



**INTERSTATE AVIATION COMMITTEE**

**AIR ACCIDENT INVESTIGATION COMMISSION**

**FINAL REPORT**

Type of occurrence	Accident
Aircraft type	Airplane, Boeing 737-505
Registration	VP-BKO (Bermuda)
Registered owner	ARN 737 Limited, Clarendon House, 2 Church Street, Hamilton HM 11, Bermuda
Operator	Aeroflot-Nord Airline, Russia
Regional Aviation Authority	Arkhangelsk Regional Office, FTOA
Place of Occurrence	Russian Federation, near Bolshoye Savino Airport, Perm (N57°58,255', E056°12,632')
Date and Time	13 September 2008, 2310 hrs UTC, local time 0510 hrs, 14 September 2008.

In accordance with ICAO standards and recommended practices, it is not the purpose of this report to apportion blame or liability.

The sole objective of the investigation and the Final Report is the prevention of accidents.

Criminal aspects of the accident are tackled within the framework of a separate criminal case.

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## Abbreviations

AAIB	– Air Accident Investigation Branch, UK
AATMC	– Automated Air Traffic Management Complex
AC	– Advisory circular – Alternating Current
ACEOS	– Aeronautical and Communication Equipment Operation Service
AD	– Airworthiness Directive
ADF	– Automatic Direction Finder
AFM	– Aircraft Flight Manual
Agreement	– Agreement on Civil Aviation and Use of Airspace
ALT ACQ	– Altitude Acquire (autopilot mode)
ALT HOLD	– Altitude Hold (autopilot mode)
AMB	– Aircraft Maintenance Base
AMM	– Aircraft Maintenance Manual
AOA	– Angle of attack
AOS-92	– Aerodrome Operation Standards, issued in 1992
A/P	– autopilot
ARP	– Aerodrome reference point
ASR	– Aerodrome Surveillance Radar
AT	– Automatic Transceiver
A/T	– autothrottle
ATC	– Air Traffic Control – Aviation Training Center
ATCC	– Air traffic Control Center
ATIS	– Automatic Terminal Information Service
ATM	– Air Traffic Management
BEA	– Air Accident Investigation Bureau, France
CA	– Civil aviation
CAA	– Civil Aviation Authority
CAFARMS-2002	– Civil Aviation Federal Aviation Rules for Medical Service, issued in 2002
CAFOM-85	– Civil Aviation Flight Operations Manual, issued in 1985
CARMS	– Complex Aerodrome Radio Meteorological Station

CAT	– category
CB	– Circuit breaker
CBT	– Computer Based Training
CDU	– Control Display Unit
CG	– Center of gravity
CIS	– Commonwealth of Independent States
CRM	– Crew Resource Management
CRP	– Compulsory Reporting Point
CVR	– Cockpit Voice Recorder
CWS	– Control Wheel Steering
DME	– Distance Measuring Equipment
DC	– Direct Current
DCA	– Department of Civil Aviation
E	– Eastern longitude
EADI	– Electronic Attitude Director Indicator
EASA	– European Aviation Safety Agency
ECG	– Electrocardiogram
EPI	– Emergency procedure
ESR	– En-route Surveillance Radar
FAA	– Federal Aviation Administration, USA
FAF	– Final Approach Fix
FANA	– Federal Air Navigation Agency, Russia
FAP	– Final Approach Point
FAR	– Federal Aviation Rules
FATA	– Federal Air Transport Service
FBS	– Fixed Base Simulator
FCOM	– Flight Crew Operations Manual
FCTM	– Flight Crew Training Manual
FCTM-92	– a common Flight Crew Training Manual issued in 1992
FD	– Flight Director
FFS	– Full Flight Simulator
FL	– Flight Level
FDR	– Flight Data Recorder

