up to 21 degrees (the flight director pitch initially targeted a pitch attitude of 15 degrees) and forced the aircraft to climb. During the climb the landing gear was retracted. The airspeed increased from 182 to 198 kt before it started to decrease.

The MCP selected altitude was 2500 ft the AFDS transitioned to Altitude Capture almost immediately after a positive rate of climb was achieved. The aircraft passes the MCP selected altitude and continued to climb (the peak altitude was 2895 feet QNH).

The speed had decreased to 137 kt (the reference speed for flaps 20 is 131 kt). Nose down was applied manually by the control column. During the next seconds, a full nose down input on the control column was made manually. The aircraft pitched over to an attitude of approx. –30°, and the FDR indicated negative g-values with a maximum load factor of –0.6 g.

The control column was briefly returned to near neutral, and then another abrupt large nose down column input was made. The aircraft pitch attitude had peaked at -48°. The aircraft was rapidly descending and the Ground Proximity Warning System (GWPS) aural warning of “Pull up” was activated.

The FO called out “PULL UP!” “PULL UP!” and both pilots made a maximum “up” input. The lowest altitude in the recovery was 321 ft radio altitude.

The control inputs resulted in a peaked load factor of +3.6 g and the aircraft pitch attitude increasing to about 40°. Eventually a normal trimmed flight was established at 4000 ft after several abrupt control inputs and after another approach the aircraft made a safe landing.

The investigation team concluded that as the PIC could not capture the glide path during the approach, he could not “catch up with the aircraft” and became stressed. The CRM was not appropriate and the FO did not provide enough assistance to the PIC. The investigation team did not reach a clear understanding of why a trained crew was flying in the described manner. The Final Report contains a reference to the PIC’s statement, assessing both himself and the FO as having abnormally high workload during the go-around. In his opinion both of them became occupied handling details instead of looking at the whole picture. And when they suddenly got the altitude capture commands from their FDS they became confused. They became even more confused on the result of their control inputs leading to a nose-down pitch upset.

1.18.10. IRS Alignment by Tatarstan Airlines Crews Before Flights

To analyze how the airline's crews perform the IRS alignment procedure before flights, 62 flights were analyzed that were conducted by different crews within September 27 to October 22, 2013. Figures 78 to 80 below show the deviations of the actual aircraft position at the start of the takeoff roll from the IRS position. The provided charts show that in the majority of flights there was significant deviation of the actual position from the IRS position, meaning the coordinates entered by the crews during the IRS alignment were not accurate enough.

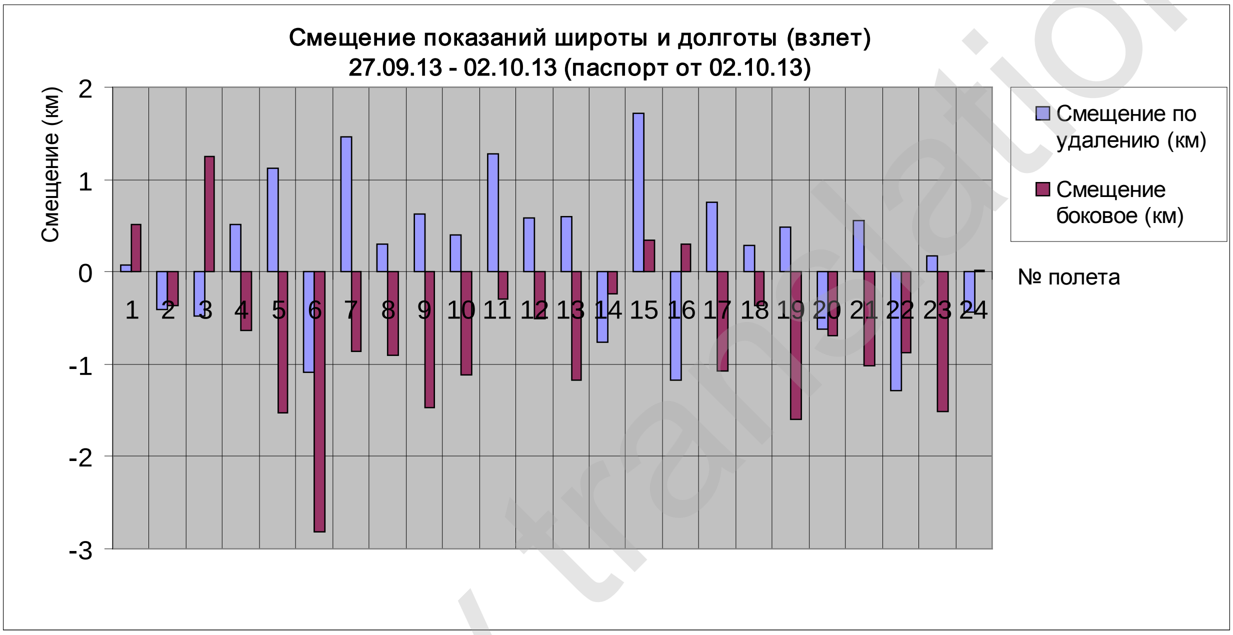

Figure 78 IRS map shift during takeoffs on September 27 to October 2, 2013

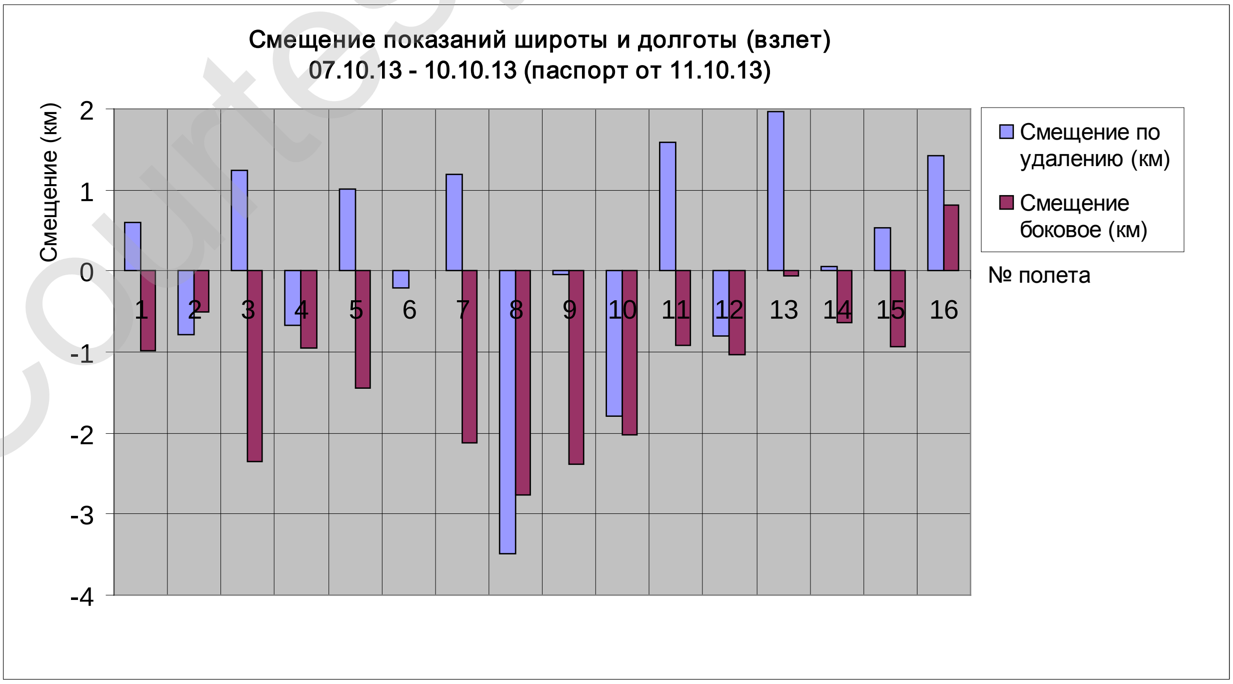

Figure 79 IRS map shift during takeoffs on October 7 to October 10, 2013

Figure 80 IRS map shift during takeoffs on October 17 to October 22, 2013

1.19. Useful or effective investigation techniques

Nothing other than routine investigative methods have been used in this investigation.

2. Analysis

2.1. Description of Accident Flight[37]

On November 17, 2013 Boeing 737-500 VQ-BBN operated by Tatarstan Airlines was on a scheduled flight TAK 364/363 Kazan-Moscow (DME) - Kazan.

At 11:22 the aircraft departed from Kazan Airport. The flight to Domodedovo was uneventful.

The aircraft landed at Domodedovo at 12:43.

After the disembarkation the crew started preparing for flight TAK 363.

The forecast and actual weather at the departure, destination and alternate airdromes were appropriate for the flight.

At 14:15 the crew started up at first the right engine and then the left one.

Note: *The FDR started recording flight data as the right engine was starting up.*

At 14:25 the crew took off. The takeoff weight was approx. 45 000 kg (the MTOW being 59 193 kg) with CG of approx. 21%, which was within the AFM limitations. The takeoff fuel weight was 7800 kg, which was sufficient for the planned route.

The takeoff was conducted with flaps 5°. At an altitude of 1400 ft (430 meters) AAL the crew engaged A/P B, meaning the FO was most likely the PF.

At 14:26:40 at an altitude of 4000 ft AAL (~ 1220 m) and airspeed of 195 kt the crew started retracting flaps and slats.

At 14:37 the aircraft levelled off at FL 290.

At 14:47:30 A/P B was disconnected and A/P A engaged. Likely the PIC was the PF since that moment. L-NAV and V-NAV modes were engaged.

There were no remarks as to the flight path from the ATC until the aircraft entered Kazan ATC control area.

By the time it happened then actual weather at Kazan airdrome as per ATIS Information Juliet at 14:42 was as follows:

wind 220 degrees 9 m/sec gusting 12 m/sec, at 100 m 230 degrees 8 m/sec, at circuit height 250 degrees 16 m/sec, visibility over 10 km, moderate sleet, overcast (8 oktas), cloudbase 270 m, temperature 3 degrees, dewpoint 2 degrees, QFE 735 mm/980 hPa, moderate icing in clouds, no significant changes.

[37] The history of the accident flight is described in Section 1.1.

The crew listened to the above information at 14:58-14:59[38]. The weather was suitable for landing.

At 15:00 the aircraft passed SHUMERLYA waypoint and was handed over to Kazan Control. At 15:01 at FL 290 the crew contacted Kazan Control to report: "*Kazan Control, Tatarstan 3-6-3, good evening, Shumerlya, flight level 2-9-0, ready for descent*". The ATC instructed them to descend to FL 70, "*Tatarstan 3-6-3, Kazan Control, descend flight level 7-0, identified*". The descent was initiated at 15:01:30 (Figure 11).

Before initiating descent the crew conducted the landing briefing and defined that they would make an ILS approach to RWY 29 (magnetic heading 292°) with the weather minima of 60x550 m, which is consistent with ICAO CAT I. The actual weather was compatible with the PIC's weather minima and was suitable for landing. There were no remarks as to the operation of aerodrome navigation aids and lighting.

The PIC did not distribute the duties during the approach briefing. Further, the PIC was the PF. The FO maintained radio communication.

When the PIC was briefing on the flight conditions, the FO was contacting Kazan Transit to report arrival information. This forced the PIC to interrupt the briefing and resume with it after communication with Kazan Transit was terminated.

At 15:06 the ATC, seeing the aircraft blip on the SSR was to the left of the flight track centerline requested the crew to report their heading. After the crew reported it was 068, the ATC advised: "Tatarstan 363, of Kazan, active runway 29, approach Uniform Whiskey 29 Delta". At 15:07 the ATC advised the crew that the aircraft was offset 4 km left from the track.

The crew received the ATC information and spent a long time discussing the map shift and transitioned from L-NAV to HDG SEL mode. At 15:08 the heading was changed from 68° to 73° (Figure 11). However, this heading change was not enough to capture the track axis.

According to the SSR record, the aircraft continued flight with the offset of 4 km to the left. The analysis of the available information revealed that by that time the map shift was also about 4 km (see Section 2.2.1). It should be noted that as the aircraft was descending, due to the change in wind direction and strength, the crosswind component was decreasing. Within 15:08 to 15:11 the drift angle decreased from +5° to 0°.

At 15:11, according to the SSR data, the aircraft passed approx. 4 km to the north of MISMI reportable point and then the crew made a corrective turn to a heading of approx. 90 degrees. This

[38] The CVR record started at 14:53:20.

heading change was not enough either. The aircraft was approaching the base turn parallel to the standard approach pattern (Figure 15 and Figure 81).

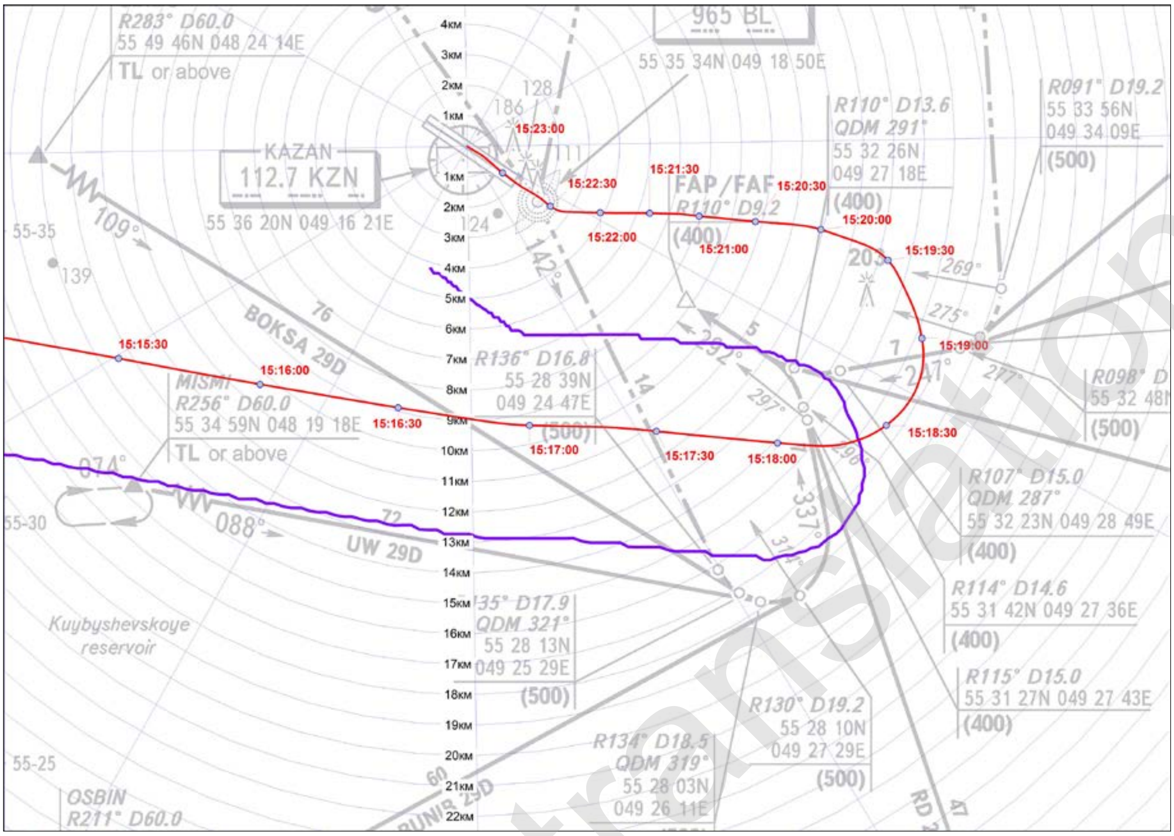

Figure 81 Actual flight path (red) and FDR (IRS) flight path (blue). There is a gap between the base turn and MISMI waypoint, the location of MISMI WP is out of scale

After the crew contacted the Radar Control, they were cleared for descent to 500 m, QFE 980 hPa[39]: “Tatarstan 363, Kazan Tower, good evening, cleared for ILS approach, RWY 29, QFE 9-8-0, descend to 500 m”.

At 15:14:30 the crew set the destination airdrome QFE at the altimeters and completed the pertinent checklist.

At 15:16:45 the crew stated there was no icing on the aircraft. Just before, at 15:10, they had activated the cowl anti-ice system.

At 15:16:50 the aircraft made a corrective left turn of 8°. The corrective turn left made the situation more complicated (the deviation from approach pattern started increasing). The Radar Controller who was watching the aircraft at that time probably perceived this maneuver as a base turn and reacted at 15:17:07 with: “Tatarstan 3-6-3, early for base turn” and clarified after 6 seconds: “Lateral 6, distance 9”.

[39] Hereinafter all altitudes are AAL (QFE).

As the aircraft was approaching the base turn the flaps were set at 1° (Figure 11). As the flaps were being extended to 1°, at an altitude of 2600 ft (800 m) the Altitude alert was triggered. It alerted approaching the altitude set at the MCP (1700 ft).

Note: *This alert serves to inform the crew when they approach the MCP altitude and leave it. It consists of light warning and aural alert. When approaching the MCP altitude the light warning is triggered (amber light) 900 ft before it and is on until 300 ft before the set altitude which is also marked with aural alert.*

Thus, the analysis revealed that the Altitude alert was triggered in a normal way.

After the crew informed the ATC on reaching the base turn point they were cleared for base and final turn. Actually the turn was initiated at 15:18 in the HDG SEL mode before the aircraft reached the altitude of 500 m with a significant deviation from the STAR pattern (Figure 15 and Figure 81), that the ATC could have seen on the radar, and the crew could have seen that using the VOR/DME.

Because of significant deviation from the STAR pattern as well as strong tailwind at the circuit altitude, the crew did not engage the VOR/LOC mode yet when they crossed the localizer centerline.

In the course of the turn, at 15:18:30, the aircraft reached the MCP altitude of 500 m that was maintained by the A/P in the ALTITUDE HOLD mode. During the turn the Flaps were set to 5°, and by the end of the turn they were extended to 10° (Figure 11).

The turn was completed with a significant "overturn" (Figure 15 and Figure 81). The cockpit communication analysis revealed that the crew was not completely aware of their position with regard to the approach pattern, which is confirmed by the following dialogue between the PIC and the FO at 15:18:46:

PIC: "*Wut's this the fiddle?*"

FO: "*Wait, I'll VOR/LOC it, what will that give?*"

PIC: "*Something strange, I've VOR/LOC'ed it*".

FO: «*111 decimal 7, 111 decimal 7, so what? What's that?*"

At 15:19 the Radar Control handed the aircraft over to Tower Control, who advised the crew they were at a distance of 14 km and offset to the right of the approach course. The ATC did not specify the lateral deviation while the crew most likely did not manage to determine it as well using on-board equipment.

After the turn was completed there was a significant offset (about 4 km to the right of the approach course), therefore the crew failed to capture the localizer (despite the active VOR/LOC mode). The HSI LOC deviation pointer was at the most left position.

The selected heading of approx. 250° in the A/P HDG SEL mode that deviated from the landing course by approx. 40° did not ensure that the aircraft capture the landing course before the glide path intercept point (7.35 km from the RWY threshold) in view of the actual wind direction an strength. According to the pattern the glideslope entry point is on 400 m/1300 ft height (it had to be reached by the end of the final turn), but the aircraft was still maintaining 500 m (1700 ft).

As the aircraft was heading approx. 250° the crew continued to prepare for landing, they extended the flaps to 15° and then to 30°, they extended the landing gear (Figure 11), while the HSI LOC deviation pointer was at the most left position. The crew completed the Landing Checklist. After the landing configuration was achieved, the aircraft was flown with an airspeed of 130-135 kt.

At 15:20:30 the FO suggested they turned on the landing lights. However, they happened to hamper visibility (they produced a light screen when in the clouds), and the landing lights were disengaged. Further, the landing lights were not used which is confirmed by the video recorded by CCTV cameras of Kazan airdrome.

At 15:20:49 the PIC who was the PF said: “Well, we neither have the landing position anywhere, nor anything else, just 4 miles to go” and at 15:20:24 he proceeded with “Now it’s going to appear... we’ll press the Go... Go-around”.

Further the crew discussed the significant deviation from the course and glide path for a number of times. At 15:20:59 the FO went: “It, asks more to the left, that’s why I’m watching” and at 15:21:24 the PIC said: “It has not even started to be alive, damn”. As the aircraft was significantly offset to the right of the final track and beyond the glideslope beacon range (the A/P ALT HOLD was maintaining the altitude of 1700 ft/500 m) the HSI LOC and GP deviation pointers were still at their respective limits.

As the ATC requested the crew at 15:21:24 if they were ready for landing the crew reported that they were. This report was not true: the aircraft was still far (more than two dots) from the landing course, at the circuit altitude (500 m/1700 ft) and 4 km from the RWY threshold. The cockpit communications analysis revealed that the crew were aware of that fact (at 15:22:01 the FO said: “It feels as if we are... going in the wrong way” and the PIC replied with: “if something goes wrong we can go-around now”) but he decided to make a formal report anyway. The ATC who saw that the aircraft was not at all in the right position for landing cleared them to land.

After they received the clearance the crew engaged the V/S mode (selected vertical speed 1200 fpm) to descend to 270 m (900 ft) height which was selected on the MCP and maintained by the A/P until the go-around (Figure 12).

The localizer was captured at 15:22:17 approx. 2 km from the RYW threshold, and then the aircraft started to intercept the landing course automatically, while the crew in compliance with the SOP selected the RWY heading to prepare for the go-around.

At 1000 ft AAL the EGPWS aural alert sounded: "*One thousand*", replied by the PIC: "*One thousand, stabilized, no flags*". The approach was definitely unstabilized and the crew were to take the decision to go-around. They did not take this decision and continued to find the ground references visually.

At 15:22:30 the FO found the runway visually and informed the PIC about it: *"Huh, that's it, here, the runway underneath us. No, we're too high. Four white lights, we're too high"*. The FO determined that they were much higher than the assigned descent path by the PAPI lights. Four white lights indicate that the aircraft is much higher than the glide path.

At 15:22:35 the PIC replied: *"Where do you see it? I don't. Where is it?"*. As the PIC could not see the runway, he could not be aware of aircraft position with reference to the runway and take the decision.

At 15:22:38 the FO again evaluated the aircraft position as unsuitable for landing and repeated: *"Here it is, the runway. No. Go around. Go around"*.

The CVR does not contain any evidence that the PIC could finally see the ground references or the runway personally, but at 15:22:39, based on the FO's recommendations instructed him: *"Go around report we are going around. Position unsuitable for landing"*.

At the time the decision to go around was taken the FDR recorded the following: the aircraft was in landing configuration (gear down, Flaps 30), one A/P and A/T on, altitude 270 m (900 ft) above runway level (maintained by the A/P ALT HOLD), in the roll axis the A/P was commanding the aircraft to make the second part of the S-shape maneuver to capture the landing track, the indicated airspeed was maintained at 130-135 kt by the A/T. As the aircraft was too high, the glideslope beacon was not captured. According to the SOP, after capturing the glideslope beacon the crew was to select the go-around altitude (500 m/1700 ft) on the MCP. The go-around altitude was not selected at that time, which is confirmed by the Altitude alert triggered several times further.

After the PIC's request the FO reported their decision to go-around to the ATC. As a reply the ATC instructed the crew to climb to 500 m and contact Radar Control. The FO requested to confirm the altitude: *"Er... climbing 600 m, right? And contact radar at 119 decimal 4, right?")*. The ATC repeated his instruction to climb to 500 m and then the FO read back the instruction correctly. The total tome spent by the FO for the exchange was about 20 seconds. Further, the crew did not contact the Radar Control.

At 15:22:45 the crew engaged the TO/GA mode to go-around. As the TO/GA mode was engaged the A/P used for the approach was automatically disengaged as per design and the FD mode was active during the following flight (Figure 12).

Note: *FCOM B-737-500 Automatic Flight – System Description (4.20.15).*

Approach (APP) Mode Single A/P.

A single A/P ILS approach can be executed by engaging only one A/P in CMD.

Single A/P approach operation is the same as dual, with the following exceptions:

Full automatic flare and touchdown capability are not available. FLARE is not annunciated, and stabilizer trim bias is not applied.

An A/P go–around is not available. One VHF NAV receiver must be tuned to an ILS frequency before the approach mode can be selected.

FCOM B-737-500 Automatic Flight – System Description (4.20.19).

F/D Go-Around

If both A/P are not engaged, a manual F/D only go–around is available under the following conditions:

Inflight below 2000 feet RA

Not in takeoff mode.

At 15:22:50-54 the flaps were retracted from flaps 30 to flaps 15. The flaps remained in the latter position until the end of the flight.

As was mentioned before, as the TO/GA mode was engaged, the A/P was automatically disconnected as per design (but the FD bars were still active). The A/P disconnection must have been accompanied with a red light warning on both pilots' control panels and an aural alert (the latter was recorded by the CVR). The crew did not discuss the causes of the warning being triggered and they did not switch off the aural alert until the end of the flight (by pressing the A/P disconnect button on the control wheel).

According to the aircraft manufacturer, when the TO/GA mode is engaged, the FD pitch bar shows the target pitch of 15° at the start of the go-around maneuver. After reaching the climb vertical speed of 300 fpm the pitch bar adheres to a different logics. It shows the pitch angle required to maintain the appropriate airspeed for the given flaps position. If the go-around altitude selected on the MCP is greater than the current flight altitude, approaching it the FD will automatically transition to ALT ACQ mode, which does not require any extra actions from the flight crew.

If the selected altitude is lower than the current altitude:

- in case the climb is continued the FD pitch bar in the TO/GA mode will keep “maintaining” the airspeed until the crew select another flight mode;
- in this case, if the aircraft starts descending the pitch bar will initially tend to regain the required climb profile. Further, if the aircraft crosses the MCP selected altitude during descent, the TO/GA mode will automatically disengage while the FD will transition to the ALT ACQ mode (at 15:23:25 in the accident flight, approx. 3 seconds before the impact).

There is one more peculiarity of the FD pitch bar indication in TO/GA mode. Its deflection value is limited (roughed sensitivity) to prevent the aircraft from PIO. This is clearly visibly in the reconstruction of the pitch FD bar position in the accident flight, made by the Boeing Company (Figure 27). The plot reveals that despite the significant deviations from the required flight profile and/or climb speeds, the FD pitch bar position did not exceed ± 5-6° when the TO/GA mode was engaged. The pitch bar position reached the highest limit only after the mode transition to ALT ACQ.

At 15:22:51 (6 seconds after the go-around maneuver had started) the target go-around thrust was achieved (N1 approx. 83%) and maintained almost until the impact.

Note: *This aircraft was provided with a reduced go-around thrust function. This function was designed to provide automatic selection of an estimated (based on the actual flight conditions) go-around thrust sufficient to climb with the predefined rate as the TO/GA pushbutton is pressed for the first time. This serves to avoid an excessively steep climb due to excessive thrust. Another pressing of the TO/GA pushbutton results in N1 of 95%. The maximum thrust can be selected manually by the pilots. The analysis revealed that the set thrust (83%) was compatible with the current flight conditions.*

As a result of the nose-up pitching moment that appeared due to the increasing engine power (with the engines installed below the CoG) and flaps retraction with no column inputs, the aircraft went nose up and started climbing. Due to the increasing thrust the indicated airspeed increased up to approx. 150 kt (by 15:22:54). As a reaction to such airspeed change, the Speed Trim System moved the stabilizer by approx. 0.5 degrees nose up (see Section 1.16.2). When the aircraft deviated 300 ft from the selected altitude of 900 ft the Altitude alert was triggered as per design (15:22:55).

As there were no significant column inputs (as the pitch angle was approx. 20 degrees the column was only slightly pushed 1 degree nose down), 20 seconds after the go-around maneuver started the pitch angle increased up to over 25 degrees nose up. Within the same time, as there were no wheel inputs, the bank angle changed from 7 degrees right to 2 degrees left.

Due to the excessive pitch angle increase, as the thrust mode was the same, the airspeed started falling (down to 117 kt by 15:23:15). As a reaction to the falling airspeed, the Speed Trim System started moving the stabilizer nose down, the total deflection making up approx. 1.7 degrees in 13 seconds (see Section 1.16.2).

At 15:23:04, after finishing the radio exchange with the ATC, the FO was finally ‘back’ to the cockpit. He reminded the PIC that it was necessary to retract the landing gear, which he did following the PIC’s command, and then selected the go-around altitude of 1700 ft/500 on the MCP (at 15:23:10 Altitude Alert was triggered at approx. 2000 ft).

The analysis of the trigger conditions for Altitude alert as well as ALT ACQ and HDG SEL signals at 15:23:25 (Figure 12) revealed the following: As the go-around was initiated the selected altitude was approx. 900 ft. After climbing to approx. 1200 ft the Altitude alert was triggered which meant they left the selected altitude. The next Altitude alert triggering occurred during the climb at an altitude of approx. 2000 ft and then it was triggered for the third time during the descent, as the aircraft was passing the altitude of approx. 1400 ft. This means that during the climb the crew reset the selected altitude to approx. 1700 ft (according to the go-around pattern). It can be concluded that the crew changed the selected altitude when they were already past it. This conclusion is drawn from the fact that the TO/GA mode was still engaged during the climb. The disengagement of the TO/GA mode (as the ALT ACQ and HDG SEL were engaged and thrust decreased) occurred only during the descent when crossing the altitude of approx. 1700 ft from above, which is compatible with the autoflight system logics – in TO/GA mode the selected altitude is captured from above only when the aircraft crosses it, while it is captured well in advance from below (during the climb). This was confirmed by the simulator experiments.

The PIC started active control inputs during landing gear retraction after the speed had fallen to 125 kt with pitch angle more than 25 degrees nose up. The control column was pushed nose down for approx. 1/3 of the travelling distance from the trimmed position (Figure 12). The actual altitude above runway level was approx. 2000 ft/600 m at that time and kept increasing with a vertical speed of over 4000 fpm (20 m/sec).

The column was kept in that position for slightly over 4 seconds, and then was deflected back to the trimmed position for just 1 second (most probably the PF just released the pushing forces on the column which shifted towards the balanced position due to the load spring). As the elevator was deflected by the column inputs and the stabilizer was trimmed by the STS a significant nose down moment appeared which resulted in a high negative pitch rate. Within 5 seconds the pitch angle changed from 25 degrees nose up to the values required for level flight and continued decreasing. The vertical load decreased to 0.5 g. The altitude almost stopped increasing (it peaked at approx. 2300 ft/700 m). The indicated airspeed dipped to 117 kt, however, the angles of attack were lower than the operational limitations and stick shaker was not activated.

At 15:23:16 the PIC pushed the column nose up again for over half the travelling distance from the trimmed position. The column was kept in that position for about 4 seconds, and then was deflected back to neutral for just 1 second.

As a result of the PIC's control inputs, by the time the column was shifted back to the trimmed position the aircraft had the following performance: vertical load about 0 g, pitch angle 20 degrees nose down that kept going further nose down, airspeed over 140 kt increasing with a rate of 10 kt/sec, altitude approx. 2000 ft (670 m), vertical speed of descent over 5000 fpm (25 m/sec).

At 15:23:20, while the A/P disengage alert was still active, a «SINK RATE» EGPWS alert was triggered followed in a second by «PULL UP» alert. The EGPWS system alerts were triggered in due time as per design.

At 15:23:21 a third column node down input was recorded (up to the forward stop). Such control input resulted in 0.8 to 0.9 g negative vertical load and the pitch angle reaching 55 to 60 degrees nose down.

Further control actions were chaotic. Just before the impact the aircraft started banking, the left bank reaching approx. 35 degrees. At 15:23:28 the aircraft impacted the ground with a speed of approx. 245 kt (approx. 450 kt) and a pitch angle of approx. 75 degrees nose down.

2.2. Aircraft Systems Operability Analysis

The aircraft airframe, components and systems, engines and the APU were operative before it departed from Moscow (Domodedovo), no evidences of their failure in last flight were detected. The limited life-time components had enough life time for the flight.

The aircraft was dispatched for the accident flight with two open deferred MEL items, Cat. D: aft galley ovens and forward galley water heater were removed. The aft galley ovens open item was to have been closed before November 14, 2013, so on the day of the accident this item was expired. The deferred defects did not have any influence on the accident outcome.

The FDR record did not contain any parameters or events that would be an evidence of any technical failure during the accident flight.

Before the crew started the descent the FO reported to Kazan Transit that there was no failures of aircraft and systems.

The engineering simulation of the final section of the accident flight revealed that the aircraft stability and controllability parameters were well consistent with the type design. The aircraft movement was commanded by the control surfaces deflection and engine thrust. No additional external forces (windshear, icing) affecting the aircraft were found.

In view of the accident flight circumstances the investigation team paid particular attention to the operability analysis of aircraft navigation system and the longitudinal control system (elevator and stabilizer).

2.2.1. Aircraft Positioning Accuracy

By the time the aircraft reached the approach pattern the map shift on the left IRS was approx. 4 km (Figure 81) southwards (i.e. the actual flight path was to the north of that recorded by the FDR)[40].

Comparison of the recorded aircraft position during taxiing and takeoff with the actual path can lead to a conclusion that during the takeoff a map shift of approx. 2 km southwards was also present (Figure 82). Thus, most probably when the crew aligned the IRS's before the flight they entered the current coordinates with some error (probably thy entered the last position that remained in the FMS memory when it was switched off after the previous flight). The analysis showed (Section 1.18.10) that the same was true for the vast majority of other flights made by the airline crews.

[40] The features of FDR position recording on the Boeing 737-500 VQ-BBN are described in Section 1.6.1).

Figure 82 Map-shift during the takeoff at Domodedovo Airport

The natural map shift can be as much as 2 nautical miles (approx. 3.7 km) per hour and depends, among other things, on the accuracy of actual aircraft position entered during the IRS alignment. The more accurate position is entered, the smaller will the map shift be during the flight.

Taking into account the actual flight time (about an hour), the accuracy of the IRS positioning was satisfactory.

It should be understood though that having the available data it is impossible to determine the aircraft position calculated by the FMC and indicated on the flight instruments.

As noted in Section 1.6.1, the aircraft was not equipped with a GPS receiver that would correct the calculated position. In such conditions the FMC accuracy at different phases of flight depends on the correct IRS alignment before the flight and the possibility to update the position using ground navigation aids. However the corrections entered into the FMC position are not transferred to the IRS. There is no way to correct the IRS data during the flight (so that the crew could eliminate the accumulated map shift). Thus, using the available information it is not possible to determine definitely if the position update with the help of ground-based navigation aids was done during the accident flight.

However, by way of comparison of the recorded flight path and the UW 29D STAR as well as analysis of the crew communications and actions during the approach, a well justified assumption can be made that the aircraft position indicated on the flight instruments was close to the IRS position. That means that most probably the FMC position was not updated during the flight. Another evidence of that is the FO's report at 15:11:24 that there was a warning saying «IRS NAV ONLY». This warning means that the actual navigation accuracy evaluated by the aircraft systems was less than required (predetermined) for that flight phase (FCOM Required Navigation Performance, RNP).

The cockpit communication analysis revealed that the Kazan VOR/DME frequency was tuned (e. g. the station callsign could be heard on the CVR for example at 15:16). At that time the aircraft was closer than 25 nautical miles away from the station, which is required to update the aircraft position using the VOR/DME signals. Using the available information it was not possible to determine why position update was not made.

2.2.2. Longitudinal Control System Operability[41]

When analyzing the accident circumstances and recorded flight data (intensive nose up pitching during the final flight segment and no nose up control inputs) some of Rosaviatsyia experts that were involved in the investigation had an opinion that there could have been no nose up control inputs because the elevator control linkage has been jammed partly and could not be moved nose up. As an argument they pointed to some remarkable peaks on the column and elevator deflection records (Figure 83, circled).

[41] The description of the elevator control and operation principles of the PCU is provided in Section 1.6.2.

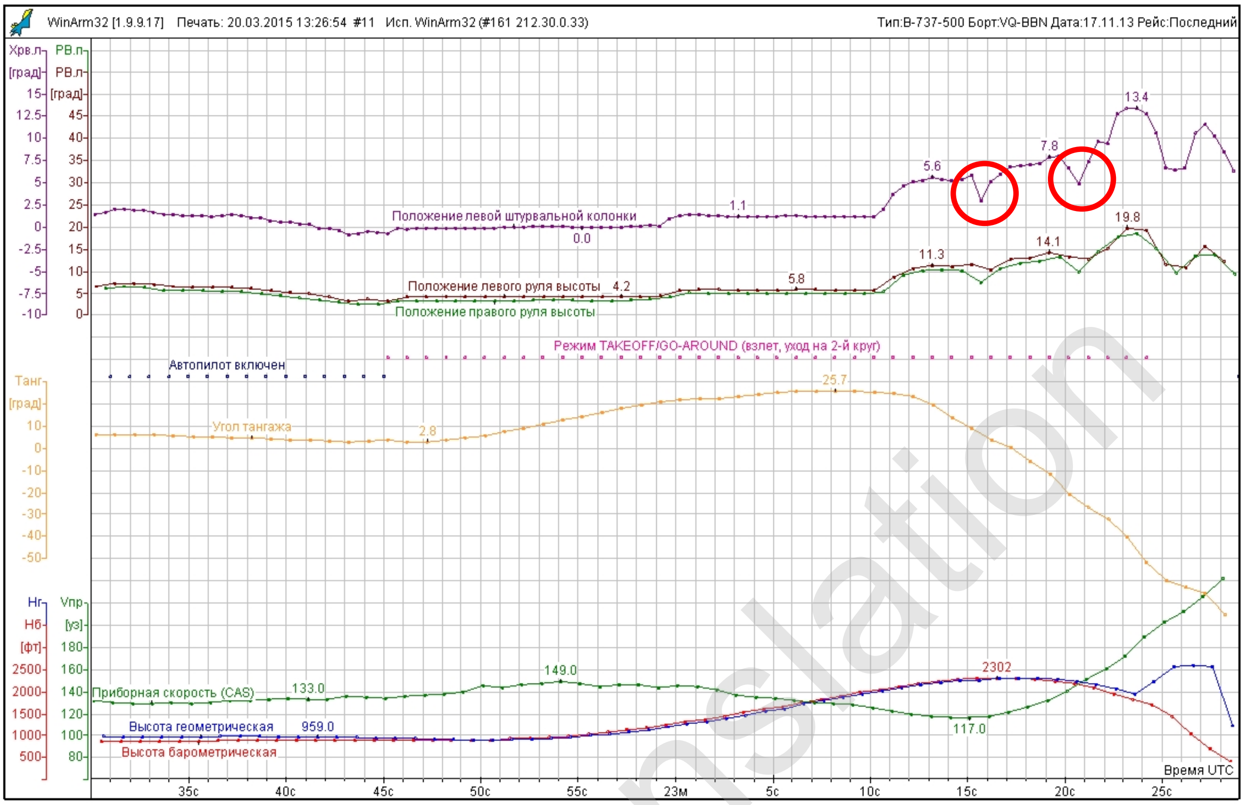

Figure 83 Longitudinal parameters during the final segment of the accident flight

The analysis of the elevator control linkage design revealed that there are two possible scenarios that could lead to the jam. The first scenario represents an external (with regards to the PCU) jamming. This scenario involves a FOD either at some point between the column and the PCU input arm or between the PCU input arm and its housing. Such single jamming may result in limitations to move both elevators. According to the Boeing 737 in-service information such events used to happen (Section 1.18.7).