FLP	– Flight Plan
FMA	– Flight Mode Annunciator
FMC	– Flight Management Computer
FMS	– Flight Management System
FOOD	– Flight Operations Oversight Department
FSUE	– Federal State Unitary Enterprise
FTI	– Flight Training International (Aviation Training Center, Denver)
FTOA	– Federal Transport Oversight Agency
GE	– General Electric
GSL	– Glideslope Localizer
HDG SEL	– Heading select – autopilot mode
HPC	– High Pressure Compressor
HPT	– High Pressure Turbine
IAC	– Interstate Aviation Committee, Russia
IAF	– Initial approach fix
IAW	– in accordance with
ICAO	– International Civil Aviation Organization
ILS	– Instrument Landing System
IRS	– Inertial Reference System
LNAV	– Lateral Navigation
LMM	– Compass Locator at the middle marker
LOC	– Localizer
LOM	– Compass Locator at the outer marker
LPC	– Low Pressure Compressor
LPT	– Low Pressure Turbine
LTD	– Limited
LVL CHG	– Level Change – autopilot mode
MAC	– Mean Aerodynamic Chord
MCP	– Mode Control Panel
MEC	– Main Engine Control
MEL	– Minimum Equipment List
MMEL	– Master Minimum Equipment List
MMO	– Main Medical Office

MSM CA-85	– Meteorological Service Manual, issued in 1985
N	– Northern latitude
N1	– Fan rotating speed
NDB	– Non-directional Beacon
NM	– Nautical mile
NTSB	– National Transportation Safety Board, USA
PCU	– Power Control Unit
PF	– Pilot Flying
PIC	– Pilot-in-command
PLC	– Public Limited Company
PM	– Pilot Monitoring
PMC	– Power Management Control
PTS	– Passenger Transportation Service
RF	– Russian Federation
RNAV	– Area Navigation
RQB	– Regional Qualification Board
RTF	– radiotelephony
QFE	– atmospheric pressure at aerodrome elevation
QNH	– atmospheric pressure at mean sea level
QRH	– Quick Reference Handbook
ROLRGA-87	– Flight Operations Management Manual for CA, issued in 1987
RSRB	– Regional Search and Rescue Base
RRTOP-2000	– Aeronautical Service and Nav aids Maintenance Manual, issued in 2000
RWY	– runway
SMS	– short message service
SOP	– Standard Operating Procedures
SRG	– Search and rescue group
SSR	– Secondary Surveillance Radar
STAR	– Standard Terminal Arrival Route
TAF	– Terminal Aerodrome Forecast
TBS	– Troubleshooting
TCAS	– Traffic Collision Avoidance System

TCRS	– Transceiving radio station
THR HOLD	– Throttle Hold, A/T takeoff mode, A/T disconnected from throttle control linkage
TLA	– thrust lever angle
TMRS	– Transmitting radio station
TO	– Takeoff
TO/GA	– Takeoff/Go-around (autopilot mode)
TOW	– takeoff weight
USPP	– Bolshoye Savino Airport, 4-letter code
UUEE	– Sheremetyevo Airport, 4-letter code
UTC	– Universal Time Coordinated
VHF	– Very High Frequency
VMC	– visual meteorological conditions
VNAV	– Vertical Navigation
VOR/DME	– Very High Frequency Omnidirectional Range/Distance Measuring Equipment
VOR/LOC	– VOR or Localizer capture (autopilot mode)
<expl>	– Expletive expression

## SYNOPSIS

On September 13, 2008 at 2310 hrs UTC (hereinafter unless stated otherwise UTC time is given), local time 0510, September 14, 2008, at nighttime, in simple meteorological conditions<sup>1</sup>, a Boeing 737-505 VP-BKO operated by Aeroflot-Nord performing a scheduled passenger flight AFL 821 from Moscow (Sheremetyevo) to Perm (Bolshoye Savino) crashed during approach to Runway 21 at Bolshoye Savino Airport (Perm).

The Air Accident Investigation Commission of the Interstate Aviation Committee was notified about the accident on September 13, 2008 at 2335 hrs UTC (0335 Moscow time).

In compliance with Order 33/452-P (September 14, 2008) of the IAC Chairperson an investigation team was appointed.

In compliance with ICAO Annex 13, notifications of the accident were sent to the NTSB USA as the State of Aircraft Design and Manufacture of the aircraft, the BEA France as the State of Engine Design and Manufacture, the AAIB UK as the State of Registry, the aircraft being registered in the UK Overseas Territory of Bermuda.

Investigation participants included representatives of the NTSB, FAA, Boeing and GE (USA), BEA and Snecma (France), AAIB (UK), Bermuda Ministry of Transportation and Tourism, experts from the Russian CAA, FTOA, FANA, Meteorological Agency, as well as pilots from the Gromov Flight Research Institute, State Research Institute of Civil Aviation, Aeroflot-Nord, Transaero and K Davia airlines.