The analysis of their circumstances described in Section 1.18.7 revealed that when they happened the crew had to apply excessive forces (up to 79 kg) to the control column.

Figure 71 contains the FDR record for the Turkish event. Apparently the significant column input forces while the control linkage was jammed led to cable (control linkage) extension. This is revealed by comparing the column and elevator positions before and after the jam. The same column position refers to different elevator deflection angles.

There are no similar deviations on the VQ-BBN accident flight record. The deflections of both elevators were symmetrical and compatible with the column deflection. There was no signs of difficulties in the column deflection (no typical “shelves” when the column could not be moved further than a certain position) on the FDR record. The CVR record does not contain any sign of excessive forces applied to the column (physical tension) or any pertinent remarks of the crew. The Speed Trim System was operating as per design (Section 1.16.2). The crew did not manually trim the stabilizer during the final segment of the flight (in the Turkish event the crew moved the stabilizer to the design limit in the direction opposite to where the elevator was deflecting due to jamming).

Thus, there were no signs of the elevator external control linkage jamming in the accident flight detected.

To analyze the possibility of the internal jamming of the PCU the investigation team, with participation of representatives of the aircraft and PCU designer and manufacturer as well as FAA who issued the initial type certificate for the aircraft type and represented the rights and obligations of the State of Design as per ICAO Annex 8 "Airworthiness of Aircraft", pertinent examinations were conducted (Section 1.16.6).

The examinations revealed that there were no signs of internal PCU jamming possibility during the accident flight. The PCU control valves were operative even after the impact.

Thus, there were no signs of the elevator PCU internal jamming in the accident flight detected either.

It should be also noted that the PCU dual design ensures the elevator controllability in case of any single internal jamming. Furthermore, within the entire PCU in-service experience (total operation time over 270 million hours) there was no jamming event reported.

Taking into consideration the abovementioned and assuming that pilots almost immediately get aware of the elevator control linkage jamming, while the CVR record contains no pertinent comments of the flight crew and the FDR did not record any evidences of excessive forces applied on the column, the investigation team concluded that the longitudinal control system (elevator and stabilizer) were operative during the accident flight.

After the accident, upon an order issued by Rosaviatsyia, a single pertinent inspection was conducted at all Boeing 737 fleet operated by Russian airlines. The inspections did not reveal any findings.

2.3. Crew Qualification Analysis

Detailed factual information on the flight crew training is given in Sections 1.5.1 and 1.5.2.

The PIC was flying as a navigator from 1991 to 2010. He did not undergo initial pilot training at a certified training organization, the documents confirming his conversion training were fake. His commercial pilot license was issued unreasonably.

The investigation team was not able to determine where, when and using which program the PIC was trained to get airmanship skills. Undoubtedly, as the PIC underwent type rating training for the Boeing 737 at a certified training organization and flew on that type for over 3 years with a total of 2500 flight hours, he must have had some airmanship skills. However, analysis of the PIC's actions during the accident flight showed that he lacked situational awareness skills that should have been received, first and foremost, during initial (basic) training and further developed in the course of line operations and training sessions. The accident flight revealed that the PIC was not able to allocate attention appropriately and distinguish things of primary concern, neither was he able to analyze flight data and fly aircraft manually with agressive evolutions. The foundation for these skills is laid during the initial training, which the PIC did not undergo.

The investigation team determined that the commercial pilot license that the PIC held had been provided by the Higher Qualification Board of Rosaviatsyia to the Aviation Training Center "North-Western Regional Center for General Aviation" (upon their application of May 12, 2009) only on May 14, 2009, that is 8 months after it was allegedly granted to the PIC (in September 2008). By that time the Aviation Training Center Certificate was revoked from that training organization (by Resolution №GK-14-r of the Head of Rosaviatsyia as of February 10, 2009) but pilot licenses were still provided to it. This is an evidence that Rosaviatsyia did not execute appropriate oversight over pilot license issuing.

In the course of the judicial investigation of the subject accident in compliance with the Criminal Code of the Russian Federation tens of questionably issued pilot licenses were found that were later revoked by orders by the Head of Rosaviatsyia, meaning the lack of oversight over pilot license issuing had been a long-term and systemic issue.

It should be noted that in this case the matter of concern is not a fake pilot license that could be revealed comparatively simply further on, but an unjustified issue of authentic license that entitles its holder (who has not demonstrated a required qualification level and not having pertinent skills) to perform functions of a flight crew member. Furthermore, air transport system stakeholders (oversight authorities, airlines, training organizations) consider (quite reasonably) the presence of a pilot license as an acknowledgement of pertinent qualification and the ability of its holder to perform flight crew functions. Thus, lack of appropriate state oversight over the issuance of pilot licenses provides a direct safety threat. This issue is to be addressed in the context of the State Safety Program.

On the other hand, the investigation team notes that in the case of the PIC the airline management (especially flight operations management) had all available information to find out that the pilot license was issued to him without any justification. The PIC had conducted line flights for the airline as a navigator since 1992, meaning he did not come from the "outside", but was always "in sight". Even a superficial analysis of the documents that allegedly confirmed the PIC's conversion training to become a pilot could help to find out obvious inconsistences. For example, when the PIC was allegedly undergoing training and passing tests, he continued conducting line flights for the airline.

The decision of Tatar ITO of Rosaviatsyia to send the PIC for type rating training for the Boeing 737 type was taken formally, without an appropriate analysis of the available data to evaluate if the PIC was ready for the type rating. The fact of the unjustified issuance of the PIC's pilot license was not found out.

In view of all that, the investigation team notes that the Safety Management System at various levels of the air transport system (Rosaviatsyia, Tatar ITO, the airline) did not provide a safety barriers to prevent a person who had not demonstrated appropriate knowledge, abilities and skills required by FAR-147 from being given a pilot license and sent for type rating.

The investigation team also notes that within the recent years (as a result of shortcomings found during various aviation occurrence investigations, among other factors) a huge number of aviation training organizations that used to hold pertinent certificates and had conducted training (including initial training) of a huge amount of aviation personnel were closed. However, no one conducted assessment of risks associated with the mentioned hazard (training/type rating conducted inappropriately). As a rule, after a dubious training organization is closed, the aviation personnel who has undergone training at those organizations is not evaluated for compliance with the applicable qualification requirements.

The FO was working for the airline as a ground mechanic from 1989 to 2008. From 2008 he conducted flights as a flight mechanic. In 2010, after completing conversion training at Ulyanovsk Aviation College he was granted a pilot license. The flight operations investigation group concluded that in the course of the conversion training the FO completed the program and acquired, among others, sufficient airmanship skills to be granted a commercial pilot license.

The PIC and the FO both underwent the Boeing 737 type rating at ANEO S7 Training (within different time periods).

Incoming tests of the applicants actual knowledge and qualification was not conducted by ANEO S7 Training (such tests are not prescribed by any regulation), which allowed the PIC to start training having a pilot license issued with no justification. Moreover he was not provided with the following mandatory training[42] (taking into account his actual qualification and experience): "Additional training for pilots graduated from civil aviation colleges and pilots who do not have experience of operating multiengine turbine aircraft, operating in multicrews or in glass cockpit". This was omitted as ANEO S7 Training only provided training against programs listed in an airline's training request (the training request for the PIC did not include this program).

[42] It used to be required by Para 6 of FAR-148.

ANEO S7 Training does not analyze if additional training is needed depending on the candidate's actual qualification and previous experience (it is not prescribed by any regulations)[43].

In accordance with the training program underwent by the PIC, one of the pre-requisites for the candidates was ELP ICAO Level 3, and they were to pass a benchmarking in accordance with the standards of ANEO Sibir Airlines Aviation Training Center. Actually the PIC was not exposed by any ELP benchmarking. Upon request from the investigation team, ANEO S7 Training responded that according to the available documents the PIC had ICAO Level 3. However, the expert evaluation revealed (Section 1.18.5) that the actual PIC's ELP corresponded to ICAO Elementary Level 2 (though according to the documents the PIC had ICAO Level 4 at the time of the accident).

Note: *The experts also noted that even ICAO Level 3 is not enough to understand the English-language documentation (like FCOM) provided for the training purposes, meaning the training program was developed and approved without taking this into account.*

In accordance to the program underwent by the FO, one of the pre-requisites was being a civil aviation pilot meeting the requirements of FAR-148[44]. Para 5 of FAR-148 determined that "applicants sent for conversion training for other (new) types of civil aircraft if the aircraft documentation is presented in the English language, shall demonstrate English language proficiency at a level sufficient to understand the documentation and conduct operational procedures." However the state did not establish any criteria of what was a sufficient level. It was neither determined who shall define this sufficiency. According to the available documents at the time of his type rating the FO had not passed any ELP testing (no level was assigned to him). However, just like with the PIC, at the day of the accident the FO actually had ICAO Level 2, while Level 4 was granted by applicable documents. The low ELP level of the FO was noted by instructors during the "Additional training…" program and during type rating simulator sessions.

Both pilots were granted ICAO Level 4 after they passed a qualification test at Tatarstan Airlines Aviation Staff Training Center. The experts requested to participate in the investigation note the unsatisfactory quality of Tatarstan Airlines Aviation Staff Training Center interlocutors' work, as well as significant deficiencies of the applied test (Section 1.18.5).

[43] The FO underwent the "Additional training" program twice. He underwent it for the first time during conversion training at Ulyanovsk Aviation College, and for the second time at ANEO S7 Training, which is also an evidence of the lack of appropriate analysis of the actual qualification level of training candidates.
[44] The same FAR was effective when the PIC underwent type rating.

Thus, in view of the actual ELP level of both the PIC and the FO, neither of them was able to completely understand documentation critical for safe operations of Boeing 737 type aircraft.

This conclusion is confirmed by the difficulties that both pilots had during the final computer-based testing of theoretical knowledge during the type rating.

According to the available information, the PIC initially failed the final computer-based test demonstrating only 57% of correct answers and spending 1 hour and 20 minutes for the test. However, in just 15 minutes he started the testing again and only spending 55 minutes demonstrated 89% of correct answers ("good"). Taking into account that most of the incorrect answers (50%) were in the field of air navigation (while the PIC had flown for number of years as navigator) it is dubious that the PIC could pass the test for himself for the second time. The analysis revealed that the way testing was arranged at that time did not prevent other persons from helping the test-taker to pass the test (according to the available information, at present there is a CCTV in the room where computer-based testing is undertaken).

The FO undertook the final theoretical testing three times (on December 3, 2010, December 6, 2010 and December 8, 2010). Failing for the first two times he showed a result of 100% during the third time, meaning he gave correct answers to all questions. Taking into account the abovementioned, the objectivity of his final test results are also dubious.

The PIC's type rating training was extended over about 6 months with a long break between the theoretical training and simulator sessions. The theoretical training was completed on November 29, 2009. As the simulator center was not ready, simulator sessions were delayed. From November 31 to December 31 the PIC was on vacation. The simulator training started only on January 18, 2010 and was completed on March 9, 2010. The flight to check if he could be commissioned was undergone on March 28, 2010. As the type rating was completed on March 28, 2010 the PIC was granted a pertinent certificate. Although the regulations available at the time of the type rating did not regulate this issue, the investigation team deems that the extension of the training could have a negative effect on the acquisition of knowledge and skills in accordance with the training program.

In the course of the PIC's Boeing 737 type rating 4 different instructors conducted the 5 FTD sessions, and 9 different instructors conducted the 11 FFS sessions. This is explained by the fact that ANEO S7 Training did not have enough staff instructors for the actual workload. Freelance instructors are invited from airlines. The situation was almost similar for the FO's training. Two instructors conducted FTD sessions and 5 instructors conducted FFS sessions.

Such approach is inappropriate in the way of methodology[45], especially taking into account the fact that according to the available documents the PIC and the FO had very little flying experience as pilots when they started their type rating training.

Thus, the investigation team comes to a general conclusion that one of the basic principles of FAR-23 defining the accountability of one definite aviation training organization for the quality of a single pilot training was not complied with. This accountability was shared between the airline who sent the pilots for type rating, Tatar ITO of FATA approving the airline's decision to send the pilots for type rating, ANEO S7 Training and the invited instructors. As a result, pilots who did not meet the pre-requisites for the type rating were accepted for the training, while the quality of the training was also dubious.

According to the information provided by ANEO S7 Training, within 2008 to 2013 297 persons completed Boeing 737 type rating. None was expelled due to low qualification or poor progress.

One of the serious drawbacks of the interaction between the training organizations and flight operation departments of airlines was that FAR-23 or the airlines' regulations do not require, while the training organizations almost never provide, apart from the training certificate, records of the trainees' current progress including training tasks with instructors' comments or flight data records of the flight checks[46]. This prevents the airlines' flight operations departments to track pilots' progress in training as well as the training quality. Information on the intermittent tests results (like simulator check forms with instructor comments) is only provided upon request of the customer airline. According to ANEO S7 Training, after the PIC and co-plot's training was completed only the following was provided to the customer airline: Training Completion Certificate, resolution on the training completion and a copy of the simulator attendance log. Tatarstan Airlines did not request provision of all the training records.

Thus, the training process was like a "black box" where the airlines put their wishes as to the selected type rating program and the fee and then after some time received a pilot holding a Training Completion Certificate.

The investigation team also notes that according to the available information, after the accredited authorities issue Certificates authorizing various aviation training organization to

[45] Currently there are no regulations that would limit the possible number of instructors engaged in the training. Previous regulations defining flight training methodology (Flight Personnel Training Programs for Civil Aviation, published in 1992 as well as Federal Air Transport Agency Resolution № GK-101-r as of June 9, 2009 on Approval of the Typical Training Programs for Multiengine Aircraft Multicrew Pilots of civil Aviation) prescribed that only one instructor was fixed for every trainee.
[46] Similar shortcomings were found in the course of the investigation of an accident involving B737-505 VP-BKO that occurred at Perm on September 13, 2008.

conduct training, they do not monitor the actual quality of aviation personnel training in those organizations, which prevents timely identification of appearing risks to take corrective measures to eliminate or mitigate them to an acceptable level.

When analyzing documents confirming the PIC's recurrent training, the investigation team noticed that during simulator sessions he was repeatedly recommended to revise the sequence of actions during a go-around. Other repeated remarks were also noted. For example, within December 22, 2010 to July 4, 2013 the PIC underwent 9 simulator sessions (in accordance with Tatarstan Airlines Flight Crew Training Program). After four of the sessions he was recommended to revise go-around procedures and after two of the sessions he was recommended to revise NDB and VOR approach procedures. During every session a one-engine go-around was trained[47]. Go-arounds with two engines operative were not trained. According to the instructors go-arounds were mostly initiated at the decision altitude.

The investigation team notes that similar comments concerning the PIC's go-arounds and non-precision approaches were noticed in the course of the type rating training (which is a normal training situation). However, the fact that these shortcomings were not corrected within a long period of time after the PIC was authorized for solo flights (first as a FO and then as a PIC) as well as their recurrent nature is an evidence of the low quality of flight operations organization in the airline.

From November 2012 the PIC conducted flights as a trainee PIC. In violation of Para 2, Section 3, Program 1 of Tatarstan Airlines Fligth Crew Training Program requiring that pilots who had never been engaged as PICs to undertake initial theoretical training for civil pilots-in-command, the PIC did not undergo this training.

Note: *Similar shortcomings were found during the investigations of other accidents.*

The line check, recorded in the PIC's individual log as being conducted on September 1, 2013, was actually not conducted.

In view of the abovementioned, it may be concluded that the PIC was granted a commercial pilot license, authorized for Boeing 737 type rating and further for commissioning as a PIC in violation of the existing requirements. The PIC's qualification did not comply with the aviation legislation of the Russian Federation and prevented him from conducting safe flight operations on Boeing 737 aircraft. By the day of the accident the PIC did not have a right to conduct flights and should not have been included into the fligth task.

[47] It was not possible to define whether the go-arounds were trained as PF or PM based on the available documents.

Note: *As it was mentioned in Section 1.5, the ATPL was also granted to the PIC without any justification. In accordance with the current regulations of FAR-128 it is required to hold an ATPL to perform PIC functions on a Boeing 737-500 type aircraft.*

When analysing documents confirming the FO's periodic training, the investigation team noticed that during simulator sessions he was repeatedly recommended to revise the sequence of actions during a go-around. Other repeated remarks were also noted. For example, within August 4, 2011 to September 26, 2013 the FO underwent 7 simulator sessions (in accordance with Tatarstan Airlines Flight Crew Training Program). After two of the sessions he was recommended to revise go-around procedures and after three of the sessions he was recommended to revise NDB and VOR approach procedures. During every session a one-engine go-around was trained (two sessions included two go-around maneuvers each: one during the training session and one during the check)[48]. Go-arounds with two engines operative were not trained. According to the instructors go-arounds were mostly initiated at the decision altitude.

The investigation team notes that similar comments concerning the FO's go-arounds and non-precision approaches were noticed in the course of the type rating training (which is a normal training situation). However, the fact that these shortcomings were not corrected within a long period of time after the FOs was authorized for solo flights as well as their recurrent nature is an evidence of the low quality of flight operations organization in the airline.

In view of the abovementioned, it may be concluded that formally the FO's training on the whole complied with the applicable regulations. However, his actual ELP level that was insufficient for complete understanding of the operational documentation, as well as recurrent remarks concerning a number of simulator tasks provided a significant safety hazard for Boeing 737 operations.

According to the available documents the last time the PIC practiced upset recovery procedures on November 16, 2012 (according to FAR-128 such training is to be conducted at least once in three years). The upset was simulated by the instructor at random, and within each simulator session all kinds of upset were simulated (great nose up and nose down pitch angles, great bank angles). The last time the FO practiced upset recovery was on August 27, 2012.

The last GPWS alert response training was taken on July 4, 2013 by the PIC and on February 25, 2013 by the FO (according to FAR-128 such training shall be taken at least once a year).

[48] It was not possible to define whether the go-arounds were trained as PF or PM based on the available documents.

Thus, according to the available documents, the training intervals for the mentioned procedures complied with the applicable requirements.

However, the investigation team notes, that the airline applied a two-year recurrent training cycle (instead of the usual three-year cycle). The analysis revealed that four simulator sessions 8 hours each were not enough for quality practice of all the tasks in the recurrent training program (Section 1.5.2). The flight crew training was conducted in the airline in accordance with the Flight Crew Training Programs (FCTP) for each aircraft type. The FCTPs were part of the Flight Crew Training Manual approved by the airline's General Director (on August 25, 2009), accepted by Rosaviatsyia (September 22, 2009) and agreed with Tatar ITO of FATA (September 21, 2009), meaning the FCTM was approved before its acceptance by the authorities. The investigation team believes that the approval and acceptance was made by the accredited authorities in a formal way, without evaluation of the possibility to ensure the declared amount of training.

Note: *In accordance with the Air Code of the Russian Federation (Article 54, Para 4) training of aviation personnel as per the list of civil aviation positions shall be conducted in accordance with training programs approved (not accepted or agreed) by accredited civil aviation authority. This Air Code requirement is compatible with ICAO Annex 6 (Part I, Chapter 9, Para 9.3.1).*

It was also determined that the ground training between the simulator sessions as well as debriefings after the simulator sessions were conducted formally or not conducted at all in the airline. If debriefings are not conducted the essential part of instructors' work is not realized.

As the crew was formed of two "weak" pilots, who were converted to become pilots from navigators or flight engineers and underwent training with deviations from the applicable requirements, there was a significant safety risk that did not comply with the basic risk management principles and was an evidence of inoperative SMS in the airline.

The simulator experiment (Section 1.16.5) showed that three of the 6 pilots who were converted to pilots from navigators or flight engineers demonstrated rather satisfactory piloting techniques during the experiment, correcting the deviations made, although with a delay. The other three pilots demonstrated significantly worse results, they had obvious difficulties when coping with a more complex situation, assessing it and taking the right decision. Mistakes made by them during the go-around were more serious, one of them even approaching stall. Within the framework of this experiment there was no aim to compare the qualification and skills of the pilots who had initial flight training and those who were converted from navigators or engineers, however it is noticeable that the average qualification level of pilots who graduated from flight schools and had initial (basic) flight training is higher.

2.4. Flight Crew and ATC Conditions and Actions Analysis

Before the missed approach

The duration of the crew's preflight rest period was within the applicable requirements. However, the analysis of both pilots' work and rest for the last half year (Section 1.18.4) before the accident revealed that there was a great amount of overtime work without enough rest time to counteract the accumulated fatigue (within some of the accounting periods overtime work constituted 75–80% and the required amount of days off duty were not provided). The unutilized leave time could have also resulted in extra fatigue accumulation (the PIC had 111 days and the FO 275 days of unutilized leave).

Thus, it is highly probable that both pilots were conducting the accident flight with accumulated fatigue. Fatigue accumulation results in increased fatigability, lack of proper attention, absentmindedness, which leads to errors in aircraft control and decision-taking. The accumulated fatigue could have had negative effect on the flight crew conditions and actions in the accident flight.

The flight from Kazan to Moscow DME was uneventful. Most apparently, before the flight back the crew entered aircraft position when aligning the IRS with some errors (Section 2.2.1). The SOP prescribes the conduct of IRS alignment (either complete (recommended) or a rapid one) before each flight. The alignment shall be made by the FO, while the PIC shall monitor and cross-check this process (the accuracy of the aircraft position, etc.)

Note: ***FCOM. Normal Procedures.***
Insert the current position into SET IRS POS. Use the most accurate latitude and longitude.

The inaccurate position entered in the IRS before the flight and the normal map shift during the flight resulted in significant errors in aircraft positioning as it approached the STAR, which was one the reasons for the go-around.

The takeoff, climb and cruise flight were uneventful. In the course of the landing briefing the crew defined the approach pattern and discussed the go-around procedure. In particular they determined to use the TO/GA mode, the altitude of 1700 ft (500 m) to reach during the go-around, which is compatible with the standard go-around pattern and report to the ATC after completing the go-around maneuver. The crew did not distribute the duties during the approach briefing. Further the PIC was the PF, and the FO was the PM. Probably the pilots had distributed the roles well in advance, as there was no misunderstanding between them as to the duty sharing.

During further descent Kazan Control advised the crew twice (within 15:06:09 to 15:06:33 and 15:07:10 to 15:07:15) that the aircraft deviated from the track axis and informed them it was 4 km to the left of the track.

Upon receipt of the ATC information, the pilots spent a long time discussing the map shift which was approx. 2.3 miles, which was compatible with the ATC data.

Note: *During that flight segment both pilots watched the same deviations from the track (at 15:15:42 the PIC went: "The lateral one is still 2 miles. I mean the shift". Which was confirmed by the FO: "It's even increasing on mine... two or three miles to the right". Most apparently, these values were read by the crew from the EHSI (Electronic Horizontal Situation Indicator) in its MAP mode (FCOM Flight Instruments and Displays, EHSI Symbology, Page 10.32.13).*

At 15:07:30 the A/P L-NAV mode was transitioned to HDG SEL and the crew made a corrective turn right for approx. 5 degrees. However, as the crosswind component decreased due to the change in wind direction and speed as the aircraft was descending this heading change was not sufficient to intercept the assigned track. This was left unnoticed by the crew.

Based on the further actual flight path it can be concluded that the crew did not use other navigation aids (VOR/DME, NDB) for position check, neither did they use ATC information to correct their flight path.

Before passing the MISMI waypoint where the STAR starts, the lateral deviation of 4 km was not critical. However, as the crew did not make an appropriate correction to the heading, the aircraft passed the MISMI waypoint with a significant offset to the north of the track. The actual flight path was "inside" the STAR (closer to the runway).

Position identification and correction skills (complex airmanship) are acquired by pilots in the course of their training and confirmed during qualification checks, including simulator checks.

Upon request of the investigation team concerning the training for situational awareness and map shift identification and correction in the course of Boeing 737 type rating, ANEO S7 Training responded as follows: "The Boeing 737 type rating training program developed by aviation experts and approved by Rosaviatsyia does not include map shift identification training. ... Every pilot, holding a license, shall ... use information from all available sources to identify and correct the aircraft location. Such skills are acquired by flight crews during initial training at civil aviation flight colleges." As was mentioned before, the PIC did not undergo initial pilot training at a certified training organization.

After passing MISMI waypoint the crew proceeded with the same track angle parallel to the assigned track with the same lateral deviation (inside the STAR pattern). Furthermore, at 15:16:50 the crew made a corrective turn left, apparently to cut short the base turn, reduce time required for the approach and proceed with the final approach a bit closer to the runway threshold.

Sometimes experienced pilots behave likewise when making approaches to familiar airdromes in VMC if they are sure their position with reference to the STAR (or the runway) is accurate and there are no landing aircraft ahead.

In the accident flight the corrective turn left made the situation more complicated (lateral deviation from the approach pattern increased). The Radar Controller who was watching the aircraft at that time probably perceived this maneuver as a base turn and reacted immediately at 15:17:07 with: "*Tatarstan 363, early base*" and clarified after 6 seconds: "*Lateral distance 6, radial distance 9...*". In fact that was the third warning (two previous ones were given by Kazan Control) for the crew concerning the difference of the position that they probably saw on the EHSI from their actual position as seen on the radar.

However, the crew did not analyze the situation as appropriate and took no corrective actions, like turning right for at least 20 degrees to align with the back landing course or requesting vectoring. In fact, if the pilots had compared the on-board DME readings with the ATC information they could have seen their compatibility (9 km or 4.8 nm), while according to the EHSI the aircraft was at a far greater distance (approx. 13 km or 7.0 nm). Instead, the PIC spent 33 seconds swearing the ATC (from 15:17:11 to 15:17:44), while he was proceeding to the base turn point. Continuing the flight with the same heading confirms that the pilots must have identified the aircraft position using the EHSI information only and were not aware of their true position. Apparently, the PIC was considering the possibility of capturing the localizer after the base turn or during the maneuver.

The ATC was watching the aircraft flight path deviating significantly from the STAR pattern, but did not offer vectoring. FAR ATM (Para 6.7) prescribes provision of such assistance determining that "the necessity of vectoring is defined by the ATC based on the air space situation analysis. Vectoring is used ... to provide air navigation service to the crew".

Note: *During the interview, the ATC officer stated that he had an idea to offer vectoring. But he was guided by Para 6.8.1 of FAR ATM ('upon request of the crew, the ATM center performs vectoring to render them air navigation assistance") and as there was no request from the crew, vectoring was not provided.*

The investigation team notes that certain passivity in the ATCs actions in case of obvious deviations of aircraft from standard patterns, had been revealed during other accident investigations (e. g. Final Report of the accident involving TU-154M RA-85744 aircraft that occurred on December 04, 2010 at Domodedovo Airport). Based on the investigation results, the FSUE "State ATM Corporation" was recommended to redesign ATM procedures, but similar events still occur.

After the crew informed the ATC on reaching the base turn point (according to the EHSI) they were cleared for combined base and final turn. Actually the turn was initiated (at 15:18:05) with a significant deviation from the STAR pattern, at a radial of 115°–116° (according to the approach pattern, the base turn point was located at a radial of 134°) with lateral deviation from the LLZ centerline of about 1.5–2 km). Besides, the base turn was initiated with flaps only 1, with excessive speed (200 to 190 kt), which made the turn radius even greater.

Because of the mentioned significant deviation from the STAR pattern, excessive speed as well as strong tailwind at the circuit altitude, the aircraft crossed the landing track 20-25 seconds after the turn was initiated, which the crew did not notice at that time. In the course of the turn the crew continued complaining about the ATC:

FO (15:18:12): "He spoiled such a... such a calculation";

PIC (15:18:16): "Well, you're right, I was just thinking...".

This means that at that time the crew were not concerned about the actual aircraft position and apparently referred to the EHSI indication. The fact that while conducting the combined base and final turn, after they crossed the LLZ centerline, the aircraft was for a short time (about 10 seconds) leveled off from the roll (on heading 313 degrees) means that the pilots believed they were following the base leg. Therefore, the crew did not engage the VOR/LOC mode before they crossed the LLZ centerline. Since that moment the crew was "behind the aircraft", i. e. they were short of time.

Note: *The analysis of previous PIC flights FDR record (Section 1.18.8) revealed that in a number of cases IRS map shift was even greater than 4 km, but he did not experience difficulties capturing the landing track. Almost in all of the flights the VOR/LOC mode was engaged in due time, which automatically aligned the aircraft with the landing track.*

Only during the second half of the turn the pilots became anxious about the unclear and unexpected situation, trying to understand it.

PIC: (15:18:44…15:18:55) "I don't get it... What the hell is that?...". FO: *"Wait, I'll VOR/LOC it, what will that give?"* PIC *"Something strange, I've VOR/LOC'ed it".*

After the FO checked the ILS frequency in both instruments, said at 15:18:59 to 15:19:10: *"What's that?! Well, what about mine?..", "I don't get it either... Looks as if we've crossed over it..."*

After the turn the aircraft was offset significantly to the right of the landing track. The cockpit communication analysis revealed that the crew was not completely aware of their position with regard to the approach pattern. The crew realized the aircraft was to the right of the landing track only thanks to the ATC information. However, the ATC did not specify the lateral deviation and the crew was not able to determine it using on-board equipment. To establish on LLZ the crew initially selected heading approx. 270 degrees (~ 20 degrees difference with landing course), then made a corrective turn left heading 257 degrees (~ 35 degrees difference with landing course) and finally heading 252° (~ 40 degrees difference with landing course). But taking into account the great lateral deviation and actual wind direction and speed, even such a heading could not ensure timely interception of LLZ.

Nevertheless, the crew continued to prepare for landing: the landing gear was extended, flaps were set first to Flaps 15 and then to Flaps 30. According to the SOP, the landing gear shall be extended and flaps set to 15 degrees only after the localizer is captured and glideslope alive, and flaps shall be set to landing configuration when the glideslope is captured.

Besides, as the crew was making the combined base and final turn the flight altitude was 500 m (1700 ft), while the approach pattern prescribes descent to 400 m (1300 ft). The crew did not follow this procedure as their attention was focused on the lateral control issues. The PIC decided to descend from 500 m (1700 ft) to 270 m (900 ft) much later (at 15:21:39), with the only purpose of trying to establish visual contact with the runway or other ground references and reestablish situational awareness (for details, see below).

As the ATC requested the crew at 15:21:24 if they were ready for landing the PIC decide to report that they were. PIC (15:21:27): *"Tell him we are ready."* This report was not true, as the aircraft had significant lateral deviation from the landing track (the HSI LOC deviation pointer was at the most left position) and was at an altitude of 500 m at a distance of about 4 km from the runway threshold, much higher than the glide path. The cockpit communications analysis revealed that the crew understood that the aircraft position with reference to the landing track and glide path was not suitable for landing, but the PIC decided to make a formal report.

The PIC's decision to continue the approach was apparently caused by his natural wish to land from the first approach. In spite of the lack of accurate aircraft position information with reference to the approach pattern and the runway he probably hoped they would finally be able to capture the glide slope and land.

Besides, there was a psychological aspect to the flight that has to be taken into account: the crew was aware of a VIP passenger on board[49], which according to the opinion of the pilots conducting the assessment of the accident flight (chapter 1.16.4) could have added to crew's stress. A go-around at the home base airdrome in relatively plain meteorological conditions could have become a ground for a debriefing in the airline that might have revealed the erroneous actions of the crew during the approach. And though the PIC was not aware why they failed to intercept the LLZ timely, he could have very well supposed that it was due to some of their erroneous actions.

Under those circumstances it would have been a better decision if the crew had asked the Controller's assistance to determine their accurate position[50] and take the decision to terminate the approach during that flight segment. But the crew did not take such a decision.

The ATC officer cleared them for landing, although he could see it on the radar that the aircraft was not stabilized (Figure 84): the distance from the localizer was about 5 km, according to Galaktika ATM automation complex, the altitude was 500 m according to the aircraft information tag without any tendency to descend (the descent symbol was not present in the tag) and the aircraft was offset to the right of the landing track. It would have been a more appropriate decision for the ATC officer to inform the crew on their actual position at least and recommend to go around.

Note: *According to the ATC Officer Operational Procedure and FAR ATM it is not required that the control officer requests and receives a report from the crew on their readiness for landing. In that situation this request was made (according to the explanation of the control officer) because the "... aircraft was offset right from the track" and he was trying to clarify if the crew was ready to land then.*

[49] There were no signs of persons other than the flight crew being present in the cockpit or any pressure on the flight crew.

[50] The crew could have also used VOR or NDB to identify their position.

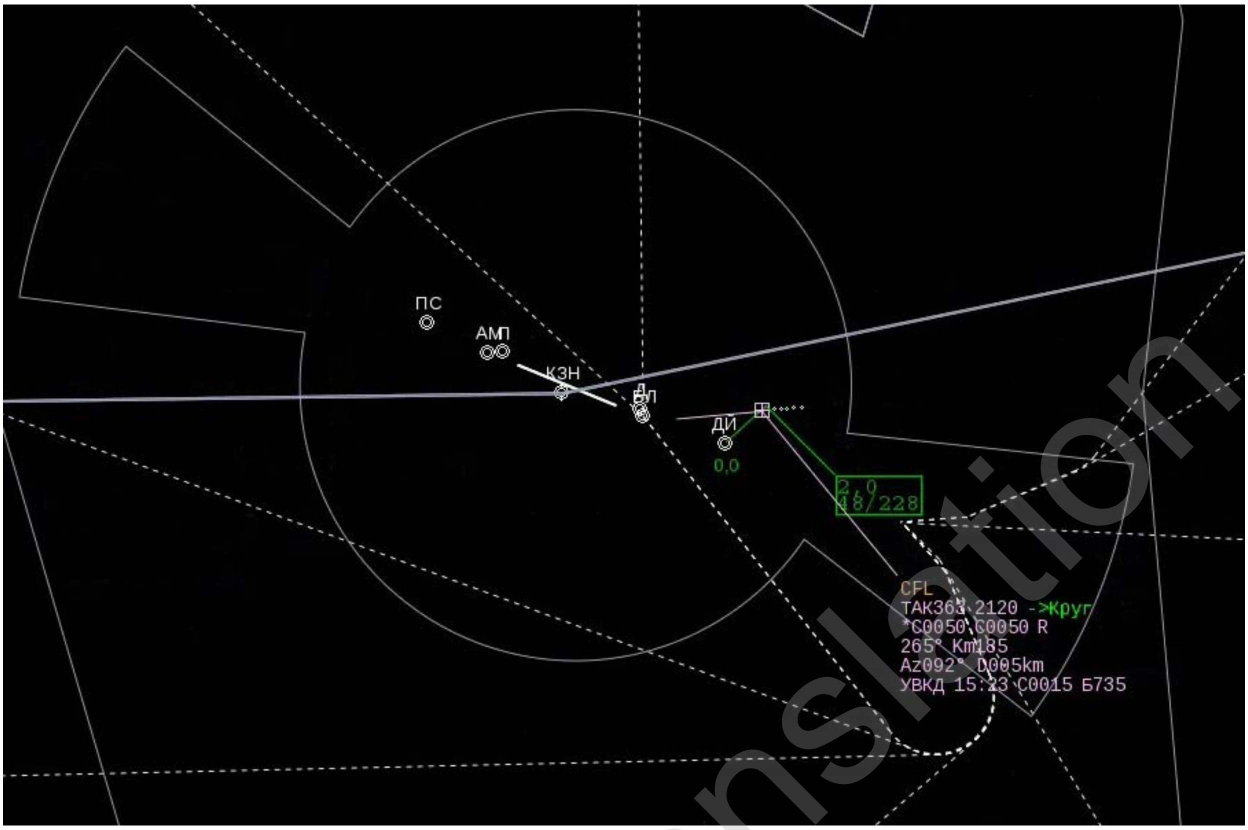

Figure 84 Radar printscreen at the time of the landing clearance providing

After they received the clearance the crew engaged the V/S mode (descent rate of 1200 fpm) to descend to approx. 270 m (900 ft) height. This altitude was mentioned in the ATIS information as the cloudbase. The cockpit communication analysis revealed that for that reason the PIC descended to the mentioned altitude hoping to establish visual contact with ground references and regain situational awareness. Most probably, the cloud base was rough: from 220 m to 270 m. As the emergency services were alerted, the following actual weather was recorded: wind at circuit altitude 250° 16 m/sec, visibility 10 km, moderate sleet, overcast 8 oktas, stratocumulus, fractinimbus, cloudbase 220 m.