In compliance with Order 1336-p of September 14, 2008 issued by the Prime-Minister of the Russian Government a governmental commission was appointed (chaired by the Minister of Transportation, Russian Federation) in order to assist families of the victims and also to eliminate the aftermath of the accident.

Preliminary judicial investigation was instituted by the Chief Investigative Office of the Investigative Committee, Prosecutor Office, Russian Federation.

Start of investigation – September 14, 2008.

End of investigation – May 18, 2009.

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<sup>1</sup> Translator's remark: According to the Russian regulations meteorological conditions not worse than 2000 m visibility and 200 m ceiling are considered to be simple ones.



## **1. FACTUAL INFORMATION**

### **1.1. History of the Flight**

On September 13, 2008 an Aeroflot –Nord flight crew (Captain and Co-pilot), were conducting a scheduled domestic passenger flight No. AFL 821 on a B-737-505 aircraft, registration VP-BKO, from Moscow (Sheremetyevo, UUEE) to Perm (Bolshoye Savino, USPP).

Apart from the two-member flight crew there were 4 flight attendants and 82 passengers on board, which makes a total of 88 people, including 66 citizens of the Russian Federation, 8 citizens of Azerbaijan, 1 citizen of Byelorussia, 1 of Germany, 1 of Italy, 1 of China, 1 of Latvia, 1 of Turkey, 1 of Uzbekistan, 5 citizens of Ukraine and 2 of France.

According to the load sheet, the aircraft payload (cargo and passengers) was 8079 kg. The takeoff weight was ~54000 kg (with the max TOW of 60554 kg), the CG was at 20.61 % MAC, which was within the B-737-500 FCOM limitations. The calculated landing weight was 49700 kg (with the maximum of 49895 kg), and the CG was at 21.9 % MAC, which was also within the B-737-500 FCOM limitations.

The pre-flight briefing was conducted in due time and in compliance with the standard procedures. All the crew members passed medical check at the medical office of Aeroflot – Russian Airlines on September 13, 2008 at 1948 hrs and got permissions to fly.

On the basis of the dispatch information (aircraft condition, aeronautical information, weather information, aircraft load data and operational flight plan) the PIC at 1955 hrs made a decision to fly.

The takeoff was performed at 2113 without delay. The climb and level flight at FL 290, 9100 metres were conducted without any deviations.

At 2245 hrs the crew started descent from the flight level to waypoint Mendeleyevo (940 MN). After passing over Mendeleyevo, in compliance with the Perm Approach Control instruction, the aircraft flew via the outer marker (705 PX) of Runway 21 which is the initial approach fix (IAF) for Runway 21 (heading 212° magnetic). After passing over the RWY with heading 110° M, the crew, following the Controller's instruction, turned right for back course and started maneuvering for ILS approach to Runway 21.

After the base turn, approaching the landing course at 600 m with both autopilot and autothrottle disengaged, the aircraft started climbing up to 1300 m, rolled 360° over the left wing and collided with the ground. The aircraft was totally destroyed and partly burnt in the ground fire.

All passengers and crew members on board died due to the ground impact.

The accident occurred at 2310 hrs 12.4 km from aerodrome reference point (ARP) of Perm Airport, azimuth 60° M. Accident site elevation is 153 m.

### 1.2. Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	6	82	-
Serious	-	-	-
Minor/None	-/-	-/-	-/-

### 1.3. Damage to Aircraft

The aircraft was totally destroyed and partly burnt in ground fire.

### 1.4. Other Damage

The crash resulted in damage to the railway and high voltage lines. According to the official data, the damage recovery cost 6355112 rubles to the Sverdlovsk Railway Department.