The cockpit communications analysis also revealed that during the descent from 500 m to 270 m both pilots were busy looking for the runway or ground references.

FO (15:21:45) (H 500 m) «It's unclear. I can't see...";

PIC (15:21:51 to 15:21:54) (H 460 m): «Wait, we'll descend 270». «Is it there? Can you see anything, eh?"

FO (15:21:56) (H 440 m): «Can't see it yet».

At 15:22:24 the GPWS alert was triggered «One thousand» (radio altitude of 1000 ft or 300 m). According to the airline's FOM (Part A, Para 8.21.9 and 8.21.9.1) and ICAO recommendations, if the aircraft is not stabilized on the glide path the crew shall initiate a go-around.

Note: ***Airline's FOM***

Para 8.21.9 The PIC shall terminate descent and conduct a missed approach (go-around) procedure, if:

…

V. *in case of commercial transportation, the aircraft is not stabilized as per the FOM requirements, when reaching a height of 300 m in IMC;*

para 8.21.9.1. Stabilized Approach Criteria *During all flights descent shall be stabilized at a height not lower than 300 m (1000 ft) AAL in IMC.*

Decent is considered stabilized for landing if:

I. *The aircraft is on the correct flight path;*

II. *Only slight yaw and pitch evolutions are required to maintain the correct flight path;*

…….

If the aircraft is not stabilized during an IFR approach without visual contact with the runway until the height of 300 m (1000 ft) is reached go around shall be performed.

In any situation the PNF shall make timely call outs of any deviations from the estimated flight parameters and take over control of the aircraft if the parameters go beyond the safe flight envelope.

At the time when the GPWS alert «One thousand» was triggered, the aircraft was significantly higher than the glideslope (the HSI GP deviation pointer was at the lowest position) and was turning right with a bank angle of 29° (right before that the localizer was captured and the A/P forced the aircraft to intercept the landing course), meaning the aircraft was unstabilized.

Note: ***Landing procedure – ILS SOP B737 of Tatarstan Airlines Extract***

At 1000 ft radio altitude

14. ANNOUNCE:"1000 STABILIZED NO FLAGS" or "1000 NOT STABILIZED ….."

In this situation the PIC was to take the decision to go-around. Instead, the PIC reported: *«One thousand, stabilized, no flags»* and continued the approach. The FO did not follow the FOM either and he did not inform the PIC that the aircraft was unstabilized.

Only at a height of 270 m (15:22:29 to 15:22:32), when the aircraft descended lower than the cloudbase, the FO finally could see the runway, regained situational awareness and informed the PIC: *“Huh, that’s it, here, the runway underneath us. Naaah... (no). We’re too high... Four white lights, we’re too high”*.

The PIC was not able to see the runway anyway: *“Eh? Where do you see it? I can’t see it, where is it?”*. Therefore, at the time of the go-around the PIC was not completely aware of their position with reference to the runway. Most probably, due to the big drift of the aircraft to the left (up to 12 degrees) and rough cloud base the FO had a better visual scan of the runway from his position.

It should be noted, that even before they were cleared for landing the crew did not exclude the go-around option.

PIC (15:20:49 to 15:20:53): “Well, we neither have the landing position anywhere, nor anything else. just 4 miles to go... Now it’s going to appear... we’ll press the Go... Go-around”.

The FO confirmed (15:20:55): «Aha. Yes».

PIC (15:20:57): “Nothing bad about it”.

After they were cleared to land the crew had another brief discussion of the go-around option:

FO 15:22:01): «It feels as if we are…». «Yeah, going the wrong way».

PIC (15:22:03): “In case anything happens we can go around now”.

Despite their discussions of the go-around option (it sounded more like self-complacency than real readiness) most probably the PIC was not psychologically ready for the go-around, as the task to find the runway and land appeared to prevail over the go-around alternative.

The cockpit communication analysis revealed that the FO found that the aircraft was unstabilized after he saw the runway and PAPI lights and it was he who initiated the decision to go around (15:22:34): *«There’s the runway. No. Go around. Go around”*. The PIC immediately took the decision at 15:22:38: « *Go around report we are going around. Position unsuitable for landing.”*

Thus, the aircraft was unstabilized and the crew took a correct decision to go around (though it was delayed).

It should be noted that according to the go-around log, since the PIC had been commissioned as a PIC he never made any real flight go-arounds.

Note: *The simulator experiment conducted by the investigation team (Section 1.16.5) revealed that the absolute majority of line pilots involved in the experiment consider go-around as a difficult* *element for a line pilot, mainly because of the increased workload and stress. Some of the pilots evaluated this process as distress or close to distress state. During the experiment, when pilots were exposed to increased stress during the approach when they were unexpectedly instructed to go around, only about 30% of the pilots made more or less successful go around. It should be noted, that over 30% of the pilots involved in the experiment had never conducted real life go-arounds.*

In order to understand further actions of the crew during the go-around it is important to note the psychoemotional atmosphere on board that was present by that time.

Based on CVR record analysis it can be concluded that before the crew became aware of the abnormal situation (after the aircraft crossed the LLZ centerline) the pilots felt quite confident and relaxed. This is confirmed by the following:

- underestimating and even neglecting the ATC information on the aircraft deviation from the assigned flight path as well as their discussions of the ATC actions during the cockpit communications;
- the desire to make an approach using a shortcut pattern;
- relaxed timbres of their voices;
- the approach being performed to the home base airdrome in relatively simple meteorological conditions.

In this situation, it can be assumed that the crew were not sufficiently mobilized psychologically. This state is characterized by the following features: a pilot assumes that the work is almost dealt with and his psychological tension is lower than required in the actual situation. In such a state the pilot, as a rule, is not able to identify implicit signs of an abnormal situation in due time. Which means that if the flight is uneventful, this state would not affect the flight outcome. But in case of implicit deviations from the normal situation a pilot will not notice this deviation timely with a high degree of probability.

The crew identified the abnormal situation after the aircraft crossed the LLZ centerline. The crew tried to establish LLZ for over 3.5 minutes, almost until the FO identified the runway and the go-around decision was taken. It can be well assumed that during that flight segment the crew were not aware of the aircraft position with reference to the runway and glideslope as accurate as required at that phase. Moreover, part of their mind and attention was devoted to solving the appearing problems. This was reflected in deviations from the SOP. Trying and hoping to recover on their own and land the pilots did not realize that position can be monitored using VOR or NDB or that they could ask the ATC officer for assistance.

Thus, the crew's unawareness of their actual position on the approach pattern, failure to use complex airmanship skills with the help of VOR/DME and NDB as well as vectoring from the ATC, as well as the PIC's wish to avoid going around and continue approach (as he did not have stable go-around skills and psychological readiness to go-around) resulted in time deficiency and growth of stress. Actually, after the crew identified the abnormal situation, in terms of aviation psychology they started to lag behind the aircraft. By the time of the go-around their attention must have been channeled, which especially concerned the PF (PIC) who did not manage to regain complete situation awareness. This was a background for the following events that resulted in the impact.

Note: *Section 1.18.9 contains a description of another event involving loss of situation awareness during the go-around. The event ended up with a safe landing, the crew was able to recover. The description of the possible causes of the event provided by the PIC of that flight and his psychological state is compatible in details with the opinion of the investigation team on the accident flight events.*

Crew Actions during the Go-Around

For convenience relative timing will be provided here beginning at the moment when the TO/GA pushbutton was pressed (15:22:45). From that moment 43 seconds passed before the impact. The mentioned time interval was divided into a number of time segments.

First segment: 0-25 seconds (15:22:45…15:23:10)

The crew engaged the TO/GA mode to go-around as had been decided during the landing briefing.

It should be noted that the airline did not have a separate procedure for go-around from an intermittent height with two engines operative. During the simulator sessions when go-arounds were practices, they were never performed from an intermittent height, in most of the cases go-arounds from the decision height with one engine-off were practiced.

As the TO/GA mode was engaged the A/P used for the approach was automatically disengaged as per design and further control of the aircraft should have been performed with reference to FD bars which means manual flying.

The A/P disconnection was accompanied with a red warning light on both pilots' control panels and an aural alert. It should be noticed that the A/P disengage alert is very loud and alarming (louder and more alarming than on many other aircraft types) and has a vivid attention-getting effect. The crew did not discuss the causes of the alert being triggered and the alert was not switched off up till the impact (by pressing the button on the control wheel). This means that the crew members (especially the PIC) were in very stressed conditions and did not identify the A/P disengagement and that they started to further lose situational awareness. A long-term duration (influence) of the alert, even when it is not realized (interpreted as an alert) by the crew, can lead to significant channeling of their attention (tunnel effect). The number of parameters that can be simultaneously monitored and analyzed is reduced abruptly to as little as one or two.

Note: *When completing the questionnaire before the FFS flights (Section 1.16.5), pilots experienced difficulties when answering questions related to the autopilot, flight director and autothrottle functioning logics during the approach and go-around. Despite four of the pilots were cheating using reference documents they had on their personal electronic devices, none of the pilots was able to answer all the seven question concerning the logics of the combined functioning of the aircraft automation system. During the go-around mode more than 30% of them experienced difficulties identifying that the A/P was disconnected. Besides, 2 pilots stated that the go-around was conducted in automatic mode by the A/P (even though the A/P disengage alert was working!). This indicates both the insufficient level of basic knowledge and a gap between theoretical knowledge and practical skills.*

Most probably, the PIC considered pressing the TO/GA pushbutton as an end-all solution:

PIC (15:20:54): «Well, it's going to appear, we'll just press the «Go…Go around» … It's not a big deal».

PIC (15:22:03): "In case anything happens we can go around now".

Most apparently, the PIC was not prepared for the A/P disconnection and expected the aircraft to make the go-around and automatically reach the required altitude (without taking into account that the approach had been made with only one A/P engaged and the go-around altitude had not been selected on the MCP in due time).

Thus, most probably, the PF believed that the A/P was engaged and commanding the aircraft to go-around automatically. This conclusion is confirmed by the fact that during the whole of that segment (25 seconds) there were almost no column or wheel inputs. A slight column nose down deflection of approx. 1 degree at 15:23:00 could not be considered a deliberate control input. Most probably, this input was instinctive, as the aircraft had already reached quite a large nose up pitch angle, and did not decrease the pitch angle.

During the go-around, due to Boeing 737 aerodynamic profile and engine location (behind the wing, lower than the center of gravity) as a result of thrust increase and flaps retraction the aircraft initially behaved very similar to automatic go-around, which meant the pitch angle was increasing, the FD pitch bar was almost matching the symbolic aircraft, the thrust and airspeed were increasing (these parameters are to be monitored during the go-around according to the SOP). The simulator experiment that simulated the final segment of the accident flight as well as EADI indication reconstruction for the final segment (Section 1.16.1) confirmed that at least for the first 10 to 12 seconds after the TO/GA pushbutton was pressed the aircraft behavior, its flight path and FD pitch bar readings during the automatic and let-alone uncontrolled go-around are very similar.

As a result of unofficial survey among Tatarstan Airlines pilots it was established that there was the following practice within the airline: if landing was not planned to be performed automatically only one A/P was engaged during the approach. However, if during simulator sessions the second A/P was used anyway (simulator training tasks analysis revealed that automatic landings were trained) the pilot could have obtained a stereotype that after the TO/GA pushbutton is pressed the aircraft went around in automatic mode and the A/P was not disconnected.

During that flight segment the key flying principle of Aviate – Navigate – Communicate was violated. For 20 seconds after the PIC's decision to go-around and for 16 seconds after the start of the go-around maneuver the FO was busy communicating with the ATC (after the PIC commanded him to report they were going around), which kept the pilot away from control loop until the peak of their flight path. However, during the landing briefing the PIC specified that in case of go-around they would have to report to the ATC after climbing to 1700 ft (500 m). The fact that the previous correct decision was changed also confirms the abnormal psychological state of the PIC.

The FO was not cross-checking the PIC's actions and failed to perform any of the SOP requirements: he did not inform the PIC on reaching positive vertical speed, did not retract the flaps to 15 degrees as requested by the PIC (most apparently, the PIC retracted the flaps himself), did not monitor the airspeed and delayed to remind the PIC to retract the landing gear. Besides, when the FO read back the ATC information he called out a wrong go-around altitude (though they were approaching to the home base airdrome!), which also gives ground for doubts if the FO was ready for the go-around.

The ATC actions were contributory to such a long-term distraction of the FO. Instead of giving a short response (like "Roger") after they had reported going around, the ATC officer started instructing them on the go-around altitude and transition to another frequency to contact Radar Control. This information did not contain anything unknown for the crew (the altitude assigned by the ATC was the same as on the go-around pattern, and the Radar Control frequency was also known by the crew), and did not affect the safety of further flight (the air space conditions were not complicated) and only provided additional distraction for the pilots during a stressful flight phase. The crew SOP do not include radio exchange during a go-around. In the Tower Controller Operation Procedures there was no section that would describe ATC actions after receiving a go-around report from the crew.

Only 20 seconds after the go-around start the FO was "back" to the cockpit and went ahead with his duties with a delay: he reminded the PIC of the necessity to retract the landing gear and then retracted them upon the PIC's command, then he identified that the go-around height of 500 m/1700 ft was not set on the MCP and set it. However, he almost did not monitor more important parameters: airspeed, pitch angle and height (the airspeed was intolerably low (120 kt) and was still falling, the pitch angle was excessively high (25 to 26 degrees nose up, which is classified as upset and requires immediate interference into aircraft control), the height increased to over 2100 ft (640 m) with the selected go-around altitude of 1700 ft (500 m) and was still increasing).

All of this is sure evidence that the pilots did not have stable skills of attention allocation and refocusing, could not distinguish the most vital parameters and take timely recovery actions. Even if it is assumed that they did have such skills, the excessive stress close to distress brought them to naught.

The crew distress at that stage was confirmed by the fact that their timbres were changed, they switched from English to Russian when using the standard callouts, mixed up the English words "up" and "down" when discussing the necessity to retract the landing gear, and asked the ATC to repeat the go-around altitude, although the altitude was consistent with the go-around pattern and could be clearly heard on the CVR record.

During the simulator experiment (Section 1.16.5) it was determined that the PF's (PIC's) stress level was higher when they did not receive the expected assistance from the PNF (FO).

Below are tables that sum up the required go-around actions (as per the SOP)[51] and the accident crew's actual actions.

[51] Only those actions are provided that are related to the accident circumstances. The complete procedures in the English language are contained in the pertinent airline's document.

PIC (PF in the accident flight)

Actions as per the SOP	**Actual actions**
• make a go-around callout; • engage TO/GA mode; • call “Flaps 15”	All actions completed.
Verify: • the rotation to go–around attitude; • that the trust increases.	Most probably retracted the flaps to Flaps 15 and monitored their position. Did not monitor the pitch angle, FD bars position or airspeed.
Verify a positive rate of climb on the barometric altimeter and VSI and call “GEAR UP”	The command was given with a significant delay, only after the FO had reminded of that.
Above **400** feet radio altitude it is prescribed, among other actions to: • select or call for appropriate roll mode; • verify that the missed approach route is tracked; • verify that the missed approach altitude is captured.	Not completed.

FO (PNF in the accident flight)

Actions as per the SOP	**Actual actions**
Upon command from the PIC Position the FLAP lever to 15 and monitor flap retraction.	Most probably, this action was performed by the PIC. The FO was maintaining radio communication with the ATC for 16 seconds after the start of the go-around.
Verify that the thrust is sufficient for the go-around or adjust *as needed.*	The actual engine thrust was consistent with the estimated thrust. However, due to the excessive nose up pitch angle, the airspeed fell to 117 kt during the go-around. The FO did not monitor the airspeed.

Verify a positive rate of climb on the barometric altimeter and VSI and call "POSITIVE RATE". Upon command of the PIC, set the landing gear lever to **UP**.	There was not any timely call out on reaching positive vertical speed. After he finished with the radio exchange, the FO reminded the PIC they had to retract the landing gear and accomplished it.
Verify that the missed approach altitude is set.	Completed with a significant delay.
Above 400 feet radio altitude it is prescribed, among other actions to: • verify that the missed approach route is tracked; • verify that the missed approach altitude is captured.	Not completed.

Second segment: Seconds 25 to 30 (15:23:10 to 15:23:15)

At that stage the PIC took control of the aircraft. It was not possible to determine what exactly encouraged the PIC to initiate control inputs. One or a combination of the following factors thereof could have forced him to do that:

- pitch angle of over 25 degrees nose up, which is classified as *upset* according to the aircraft manufacturer's documentation and requires immediate inputs from the crew;
- exceeding the established go-around altitude;
- FD pitch bar indications;
- airspeed falling below the target values.

Note: *The simulator experiment revealed that during the go-around less than 20% of pilots followed the flight director guidance, while others preferred to fly with reference to the artificial horizon, maintaining the pitch angle of approx. 15 degrees and monitoring the airspeed. They explained that they used this go-around technique as the difference between the FD bar and the symbolic aircraft during the go-around is insignificant as a rule. Figure 27 shows that within the whole go-around maneuver, even if the actual flight parameters significantly deviated from the required values, the difference between the FD pitch bar and the symbolic aircraft position did not exceed 5 or 6 degrees (Section 2.1).*

At 15:23:10 the PIC made the first column nose down input. The column was deflected for about one third of the travelling distance from the trimmed position to the forward stop (the column was deflected for 5–5.5 degrees, while the elevator was deflected for eleven degrees nose down) and was simultaneous with the automatic stabilizer nose down trim of approx. 1.7 degrees. The column was kept in that position for slightly over 4 seconds, and then was deflected back to the trimmed position for just 1 second (most probably the PF just released the pushing forces on the column which shifted towards the balanced position due to the load spring).

This PIC's input resulted in the nose down pitch to almost level flight position: the pitch angle was 6 to 8 degrees and was still decreasing. The left bank was about 10 degrees, the airspeed was 118-117 kt (minimum recorded airspeed), height approx. 2300 ft (700 m) QFE, actual vertical speed of climb was about 0 fpm (the vertical speed indicator was apparently still indicating climb due to the existing lag), the FD pitch bar almost matched the symbolic aircraft on the pitch scale. The vertical load during that maneuver decreased to approx. 0.5 g. This vertical load value can be considered acceptable for upset recovery.

The PF actions during this segment could have been evaluated as correct though delayed, if he had finished the maneuver properly meaning if he had returned the column to the trimmed position (like he had done initially) and **made it remain in the trimmed position for some time**, so that the aircraft could have transitioned to a smooth descent. In this case the aircraft that had actually recovered from the upset would have reached the required acceleration and descend to the circuit height (1700 ft/500 m).

However, the PIC's inability to evaluate the actual aircraft position promptly and correctly and foresee its further behaviour as well as his stress and channelled attention resulted in lack of situational awareness and following erroneous actions.

As abovementioned, the FO, who was busy retracting the landing gear and monitoring it, as well as monitoring and setting altitude on the MCP, was still out of the control loop.

Third segment: Seconds 30 to 35 (15:23:15 to 15:23:20)

After returning the control column to a close-to-trimmed position for a short period, the PIC pushed it again for just over one half of the travelling distance (the average column deflection was 7 degrees and the elevator was deflected for 13.5 degrees with the stabilizer position unchanged). The column was kept in that position for about 4 seconds, and then was deflected back to trimmed position for just 1 second. The shift back was either due to release of pushing input forces on the column or probably the FOs interference with the aircraft control (15:23:20). As abovementioned, before the second nose down column input the aircraft had already reached position close to level flight with a relatively small bank angle (10 degrees) and the second nose down input was not required. The most probable cause of the second column nose down input was that being stressed and having no stable attention allocation skills the PIC was not able to monitor and analyze the number of parameters required to make an adequate assessment and forecast of the situation. Supposedly, by that time the PIC was able to concentrate only on a single parameter that was the height, as it was much higher than the target height (1700 ft/500 m) that was to be reached. The situation was even worse if the PIC had monitored the height on the EADI radio altimeter, as from 15:23:16 the radio altimeter indications were higher than the pressure altimeter indications (by approx. 50 to 70 ft), and further (as the nose down pitch angle of over 40 degrees was reached) the radio altitude was indicated with a great inaccuracy (higher than the actual height) due to natural limitations of the radio altimeter operation at significant bank and/or pitch angles.

Seeing that the flight height did not decrease after the first nose down input the PIC could have assumed that the actions taken were not sufficient to reach the assigned height as soon as possible, which he considered his basic goal. Therefore he made another, even greater, nose down column input without monitoring other flight parameters (the pitch angle, the pitch rate and the rapidly increasing airspeed). By the end of the second segment the aircraft had the following parameters: nose down pitch angle of 20 degrees, left bank of 5 degrees, airspeed over 140 kt with an incredibly intensive acceleration (10 kt per second), height about 2200 ft (670 m) QFE, and actual rate of descent being over 5000 fpm (25 m/sec). Meanwhile the pitch bar on the FD was 4.5 degrees higher than the symbolic aircraft and indicated the need to recover from descent. The aircraft that just approx. 10 seconds before had been upset nose up reverted to nose down upset. Taking into consideration the quickly changing situation as well as the PIC’s lack of pertinent skills and his actual qualification level, he was not able to apply the required upset recovery techniques.

Vertical acceleration that had almost reached zero due to control inputs was a serious contributing factor to the PIC losing situational awareness and his inability to react adequately (the aircraft was actually in null-gravity condition). The experience of flights with near-zero acceleration reveals that persons who get into the null-gravity state for the first time lose both the ability to act and spatial orientation for the first few seconds. Besides, during near-zero and negative acceleration unattached objects as well as dirt and dust that are always present in the cockpit get up in the air. This usually happens unexpectedly and produces a startling effect on the pilots. The dirt and dust as a rule get into the pilots’ eyes and noses obstructing their vision and breathing. Most probably the pilots had not have an idea of what null-gravity actually is like nor pertinent training.

Nevertheless, it should be noted, that the FO who was finally “back” to the cockpit did notice that something wrong was happening to the aircraft and asked anxiously: “What’s up?” at

15:23:19. This is an evidence that he only started to analyze the current situation at that moment and probably even tried to correct it by pulling up the control column in order to show the appropriate actions to the PIC. But the PIC must not have heard the FO at that time and did not react to his phrase in any way as he was totally disoriented and could not control the aircraft.

There is no doubt that if recovery from descent had been initiated at that moment, the height margin would have been enough for the safe recovery of the flight profile without even exceeding the operational limitations.

Fourth segment. Second 35 (15:23:20) up to the end of the record

During that segment the PF's actions clearly confirm his spatial disorientation as well as disintegration and critical tunnelling of his flight perception. This explains why there was no reaction to the EGPWS «SINK RATE» and «PULL UP» warnings, whereas the PF should have immediately pulled up to terminate descent. Instead an opposite action followed meaning the nose down column input up to the mechanical stop. The engineering simulation revealed that the forces applied by the PF on the control column at that time exceeded 50 lbf (22 kg).

This nose down control input (apart from increasing nose down pitch angle, vertical speed of descent and airspeed) resulted in significant negative acceleration (-0.5 to -0.8 g) that could have prevented the FO from taking over control especially if the safety harness was loose.

Note: *The forensic expertise revealed that most probably the pilots had been fastened with seat belts. It was not possible to determine the condition of the shoulder straps.*

The FO, who had noticed the abnormal aircraft position before, tried to attract the PIC's attention by calling his name twice, but the latter reacted only with: "What?" that confirms that he had completely lost situational awareness.

Further control actions were chaotic, which resulted in the impact.

As a number of simulator experiments revealed the last moment when it was possible to recover from the nose down pitch with an acceleration of 3.0 to 3.5 g (exceeding the operational limitations with no structural damage to the aircraft) was apparently at 15:23:23 (the aircraft was descending with a nose down pitch angle of 40 degrees, the height was 1900–2000 ft (580-610 m) with an airspeed of 175 to 180 kt. The height loss would have been 1600–1700 ft (about 500 m) meaning the aircraft would have been recovered at a height of 200 to 300 ft. However, neither at that moment nor further did the crew regain situational awareness or initiated any recovery actions.

It cannot be excluded however that during the last 20 seconds of the flight the pilots could have experienced a nose up somatogravic illusion. The possibility of such an illusion is confirmed by the pertinent analysis (Section 0).

Note: *Somatogravic illusion is a general form of vestibular illusion or wrong perception. Somatogravic illusions can lead to spatial disorientation. Significant longitudinal aircraft acceleration can create a nose up pitch illusion. In this case the pilot can instinctively push the control column in order to prevent the increase of perceived pitch angle. Rapid deceleration of the aircraft, on the contrary, leads to a nose down pitch illusion and the pilot can instinctively pull up resulting in pitch angle increase.*

Recommendations for upset recovery should be mentioned separately. The sequence of recovery actions is described in the QRH.

Pilot Flying	**Pilot Monitoring**
Recognize and confirm the situation	Recognize and confirm the situation
Disconnect autopilot and autothrottle	Call out attitude, airspeed and altitude throughout the recovery
Apply as much as full nose-down elevator	Verify all required actions have been completed and call out any omissions.
*Apply appropriate nose down stabilizer trim	
Reduce thrust	
* Roll (adjust bank angle) to obtain a nose down pitch rate	
Complete the recovery: When approaching the horizon roll to wings level Check airspeed and adjust thrust Establish pitch attitude.	
WARNING: *Excessive use of pitch trim or rudder may aggravate an upset situation or may result in loss of control and/or high structural loads.	

The original English QRH contains the phrase: *«Apply as much as full nose-down elevator», that must be understood as "deflect the elevator nose down to a required position may be up to full deflection"*. However, the English structure used can lead to ambiguous interpretation as to the required actions, especially for the non-native speakers of English. This instruction can be interpreted as a requirement to apply full nose down elevator (column), especially taking into account that the following action described in the QRH is the possible additional stabilizer trim, while the warning below the table concerning loss of control or high structural loads only mentioned the use of stabilizer and rudder.

During the accident flight the PIC acted accordingly at some moment (applying full nose down column), which resulted in near-zero and negative loads and transition from the abnormal situation to emergency.

Note: *The simulator experiment and survey among the pilots revealed that the absolute majority of them (10 out of 11) understand this QRH provision as a requirement to always apply full nose down elevator (control column) and apply stabilizer if necessary. None of the pilots managed to recover properly from the nose up upset, including experienced instructors.*

In most cases, however, full elevator is not required. The required value shall depend on the aircraft position and its flight profile (pitch, airspeed, thrust, speed decrease rate, etc.) and **shall not result in the near-zero or negative loads.** This has to be emphasized for both pilots who undertake upset recovery training and instructors who are providing such training. Unfortunately, even modern simulators cannot reproduce the actual loads, therefore pilots cannot experience its negative effect on the aircraft control if the column is pushed too far. As a result pilots can acquire a wrong (negative) skill that can lead to emergency in real flight conditions. This is particularly urgent for aircraft not equipped with angle of attack and vertical acceleration indicators.

Similar conclusions can be drawn with respect to nose down upset recovery. In case the aircraft is not equipped with a vertical acceleration indicator it is really difficult to estimate the loads during the nose down upset recovery. In some cases if the height margin is small or nose down pitch angle is too large, it will be required to exceed the operational loads limitations (within acceptable limits not resulting in structural damage) to avoid the impact. During training sessions pilots have to be aware of this limits and in case of emergency use all aircraft potentials to avoid an accident.

Therefore, the abovementioned factors (vertical loads value, airspeed limitations, loss of height during recovery) shall be taken into consideration when assessing the crew actions during upset recovery training. However, the analysis revealed that most airlines don’t use simulator flight data records to assess the performance of training tasks.

As loss of control is one of the most frequent accident causes the upset recovery training for civil flight crews shall be reconsidered in terms of methodology improvement and practical use.

3. Findings and Conclusions

The investigation of the accident involving a Boeing 737-500 VQ-BBN operated by Tatarstan Airlines was conducted in compliance with the Standards and Recommended Practices of ICAO Annex 13 as well as Rules for Investigation of Accidents and Incidents Involving Civil Aviation Aircraft in the Russian Federation approved by Decree of the Government of the Russian Federation as of June 18, 1998 № 609. In accordance with the mentioned documents, it is not the aim of accident investigation to apportion blame or liability of any kind.

3.1. Findings

The analysis of the available facts and flight circumstances; results of field investigation stage, including wreckage plot drawing and layout of the remaining aircraft fragments; results of specific elevator PCU examinations; ground and flight recorders data readout and analysis; engineering simulation; FFS activities, crew qualification and training records, duty time and rest period records, information on the flight operations management and SMS in the airline; medical document and forensic expertise results; available maintenance records; flight crew actions assessment made by test pilots and experienced line pilots, **revealed the following:**

3.1.1. The aircraft airframe, components and systems, engines and the APU were operative before the aircraft departed from Moscow (Domodedovo). The limited life-time components had enough life time for the flight. The aircraft was dispatched for the accident flight with two open deferred MEL items, Cat. D: aft galley ovens and forward galley water heater were removed. The deferred defects did not have any influence on the accident outcome.

3.1.2. The aircraft was fuelled with sufficient amount of certified fuel for the filed flight route and selected alternate airdromes.

3.1.3. The takeoff and landing weights and the CGs were within the AFM limitations.

3.1.4. No signs of airframe, systems or engines failure during the accident flight were revealed. There was no fire, explosion or any kind of in-flight destruction before the impact.

The elevator PCUs special examinations including scanning, bench tests of control valves, control valve boroscopic examination and partial teardown and piston elements (head and rod) condition evaluation did not reveal any signs of failure.

3.1.5. The engineering simulation of the final section of the accident flight revealed that the aircraft stability and controllability parameters were well consistent with the type design. The aircraft movement was commanded by the control surfaces deflection and engine thrust. No additional external forces (windshear, icing) affecting the aircraft were detected.

Both elevators were deflected symmetrically, compatible with the column deflection. There were no signs of elevator PCU cable jamming (that would have required excessive control column input forces). The Speed Trim System was operating as per design.

3.1.6. The meteorological support of the flight complied with the existing regulations. The weather conditions at the time of the accident were as follows: *surface wind 220 degrees magnetic 07 m/sec, gusting 10 m/sec; wind at 100 m – 230 degrees 08 m/sec; wind at circuit height (500 m) – 250 degrees 16 m/sec, visibility 10 km, light sleet, overcast (8 oktas), cloud base 220 m, temperature +3.2 degrees, dewpoint +2.5 degrees.* The weather conditions were appropriate for safe ILS approach and landing on RWY 29 of Kazan International Airport.

3.1.7. The PIC was flying as a navigator from 1991 to 2010. He did not undergo initial pilot training at a certified training organization; the documents confirming his conversion training were faked. His commercial pilot license was issued on no justified basis.

3.1.8. The FO was working for the airline as a ground mechanic from 1989 to 2008. From 2008 he conducted flights as a flight mechanic. In 2010, after completing conversion training at Ulyanovsk Aviation College he was granted a pilot license.

3.1.9. ANEO S7 Training, where both pilots undertook Boeing 737 type rating training, had a Certificate of Compliance issued by the Russian Aviation Authorities on the basis of FAR-23 “Certification of Aviation Training Centers”. FAR-23 was approved in 1999, however the industry standards for the arrangement of ground, simulator and flight training prescribed by its regulations have not been completely developed. Despite the publication of ICAO Manual on the Approval of Training Organizations (Edition 1 in 2006 and Edition 2 in 2012), FAR-23 has never been amended or revised. Thus, the regulatory basis that regulates the operation of aviation training centers requires significant improvement with consideration of ICAO Annex 1 and Annex 19 provisions as well as applicable ICAO Doc 9859 Safety Management Manual and Doc 9841 Manual on the Approval of Training Organizations.

Furthermore, some provisions of FAR-23 contradict the documents used by the Ministry of Education for Moscow Region when licensing ANEO S7 Training.

3.1.10. The aviation authorities actually did not provide methodological guidance and oversight of the actual quality of type rating training. The airlines sending trainee pilots to S7 Training also failed to exercise such oversight. According to the information provided by ANEO S7 Training, within 2008 to 2013 297 persons completed Boeing 737 type rating. None was expelled due to low qualification or poor progress. Within the whole of this period none of the airlines requested detailed information on their employees’ progress in training (like copies of training tasks with instructors' comments, etc.). Thus, the training process was like a "black box" where the airlines put their wishes as to the selected type rating program and the fee and then after some time received a pilot holding a Training Completion Certificate.

3.1.11. The PIC and the FO underwent ICAO ELP testing at Tatarstan Airlines Aviation Staff Training Center. At the day of the accident both pilots were granted ICAO Level 4. At the moment of undergoing Boeing 737 type rating training the PIC was granted ICAO Level 3, while the FO did not have any assigned ELP level.

The evaluation of the actual pilots' ELP level made by two independent experts (ICAO ELP raters who had undergone special training and were registered in the List of Accredited Raters of Rosaviatsyia) revealed that both pilots had demonstrated ICAO Elementary Level 2 in English[52]. This ELP level was not sufficient to understand the Boeing documentation provided in the English language (AFM, FCOM, QRH, FCTM[53]) that was used during the type rating and line flights, which is confirmed by significant difficulties the pilots experienced when taking the computer-based testing (they had to take them for several times) and the instructors' comments. Neither the PIC nor the FO underwent acceptance benchmarking in English when they were sent for the type rating training.

The experts also noted an insufficient ELP of the Tatarstan Airlines Aviation Staff Training Center interlocutors who were conducting the testing as well as their low qualification as to the methodology of the testing. The test used for the ELP assessment purposes could not be deemed valid, in the opinion of the experts.

3.1.12. The PIC's type rating training was extended over about 6 months with a long break between the ground training and simulator sessions. Moreover he was not provided with the following mandatory training "Additional training for pilots graduated from civil aviation colleges and pilots who do not have experience of operating multiengine turbine aircraft, operating in multicrews or in glass cockpit". In the course of the PIC's Boeing 737 type rating 4 different instructors conducted the 5 FTD sessions, and 9 different instructors conducted the 11 FFS sessions. Although at the time of the type rating training there were no limitations on the number of instructors in any applicable regulations, the investigation team considers this approach incorrect in terms of

[52] The assessment was done using archived records of the testing conducted at Tatarstan Airlines Aviation Staff Training Center.
[53] Here only the "FCTM" means the Boeing Company document.

methodology. The mentioned fact could have negatively affected the training quality. The situation was almost similar for the FO's training. Two instructors conducted FTD sessions and 5 instructors conducted FFS sessions.

3.1.13. In the course of the Boeing 737 type rating training both the PIC and FO received regular comments concerning go-arounds and non-precision approaches (which is a normal training situation). However they received the same comments during their commissioning and recurrent training when conducting line operations. The fact that these shortcomings were not corrected within a long period of time as well as their recurrent nature is an evidence of the low quality of flight operations organization in the airline.

3.1.14. The airline applied a two-year recurrent training cycle (instead of the usual three-year cycle). The analysis revealed that four simulator sessions 8 hours each were not enough for quality practice of all the tasks in the recurrent training program. The flight crew training was conducted in the airline in accordance with the Flight Crew Training Programs (FCTP) for each aircraft type. The FCTPs were part of the Flight Crew Training Manual approved by the airline's General Director (on August 25, 2009), accepted by Rosaviatsyia (September 22, 2009) and agreed with Tatar ITO of FATA (September 21, 2009). The investigation team believes that the approval and acceptance was made by the accredited authorities in a formal way, without evaluation of the possibility to ensure the declared amount of training.

The FCTM was approved before it was accepted and agreed with the authorities. The investigation team notes that in accordance with the Air Code of the Russian Federation (Article 54, Para 4) training of aviation personnel as per the list of civil aviation positions shall be conducted in accordance with training programs approved (not accepted or agreed) by an accredited civil aviation authority. This Air Code requirement is compatible with ICAO Annex 6 (Part I, Chapter 9, Para 9.3.1).

It was also determined that the ground training before simulator sessions and debriefings after them were done nominally or not conducted at all. If debriefings are not conducted the essential part of instructors' work is not realized.

3.1.15. The PIC did not complete the mandatory initial ground training program for civil aircraft PIC's as prescribed by the airline's FCTP. The line check, recorded in the PIC's individual log as being conducted on September 1, 2013, was actually not conducted. By the day of the accident the PIC did not have a right to conduct flights and should not have been included into the flight task.

3.1.16. As the crew was formed of two “weak” pilots, who had underwent training with deviations from the applicable requirements, there was a significant safety risk that did not comply with the basic risk management principles and was an evidence of inoperative SMS in the airline.

3.1.17. The investigation team notes that none of the safety barriers at any level prevented the unprepared crew to perform a flight, including instructors, flight operations department and top management of the airline (within the corporate SMS), S7 Training (incoming and outgoing monitoring of pilots), Tatar ITO of Rosaviatsyia (who approved the PIC with a fraud pilot license to undergo Boeing 737 type rating) and Rosaviatsyia (no oversight of pilot license issuance, which allowed the PIC to get a license without passing required training), which is an evidence of insufficient safety management in the entire industry.

3.1.18. The pilots had valid medical certificates.

The duration of the crew’s preflight rest period was within the applicable requirements.

However, the analysis of both pilots’ work and rest for the last half year before the accident revealed that there was a great amount of overtime work without enough rest time to counteract the accumulated fatigue (within some of the accounting periods overtime work constituted 75–80% and the required amount of days off duty were not provided). The unutilized leave time could have also resulted in extra fatigue accumulation (the PIC had 111 days and the FO 275 days of unutilized leave).

The accumulated fatigue could have had negative effect on the flight crew state and actions in the accident flight.

3.1.19. According to the forensic expertise there were no signs of ethanol, addictive substances or strong medicines in the pilots’ tissues. At the time of the accident the pilots were at their respective stations. Most probably the pilots were fastened with seat belts. It was not possible to determine the condition of the shoulder straps. There were no signs of persons other than the flight crew being present in the cockpit during the approach and go-around. The flight deck door was locked at the time of the accident.

3.1.20. The takeoff, climb and cruise flight were uneventful. The flight was conducted in automatic mode (one A/P and A/T engaged). Before initiating descent the crew conducted the landing briefing and defined that they would make an ILS approach to RWY 29 (magnetic heading 292°) with the weather minima of 60 x 550 m, which is consistent with ICAO CAT I. There were no signs of ILS or NDB system failure. There were no complaints about their operation from pilots or ATC officers on November 14 to 18.

The crew also discussed the go-around procedure. In particular they determined to use the TO/GA mode, the altitude of 1700 ft (500 m) to reach during the go-around, which is compatible with the standard go-around pattern, and report to the ATC after completing the go-around maneuver.

The crew did not distribute the duties during the approach briefing. Further, the PIC was the PF. The FO maintained radio communication.

3.1.21. The approach pattern was to be joined in accordance with STAR UW 29D, starting from MISMI waypoint. The aircraft passed over MISMI being offset for approx. 4 km to the north of the track, and the ATC officers timely informed the crew about the fact.

Such a deviation was caused by a map shift due to inaccuracy of aircraft positioning by the FMC. The aircraft was not equipped with a GPS-receiver, which prevented updating the aircraft position using satellite signals. The map shift that remained until the end of the flight was caused by a natural shift of the IRS during the flight, the failure of the crew to properly align the IRSs at the departure airdrome (Domodedovo) as well as absence, most likely, of FMC position update during the flight using ground based navigation aids (e. g. VOR/DME), which is confirmed by the crew report of IRS NAV ONLY message, meaning the actual navigation accuracy was lower than required. By the available information it was not possible to determine the cause of no position update. The VOR/DME beacon of Kazan International Airdrome was operating normally, the beacon frequency was selected by the crew several times, which is confirmed by the beacon call signs recorded by the CVR.

3.1.22. In the course of further flight the crew discussed the map shift for several times, but they could not use other navigation aids (implementing the complex airmanship principle) to enter required corrections into the flight path. Both of the pilots had received numerous comments from instructors during simulator training sessions with respect to non-precision approaches.

According to the information provided by S7 Training, the Boeing 737 type rating program did not include map shift correction training.

3.1.23. The crew did not request radar vectoring. The ATC officer who was watching the aircraft significant deviations from the STAR for a long time did not offer vectoring to the crew. After the crew informed the ATC on reaching the base turn point (according to the EHSI) they were cleared for combined base and final turn. Actually the turn was initiated with a significant deviation inside of the STAR pattern, which the ATC could have seen on the radar, and the crew could have seen that using the VOR/DME.

Because of significant deviation from the STAR pattern as well as excessive airspeed at the beginning of the turn and strong tailwind at the circuit altitude, the localizer was not captured as the crew did not engage the VOR/LOC mode when they crossed the localizer centerline. The crew started to be “behind aircraft” from that moment.

After they finished the turn there was a significant offset (about 4 km to the right (north) of the approach course), therefore the localizer was not captured either (despite the active VOR/LOC mode).

Further, the mentioned deviations from the approach pattern resulted in unstabilized approach and necessity to go-around.

3.1.24. Due to the deviations from the approach pattern the crew experienced time deficiency, which led to stress and deviations from the SOP.

The heading of approx. 250 degrees (in HDG SEL mode) was selected to join the LLZ centerline. Taking into account the great lateral deviation and actual wind direction and speed at circuit height, this heading could not ensure timely interception of the LLZ.

While approaching the landing course the crew extended the landing gear and then Flaps 15 and Flaps 30. The crew completed the Landing Checklist. After the landing configuration was achieved, the aircraft was flown with airspeed of 130–135 kt, which is consistent with the values defined by the PIC during the landing briefing.

According to the SOP, the landing gear should be extended and flaps set to 15 degrees only after the localizer is captured and glideslope alive, and flaps should be set to landing configuration when the glideslope is captured. Actually, neither the localizer nor the glideslope was captured at that time.

3.1.25. As the ATC requested the crew if they were ready for landing the crew reported that they were. This report was not true: the aircraft was still far (more than two dots) from the LLZ centerline, at the circuit height (500 m/1700 ft) and 4 km away from the RWY threshold (the glideslope intercept point is at a height of 400 m and 7.35 km from the RWY threshold). The cockpit communications analysis revealed that the crew was aware of that fact but decided to make a formal report anyway. The ATC who saw that the aircraft was not at all in the right position for landing cleared them to land. It would have been wiser at that time to terminate the approach and capture the navigation aid to define the actual aircraft position.

3.1.26. After they received the landing clearance the crew descended to approx. 270 m (900 ft) above RWY level in order to continue flight visually (this height was mentioned in ATIS information as the cloud base), which is confirmed by the cockpit communications.

3.1.27. In the course of the descent the localizer was captured and the aircraft started to join the landing course in automatic mode. At 1000 ft AAL the EGPWS aural alert sounded: “One thousand”. The approach was definitely unstabilized and the crew was to take the decision to go-around. They did not take this decision and continued to look for ground references visually.

3.1.28. After descending to 270 m (900 ft) the FO found, after he saw the runway and PAPI lights, that the aircraft’s position was unsuitable for landing and it was he who initiated the decision to go around (most probably, the PIC failed to see the runway and regain situation awareness). The PIC agreed with that decision immediately. The crew took a correct decision to go around (though it was delayed).

After the go-around decision, the PIC asked the FO to make a relative report to the ATC, by which he cancelled his own instruction given during the landing briefing to report to the ATC only after completing the go-around maneuver. The PIC’s instruction did not comply with the Aviate – Navigate – Communicate principle and made the FO out of the control loop for a long time, which contributed to the unfavourable outcome.

3.1.29. At the time the decision to go-around was taken the FDR recorded the following: the aircraft was in landing configuration (gear down, Flaps 30), one A/P and A/T on, altitude 270 m (900 ft) above runway level (maintained by the A/P ALT HOLD), in the roll axis the A/P was commanding the aircraft to make the second part of the S-shape maneuver to join the landing course, the indicated airspeed was maintained at 130–135 kt by the A/T. The go-around altitude of 500 m (1700 ft) was not selected, the value of approx. 270 m (900 ft) remained selected on the MCP.

3.1.30. After they detected the significant deviation from the approach pattern the crew discussed the go-around option for several times. Despite their discussions of the go-around option (it sounded more like self-complacency than real readiness) most probably the PIC was not psychologically ready for the go-around, as the task to find the runway and land appeared to prevail over the go-around alternative. After the PIC had completed the Boeing 737 type rating he had never made go-arounds in real flights. Most probably, the understanding that they would have to go-around made the crew even more stressed. The crew had earlier started lagging from the aircraft and by the time of the go-around their attention must have been channeled, which especially concerned the PF (PIC) who did not manage to regain complete situational awareness. This was a background for the following events that resulted in the impact.

The simulator experiment conducted by the investigation team revealed that the absolute majority of line pilots involved in the experiment[54] consider the go-around procedure as a difficult element for a line pilot, mainly because of the increased workload and stress. Some of the pilots evaluated this process as distress or close to distress state. During the experiment, when pilots were exposed to increased stress during the approach when they were unexpectedly instructed to go around, only about 30% of the pilots made a more or less successful go around. It should be noted, that over 30% of the pilots involved in the experiment had never conducted real life go-arounds.

3.1.31. The crew initiated the go-around by pressing the TO/GA pushbutton, which led to A/P disconnection as per design and N1 increase to ~ 83% (estimated intermittent N1 for go-around). The TO/GA mode and N1 remained almost until the end of the flight.

3.1.32. After the FO was instructed to report to the ATC on the go-around, he communicated for 20 seconds (16 seconds from the moment when TO/GA pushbutton had been pressed) with the controller and did not perform the PNF duties. The flap retraction to Flaps 15 command called out by the PIC right after the go-around start, was most probably performed by the PIC on his own.

3.1.33. The A/P disengage triggered the pertinent alert, recorded by the CVR. The alert was on until the end of the flight, meaning the crew did not switch it off by pressing the button on the control wheel. The A/P disengage alert is very loud and alarming (louder and more alarming than on many other aircraft types) and has a vivid attention-getting effect. Apparently the crew was in distress and did not identify the A/P disconnection, which is confirmed by their further actions. The failure to identify the A/P disconnection is an evidence of loss of situational awareness and significant channeling of attention.

When completing the questionnaire before the FFS flights, pilots experienced difficulties when answering questions related to the autopilot, flight director and A/T functioning logics during the approach and go-around. Despite four of the pilots were cheating using reference documents they had on their personal electronic devices, none of the pilots was able to answer all the seven question concerning the logics of the combined functioning of the aircraft automation system. During the go-around mode more than 30% of them experienced difficulties identifying that the A/P was disconnected. Besides, 2 pilots stated that the go-around was conducted in automatic mode by the A/P (even when A/P

[54] The experiment was participated by 11 pilots holding different positions, from a FO to an instructor.

disengagement alert was triggered!). This indicates the insufficient level of basic knowledge as well as a gap between theoretical knowledge and practical skills.

3.1.34. Due to the thrust increase and flaps retraction from Flaps 30 to Flaps 15, there was a nose up pitching moment that resulted in pitch angle increase and positive vertical speed. The engineering simulation revealed that within the first 10–12 seconds of the go-around maneuver the pitch change was compatible with the FD pitch bar position that could have been interpreted by the crew as automatic go-around. This conclusion is confirmed by the fact that within 25 seconds after the start of the go-around there were almost no column or wheel inputs.

The airline did not have a separate procedure for go-around from an intermittent height with two engines operative. During the simulator sessions when go-arounds were practiced, they were never performed from an intermittent height; in most of the cases go-arounds from the decision height with one engine-off were practiced.

3.1.35. As there were no control inputs, 20 seconds after the start of the go-around the pitch increased to over 25 degrees, the airspeed was decreasing (the minimum speed of 117 kt was recorded 30 seconds after the go-around has been initiated).

3.1.36. The FO, distracted by communication with the ATC, was not cross-checking the PIC's actions and failed to perform any of the SOP requirements: he did not inform the PIC on reaching positive vertical speed, did not monitor the airspeed and delayed to remind the PIC to retract the landing gear. Only 20 seconds after the go-around start the FO was "back" to the cockpit and went ahead with his duties: he reminded the PIC of the necessity to retract the landing gear and then retracted them upon the PIC's command, then he identified that the go-around altitude of 500 m/1700 ft was not set on the MCP and set it. The simulator experiment revealed that when the FO was distracted (e. g. by radio communication) during critical stages of flight (like go-around) the PF is not always ready to cope alone, which can cause a significant safety risk in case of pilot incapacitation.

3.1.37. The ATC actions were contributory to such a long-term distraction of the FO. Instead of giving a short response (like "Roger") after he had reported going around, the ATC officer started instructing them on the go-around altitude and transition to another frequency to contact Radar Control. This information did not contain anything unknown for the crew (the altitude assigned by the ATC was the same as on the go-around pattern, and the Radar Control frequency was also known by the crew), and did not affect the safety of further flight (the air space conditions were not complicated) and only provided additional distraction for the pilots during a stressful flight phase. The crew's SOP do not include radio exchange during a go-around. In the Tower Controller Operation Procedures there was no section that would describe ATC actions after receiving a go-around report from the crew.

3.1.38. The abovementioned high psychological stress experienced by the pilots increased even more and could have reached distress. This was confirmed by the fact that their timbres were changed, they switched from English to Russian when using the standard callouts, mixed up the English words “up” and “down” when discussing the necessity to retract the landing gear, and asked the ATC to repeat the go-around altitude, although it was consistent with the go-around pattern and could be clearly heard on the CVR record.

During the simulator experiment it was determined that the PF’s (PIC’s) stress level was higher when they did not receive the expected assistance from the PNF (FO).

3.1.39. The PIC took control of the aircraft only 25 seconds after the go-around had been initiated. He pushed the column nose down for about 1/3[55] of the travelling distance. It was not possible to determine what exactly encouraged the PIC to initiate control inputs. One or a combination of the following factors thereof could have forced him to do that:

- pitch angle of over 25 degrees nose up, which is classified as upset according to the aircraft manufacturer’s documentation and requires immediate inputs from the crew;
- exceeding the established go-around altitude; The actual height above runway level was approx. 2000 ft/600 m at that time and kept increasing with a vertical speed of over 4000 fpm (20 m/sec).
- airspeed falling below the target values (actual airspeed 125 kt, required airspeed at least 150 kt).

3.1.40. EADI FD guidance could have also encouraged the PIC to apply control inputs. However, the simulator experiment revealed that during the go-around less than 20% of pilots followed the flight director guidance, while others preferred to fly with reference to the artificial horizon, maintaining the pitch angle of approx. 15 degrees and monitoring the airspeed. They explained that they used this go-around technique as the difference between the FD pitch bar and the symbolic aircraft during the go-around is insignificant as a rule. This fact is confirmed by the engineering simulation of the accident flight: the maximum deviation of the FD bar below the symbolic aircraft was approx. 5 degrees (the FD bar sensitivity is low in the go-around mode). This deviation can be perceived by pilots as insignificant, especially in a stressful situation.

[55] At this stage the autotrim system had set the stabilizer to nose down direction (approx. at ~ 1.7°), which "helped" the pilot to decrease the pitch angle.

3.1.41. The column was kept in that position for slightly over 4 seconds, and then was deflected back to the trimmed position for just 1 second. This PIC's input resulted in the nose down pitch to almost level flight position: the pitch angle was 6 to 8 degrees and was still decreasing, the vertical loads fell to 0.5 g, the height almost stopped growing (maximum height was approx. 2300 ft / 700 m), the FD pitch bar was almost matching the symbolic aircraft. The indicated airspeed decreased to its minimum value of 117 kt, which was still higher than the stall airspeed and no stick shaker was recorded.

The PF actions during this segment could have been evaluated as correct though delayed, if he had finished the maneuver in the proper way, meaning if he had returned the column to the trimmed position (like he had done initially) and **made it remain in the trimmed position for some time**, so that the aircraft could have transitioned to a smooth descent. In this case the aircraft that had actually recovered from the upset would have reached the required acceleration and descend to the circuit height (1700 ft/500 m).

3.1.42. After the short-term return of the control column to its trimmed position, it was pushed forward again for over one half of the way to the forward stop. The column was kept in that position for about 4 seconds, and then was deflected back to the balanced position for just 1 second. Supposedly, by that time the PIC was able to concentrate only on a single parameter that was the height, as it was much higher than the assigned value (1700 ft/500 m) that was to be reached.

As a result of the PIC's control inputs, by the time the column was shifted back to the trimmed position the aircraft had the following performance: vertical load about 0 g, pitch angle 20 degrees nose down that kept going further nose down, airspeed over 140 kt increasing with an unusually excessive rate of 10 kt/sec, altitude approx. 2200 ft (670 m), vertical speed of descent over 5000 fpm (25 m/sec), FD pitch bar 4.5 degrees higher than the symbolic aircraft and indicating the aircraft had to be recovered from the descent. Thus, the aircraft that just approx. 10 seconds before had been upset nose up reverted to nose down upset.

3.1.43. At that moment the aircraft could have been recovered to normal flight even without exceeding operational limitations. Taking into consideration the quickly changing situation as well as the PIC's lack of pertinent skills and his actual low qualification, he was not able to apply the required upset recovery techniques. The near-zero loads produced additional complications. The in-service experience of flights with near-zero acceleration reveals that persons who get into the null-gravity state for the first time lose both the ability to act and spatial orientation for the first few seconds. Most probably the pilots did not have an idea of what null-gravity actually was like nor pertinent training.

Besides, during near-zero and negative acceleration unattached objects as well as dirt and dust that are always present in the cockpit get up in the air. This usually happens unexpectedly and produces a startling effect on the pilots. The dirt and dust as a rule get into the pilots' eyes and noses obstructing their vision and breathing.

The simulator experiment revealed that only about 50% of the pilots had experienced negative loads and this experience was insignificant.

3.1.44. The third nose down column input produced by the PIC confirmed his spatial disorientation as well as disintegration and critical tunnelling of his flight perception. In the current circumstances the PIC could also have experienced somatogravic nose up pitching illusion.

As per calculation the forces applied on the control column were over 50 lb (22 kg). The crew did not react to the EGPWS alerts (SINK RATE и PULL UP), though the alerts were triggered in due time as per design.

Such control input resulted in 0.8 to 0.9 g negative vertical load and the pitch angle reaching 55 to 60 degrees nose down. The abnormal situation turned into an emergency. Further control actions were chaotic. The aircraft impacted the ground with a high speed (over 450 km/h) and large nose up pitch angle (approx. 75 degrees).

As a number of simulator experiments revealed the last moment when it was possible to recover from the nose down pitch with a vertical acceleration of 3.0 to 3.5 g (exceeding the operational limitations with no structural damage to the aircraft) was the moment when the aircraft was descending with a nose down pitch angle of 40 degrees, the height was 1900–2000 ft (580-610 m) with an airspeed of 175 to 180 kt. The height loss would have been 1600–1700 ft (about 500 m) meaning the aircraft would have been recovered at a height of 200 to 300 ft (about 100 m).

3.1.45. The FO was monitoring the situation better at the final flight segment and tried to attract the PIC's attention (probably he even tried to interfere with the aircraft control, but could not counteract the PIC's control inputs). The verbal reaction of the PIC to the FO's challenges (he replied with "What?") and no corrective control inputs revealed that he had lost spatial orientation and situational awareness completely.

3.1.46. During the simulator experiment, none of the pilots managed to recover properly from the nose up upset, including experienced instructors. A typical mistake during the recovery was an almost full nose down column input. Such actions, in their turn, resulted in high negative pitch rate and vertical acceleration that was close to zero or, in some cases, negative. In real flight conditions such accelerations would have apparently led to spatial disorientation and/or crew incapacitation. At present, this is not taken into consideration during simulator upset recovery training as a criterion for mode completion evaluation. Flight data (in particular, vertical acceleration values) are not used to assess the quality of the recovery performance. Furthermore, even the modern FFS cannot simulate near-zero and negative loads.

3.1.47. The Boeing QRH recommendations for nose up upset recovery include the following procedure: «*Apply as much as full nose-down elevator*». It is followed by: *Apply appropriate nose down stabilizer trim*. The simulator experiment and survey among the pilots revealed that the absolute majority of them understand this QRH provision as a requirement to always apply full nose down elevator (control column) and apply stabilizer if necessary, which in most cases would lead to near-zero and even negative loads with the abovementioned outcome.

3.1.48. After the impact the fuel tanks were destroyed and there was fire. The firefighting operations were initiated in 2 minutes that complies with the established standards. The fire fighters localized the fire in about 40 minutes, but it was completely extinguished only 9 hours after. The long duration of the firefighting was due to the fire cell inside the impact crater that contained a significant number of aircraft fragments.

3.1.49. The implementation of the following hazards contributed to the accident:

- lack of due oversight system over personnel licensing, compliance of pilots with qualification requirements and granting of various ratings;
- inoperability of SMS in airlines, lack of guidance on their development and approval, a nominal approach of the accredited authorities to the approval/acceptance of SMS and flight crew training programs;
- imperfectness of aviation training organizations operation and actual lack of control over the results of type rating training;
- no requirements to flight crews as to the ELP as appropriate to undertake type rating training for foreign-made aircraft and nominal approach to the ELP assessment;
- nominal approach to recurrent and qualification checks of flight crews;
- systemic violations of duty and rest time limitations;
- insufficient training of flight crews with respect to go-arounds from intermittent heights, manual flying and upset recovery;
- map shift effect appearing on aircraft not equipped with GPS and insufficient training of flight crew with regard to flight conduct with map shift;

- lack of active assistance to the flight crew from the ATC when the latter detected significant long-term deviations from the standard patterns;
- violation of the Aviate – Navigate – Communicate concept.

These factors have been noted by various investigation teams previously, however, no corrective actions (especially regulatory actions) to eliminate the mentioned factors or mitigate/manage the risk level were taken on various levels of the aviation system.

3.2. Conclusion

The accident involving the Boeing 737-500 VQ-BBN was caused by systemic deficiencies in hazard identification and risk management, inoperability of airline SMS, and lack of oversight over flight crew training from authorities of various levels (Tatar ITO, Rosaviatsyia), which resulted in authorizing an unduly trained crew for flights.

During the go-around the crew failed to identify the A/P disconnection and let the aircraft get into nose up upset. As the PIC (PF) lacked upset recovery skills he produced significant negative loads, lost spatial orientation and made the aircraft pitch nose down steeply (nose down pitch angle reaching 75 degrees) until it impacted the ground.

The need to go-around was caused by the aircraft being unstabilized when approaching the runway, as a result of the map shift of about 4 km, failure of the crew to apply complex airmanship skills and navigate with required accuracy, as well as lack of active assistance from the ATC who were watching the long-term deviations of the aircraft from the established pattern.

The accident was caused by the combination of the following[56]:

- The PIC had no initial flight training;
- pilots not completely meeting the qualification pre-requisites for training, including the ELP requirements, were accepted for Boeing 737 type rating training;
- The training process was methodologically imperfect, the oversight of results and quality of training was nominal;
- the level of flight operations organization in the airline was low, which resulted in the failure to eliminate deficiencies in navigation equipment usage, airmanship and CRM (during various flight phases including go-around) that had been revealed for a long time.
- there were systemic violations of duty time and rest period requirements and a sufficient amount of unused leaves, which could have resulted in fatigue accumulation and affected the crew working efficiency;
- the airline's simulator training program did not include training for conducting go-arounds from an intermittent height with two engines operative;
- The crew was stressed before the go-around as they had been unable to determine the aircraft position with required accuracy for a long time;

[56] In accordance with the Manual of Aircraft Accident and Incident Investigation (ICAO Doc 9756 AN/965), the factors are given in the logical sequence, without priority assessment.

- the Aviate – Navigate – Communicate concept was violated both by the crew and the ATC, which resulted in the crew failing to follow the SOP during the go-around as the FO was distracted from his duties and monitoring flight parameters for a long time;
- The crew failed to identify the A/P disconnection and delayed to apply manual control, which resulted in nose up upset;
- The applied upset recovery simulator training programs and its quality assessment criteria were imperfect, which resulted in the crew failing to recover;
- The crew was possibly affected by somatogravic illusions.

The failure of applicable addressees of the safety recommendations given in previous investigations, to follow the recommendations serving to mitigate hazards and manage risks related to:

- lack of due oversight system over personnel licensing, compliance of pilots with qualification requirements and granting of various ratings;
- inoperability of SMS in airlines, lack of guidance on their development and approval, a nominal approach of the accredited authorities to the approval/acceptance of SMS and flight crew training programs;
- imperfectness of aviation training organizations operation and actual lack of control over the results of type rating training;
- no requirements to flight crews as to the ELP as appropriate to undertake type rating training for foreign-made aircraft and nominal approach to the ELP assessment;
- nominal approach to recurrent and qualification checks of flight crews;
- systemic violations of duty and rest time limitations;
- insufficient training of flight crews with respect to go-arounds from intermittent heights, manual flight skills and upset recovery;
- map shift effect appearing on aircraft not equipped with GPS and insufficient training of flight crew with regard to flight conduct with map shift;
- lack of active assistance to the flight crew from the ATC when the latter detected significant long-term deviations from the standard patterns; and
- violation of the Aviate – Navigate – Communicate concept,

made it impossible to prevent the accident under investigation.

4. Shortcomings[57]

4.1. While the PIC was under training (from October 1, 2009 to March 28, 2010) for a period of time (October 12, 2009 to November 26, 2009) ANEO Sibir Airlines Aviation Training Center did not have a valid license of the Ministry for Education of Moscow Region.

4.2. On the day of the accident, the date of a deferred Category D MEL item elimination (removed ovens in the aft galley, to be eliminated before November 14, 2013) was exceeded.

4.3. When a ticket was confirmed for a passenger who was born on September 7, 2002 (at the time the ticket was sold the passenger was 11 years old), he was noted as ADULT. In accordance with FAR "General Rules for Air Transportation of Passengers, Baggage, Cargo and Requirements to Serving Passengers, Consignors and Consignees" approved by Order №82 of the Ministry of Transport as of 28.06.2007, children in the age of 2 to 12 shall be noted as CHD.

4.4. The flight catering supplier, LLC Sultan (Kazan) did not specify the catering weight in the way-bill, so it was not taken into account during payload calculations.

4.5. LLC Sultan did not comply with the requirements of Para 3.3.1 of the Manual on Load and Balance of Civil Aviation Aircraft, approved by Order №58/I of the Ministry of Civil Aviation, USSR as of 14.11.1983 to inform the crew on the weight of supplies loaded onto the aircraft.

4.6. There are inconsistencies in the emergency notification requirements in the Arrival Control Officer Operational Procedure and Emergency Response Plan for Emergencies on Aerodrome and Search and Rescue Area of Kazan International Airport (further referred to as ERP), approved by the General Director of Kazan International Airport as of 15.10.2013: the Arrival Control Officer Operational Procedure assigns the function of emergency notification to the Arrival Controller (Para 7.1), while the ERP assigns this function to the Airdrome Shift Supervisor, which is specified in his job description.

4.7. The airdrome shift supervisor, when requesting the weather evaluation, did not notify the weather observer of the emergency alarm and did not specify that irregular weather observations were to be made (Para 10.5.1 of Instruction for Meteorological Service in Civil Aviation (IMS CA-95)). Appendix 3 to the ERP "General scheme of notification of search and rescue teams of Kazan International Airport, interacting organizations,

[57] This section contains shortcomings that did not affect the outcome of the flight.

administrative and law-enforcement entities” did not provide for centralized notification of a weather observer when emergency alarm is declared.

4.8. Professional training of controllers that provided air traffic services on November 17, 2013 did not completely comply with the applicable regulations:

- during seasonal training for autumn 2013 winter 2014 the simulator training for exercise 6 only lasted for 2 hours, in violation of Order № 18 of FSUE "State ATM Corporation" as of 05.03.2001 “On enforcing the temporary instruction on organization and conduct of ATM personnel simulator training” (further referred to as Order SC 18), which prescribes the simulator training duration of 3 hours.
- the test exercise of the controller, who was in charge of the Area Control “South” controller duties, when he was authorized for unassisted work at Kazan Area Control of Unified ATM System lasted for only 2 hours, which is not consistent with the requirements of Order SC 18, prescribing 3 hours for this exercise;
- the airdrome shift supervisor undertook seasonal simulator training for autumn 2013 winter 2014 in accordance with exercise 4 instead of exercise 6, prescribed by Order SC 18 for autumn/winter seasonal training;
- as there was no simulator for Arrival Control Point at Kazan ATM Center, the simulator check of the officer in charge of Arrival Control on the day of the accident, to get initial authorization to work as a controller and authorization to provide ATS in the English language, was replaced by on-the-job check for 2 hours, which did not comply with Para 29 of “Procedure for Continuous Professional Training, Including Certification, On-the -job Training, Authorization, Recurrent Training Frequency of ATM Management and Non-Management Personnel”, approved by Order №93 of the Ministry of Transport of Russian Federation as of 14.04.2010, that prescribes that the check shall last for 9 hours;
- The Area Control shift supervisor, assigned for the position by order № 155/l of the director of subsidiary as of 27.09.2012, did not comply with the qualification requirements in terms of higher professional education, that he did not have (Para 1.6 of the job description of shift supervisor for the Kazan Area Control of Unified ATM System, approved on 26.09.2012).

5. Safety Actions Taken and Safety Recommendations

5.1. Safety Actions

5.1.1. On December 11, 2013, within the framework of the investigation team activities, preliminary results of the available information analysis were reported to airlines' flight operations managers, CAA managers during a special debriefing. The following urgent safety recommendations were given at the debriefing (the recommendations were also sent to all interested organizations in the form of a follow-up report):

Consider the practicability of conducting additional ground and simulator training with flight crews:

- to train go-around actions in FD mode, paying special attention to conducting go-around from intermittent heights, when the height to be reached in the course of the go-around is close to the current height, as well as to radio communications issues;
- to train identification of aircraft upset and upset recovery techniques;
- to train the features of aircraft systems' operation (A/P, FD) during approach and missed approach in various circumstances;
- to study the features of the aircraft navigation system (FCOM: FMC Navigation Check и Navigation Position).

Consider the necessity to revise the ATM personnel operation procedures in terms of rendering (in case of significant aircraft deviations from the track) more active assistance to aircraft flight crews if technically possible, e. g. by offering radar vectoring to lead the aircraft to landing track.

Arrange a Flight and Engineering Conference to share in-service experience of Boeing 737 aircraft family operation.

5.1.2. The investigation preliminary results and appropriate measures for the Safety improvement (including the systemic measures) available for December 2013, were presented to the 34th Meeting of Interstate Council on Aviation and Airspace Use, which was hold in IAC and where senior managers of Federal agencies of executive authority took part.

5.1.3. More than 200 aviation personnel licenses that had been granted with violations of applicable regulations, were revoked during 2014 and 2015 by orders issued by Rosaviatsyia.

5.2. Safety Recommendations

It is recommended that the Russian Aviation Authorities[58]:

5.2.1. Inform flight personnel, training organizations personnel and ATM personnel about the results of this investigation during special briefings.

5.2.2. Conduct an analysis of how safety recommendations after investigations of accidents involving heavy transport aircraft for the recent 10 years have been considered. Consider the possibility of resuming the practice of developing departmental and interdepartmental action plans to be approved by heads of federal executive bodies that would include the consideration of practicability for any recommendation, assignment of responsible organizations and deadlines.

5.2.3. With consideration of ICAO Annex 19 and ICAO Docs on safety management and safety assurance oversight, develop and implement guidance for assessing civil aviation organizations for compliance with existing requirements, and for development and approval/acceptance of operators' safety management systems and flight crew training programs.

5.2.4. Revise FAR-23 "Certification of Aviation Training Centers" with reference to ICAO Annex 1 and Annex 19, as well as ICAO Docs on safety management and approval of training organizations. Develop and implement departmental regulations for the organization of ground, simulator and flight training, as prescribed by FAR-23, that would ensure, among other issues, guidance for aviation training centers activities and training quality control. In order to improve personnel qualification level and avoid reductionism, consider the practicability of developing typical flight crew training and type rating programs that would include a minimum set of standard provisions for each aircraft type.

5.2.5. Introduce a unified database to control the issued licenses to aviation personnel, that would contain data enabling determination when and where the license was issued, as well as a copy of the application for the license and copies of qualification evidence for the application. Define a procedure to verify data in the provided qualification evidence.

5.2.6. Draw the attention of qualification board members of all levels to the mandatory control of compliance with applicable civil aviation regulations when authorizing flight crews

[58] We recommend CAA of other States of Agreement to consider the applicability of these SRs with due regard for the actual situation in the States.

for relative functions. Establish personal accountability of qualification board chairs for unjustified issuance of authorizations.

5.2.7. Consider the practicability of amending FAR-147 with provisions specifying the revocation of aviation personnel licenses from persons conducting intentional violations of regulatory requirements.

5.2.8. Revise regulatory documents that regulate the ATM in terms of setting quantitative criteria of what a “significant” deviation from established flight routes and patterns is at various flight phases, and establishing a procedure for offering assistance from ATM to aircraft flight crews who experience significant deviations.

5.2.9. Taking into account modern aircraft performance, conduct an analysis in cooperation with representatives of airlines and ATM services of existing missed approach patterns to check the consistence of the established missed approach altitude with the crew ability to follow the SOP without any need to hurry.

5.2.10. With consideration of ICAO Doc 10011, Manual on Aeroplane Upset Prevention and Recovery Training requirements arrange and conduct a study of conditions for flight crews' spatial disorientations and aircraft upset to work out practical safety recommendations. Based on the findings of the study, develop and implement a special recurrent training course (like upset recovery training) including theoretical and practical training.

5.2.11. Revise initial flight training programs to include pilots’ familiarization with stall and spin modes as well as null-gravity and negative loads. Consider the practicability of revising FAR-128 to include provisions on regular training (e. g. once in 3 years) of pilots to practice aircraft operation in the abovementioned conditions. If such decision is taken, with participation of test pilots, determine the aircraft types appropriate for such training and develop pertinent training programs with consideration of safety requirements.

5.2.12. Develop and implement qualification requirements for English language proficiency for flight personnel operating aircraft with operational and technical documentation in English, as well as for maintenance personnel who conduct maintenance of the mentioned aircraft.

5.2.13. Conduct a quality check of training organizations operation and qualification of teaching staff who act as interlocutors or raters for ICAO ELP testing as well as the used tests (to check if they comply with the provisions of ICAO Doc 9835 “Manual on the Implementation of ICAO Language Proficiency Requirements”).

5.2.14. In order to provide guidance to airlines as to identification of deviations with the help of flight data records, implement guidance on the contents of Flight Data Analysis Programs prescribed by Para 5.7 of FAR-128 “Preparation and Conduct of Flights in Civil Aviation of the Russian Federation”.

5.2.15. Ensure, when selecting personnel to be undergo training for new types of aircraft, that medical certification and airline psychologists pay attention to personal traits of the applicants related to emotional reactions to and behaviour in abnormal conditions (excessive workload, stress), and, in case they detect any unfavorable signs, provide recommendations if the applicants are fit for the type rating or/and if they need individual approach during the training.

5.2.16. Consider the possibility of resuming to conduct regular conferences and workshops to share in-service experience with participation of representatives of airlines and test pilots.

5.2.17. Consider the possibility of conducting a joint conference for flight operations management personnel of airlines and ATM management personnel to facilitate sharing of experience. Ensure special attention is paid to radio communications and the Aviate – Navigate – Communicate concept at various flight phases.

5.2.18. Consider the practicability of equipping aircraft with GPS to ensure required navigation accuracy and correction of data received from IRS.

5.2.19. Consider the applicability of safety recommendations of the specific safety study conducted by the BEA relating to aeroplane state awareness during go-around (ASAGA) (Section 1.18.6).

It is recommended that airlines of the States of Agreement[59]

5.2.20. Evaluate the need to revise their safety management systems and flight crew training programs with consideration to the investigation findings.

5.2.21. In order to assess the quality of training undertaken by the airline pilots in training organizations, request the complete set of training evidence including copies of training tasks with instructor comments.

5.2.22. Evaluate the need to arrange additional training for flight crews with respect to the operation of flight automation systems (A/P, A/T, FD), missed approach procedures, including conduct of go-around from an intermittent height with two engines operative, as well as upset recovery. Ensure special attention is paid to manual control skills, attention allocation and switch skills, especially during critical phases of flight (like missed approach) and in complicated situations including pilot incapacitation.

[59] If these recommendations are applicable taking into account the actual state of affairs in the airlines.

5.2.23. Ensure available recorded simulator data analysis is used to assess the quality of task performance during simulator training (especially when upset recovery is trained).

5.2.24. Conduct extra checks of flight crews' compliance with the SOP during various types of approaches (precision and non-precision) and during missed approaches. Ensure special attention is paid to compliance with the Aviate – Navigate – Communicate concept.

5.2.25. Evaluate the sufficiency of ELP of pilots conducting flights on foreign-made aircraft to understand the manufacturer's documentation required for flight operations (including guidance, like Cold Weather Operations etc.). The same recommendation is applicable to personnel conducting maintenance and ground handling of foreign-made aircraft.

5.2.26. Amend airlines' FOMs and SOPs for various aircraft types with additional sections containing recommendations as to the conduct of flight along routes and to aerodromes with insufficient radio and navigation aids. Introduce training of approaches with map shift effect into simulator sessions scenarios.

5.2.27. Determine "aerodromes of concern" for each airline (with relevance to the map shift effect), ensure the flight methodological departments of airlines develop recommendations as to the conduct of flight to such airdromes and recurrently train pilots to conduct approaches by using raw data during simulator training (without using automatic systems or FD guidance).

5.2.28. Conduct an inspection of compliance with flight personnel duty time and rest period requirements and make them use the unutilized leaves.

It is recommended that FSUE "State ATM Corporation":

5.2.29. Consider the possibility of revising some sections of ATM personnel operation procedures in terms of providing more active assistance (if technically possible) to flight crews if seeing significant deviation of aircraft from established routes and patterns at various flight stages, for example, by offering radar vectoring, as well as determining flight phases when instructions or advice to flight crews cannot be provided unless there is a safety threat.

5.2.30. Draw attention of ATM personnel to the need to make a complex assessment of all available information before clearing aircraft for landing.

5.2.31. Eliminate other shortcomings in this Report and the ATM investigation group report.

It is recommended that ANEO S7 Training:

5.2.32. Taking into account the investigation findings, consider revising documents regulating the training process, paying special attention to the sufficiency of ELP of candidates for type rating training, availability of regular staff instructors to assure the declared training amount and methodological guidance for the training process, as well as to taking measures to prevent personnel with inappropriate qualification level from passing final qualification tests.

It is recommended that the Boeing Company:

5.2.33. Consider the necessity of introducing changes or/and clarifications to the QRH section containing nose up upset recovery procedures to exclude misinterpretation of the provisions contained therein by pilots.

It is recommended that ICAO:

5.2.34. Define the minimum English language proficiency requirements to understand aircraft manufacturer's documents or other English-language materials used for flight crew training and flight operations.

It is recommended that Civil Aviation Authorities of States of Agreement, FSUE "State ATM Corporation", Aircraft Design companies, Airlines and Aviation Training Organizations

5.2.35. Within their respective competence, analyze the applicability of recommendations (Section 1.18.6) to prevent accidents and incidents during go-around, developed by the BEA based on the safety study related to Aeroplane state awareness during go-round (ASAGA). Depending on the results of the analysis, take applicable safety measures.