### 1.5. Personnel Information

<b>Captain</b>	<b>Rodion M. Medvedev</b>
Position	Captain of Boeing 737
Date of birth	November 21, 1973
Class	Class II ATPL, protocol No. 13 of August 11, 2005 issued by the RQB of Tatar Office, FTOA
Pilot's License, No., date of expiry	II II № 001149, violation ticket No. 006053, valid until November 27, 2008.
Pilot's License Validation	No. 2008/14, issued 04.01.2008 by the DCA Bermuda, valid until December 31, 2008.
Education, general and professional	<p><b>Higher:</b> St Petersburg State University of CA, graduated 2002. Diploma ДБ 1008748, qualification: engineer-pilot.</p> <p><b>Specific:</b> Krasny Kut Flight School of Civil Aviation, graduated 1994. Diploma PT 229998. Qualification – Pilot of Civil Aviation.</p> <p><b>Transition to Boeing 737:</b> Transition course at the FTI Centre (Denver, USA) in September 2006</p>

	(co-pilot transition program).
Total flying experience	3900+ hours, including night flights 1400+ hours.
Total on B-737 as Captain	1190 hours 477 hours
Experience on Tu-134 (co-pilot)	2700+ hours
Experience on An-2 (flight school)	90 hours
Pre-flight preparation	Spring-summer 2008 preparation: May 06, 2008 Pre-flight briefing: September 13, 2008 before flight (complete).
Weather minima, date of last checkride	Weather minima CAT II ICAO (30x350, takeoff 200) assigned June 23, 2008. Checkride on June 21, 2008 by Captain of flight squadron 5, Aeroflot-Nord. Total mark "Excellent".
Last simulator based training	June 13-16 2008, Lufthansa Training Centre, Berlin, "Good".
Flying time within last month	32 hrs 40 min
Flying time and number of flights within last 3 days	15 hrs 35 min, 6 flights (excluding the accident flight)
Flying time on the day of occurrence	1 hour 56 min
Time in the airport before last flight	1 hour 30 min
Rest before last flight	At home, 15 hours
Breaks in flights	from Dec 21, 2007 to Jan 10, 2008 – vacation from Feb 06, 2008 to Feb 15, 2008 – vacation from Aug 20, 2008 to Sept 10, 2008 – vacation
Annual medical check	November 27, 2007 at the medical office of Aeroflot-Nord, fit for flying as a pilot.
Pre-flight medical check, person in charge	Ground doctor of Aeroflot – Russian Airlines, September 13, 2008 at 19 hrs 37 min.
Previous accidents or incidents	None
<b>Co-pilot</b>	<b>Rustem R. Allaberdin</b>
Position	Co-pilot of Boeing 737
Date of birth	January 02, 1965

Class	Class II ATPL, protocol № 25 of October 21, 2003 High Qualification Commission, Federal Aviation Service, Russia.
Pilot's License, No., date of expiry	ATPL II II № 011831, violation ticket 093288, valid until May 23, 2009.
Pilot's License Validation	№ 2008/14 issued January 04, 2008 by DCA Bermuda, valid till December 31, 2008.
Education, general and professional	<p><b>Higher:</b> Ufa Aviation Institute, graduated 1991. Diploma No. YB-380938. Qualification: electronic engineer.</p> <p><b>Specific:</b> Buguruslan Flight School of Civil Aviation, graduated 1985. Diploma No. 3T 078017. Qualification: civil pilot.</p> <p><b>Transition to B-737:</b> Aviation Training Centre of St Petersburg State University of Civil Aviation, 2008. Certificate No. B-TR-08/004 issued January 17, 2008 r. and Certificate No. 126.</p>
Total flying experience	8900+ hours, including 639 hours at nighttime.
Total on B-737	236 hours
Experience on Tu-134 (co-pilot)	1600+ hours
Experience on An-2 as a Captain	7000+ hours 3400+ hours
Pre-flight preparation	<p>Spring-summer 2008 preparation: May 06, 2008 (complete).</p> <p>Pre-flight briefing: September 13, 2008 before the flight (complete).</p>
Weather minima, date of last checkride	<p>Weather minima CAT I ICAO (60x550, takeoff 200) assigned May 16, 2008.</p> <p>Checkride on July 07, 2008 Captain of Squadron 5 of Aeroflot-Nord. Total mark "Good".</p>
Last simulator based training	July 22, 2008, Lufthansa Training Centre, Berlin, "Good".
Flying time within last month	12 hours 35 min
Flying time and number of flights within	5 hours 20 min, 2 flight (excluding accident

last 3 days	flight)
Flying time on the day of occurrence	1 hour 56 min
Time in the airport before last flight	1 hour 30 min
Rest before last flight	Nord Hotel, Himki, Moscow Region, 15 hours
Breaks in flights	from Jan 21, 2008 to Feb 29, 2008 - vacation from July 14, 2008 to July 31, 2008 - vacation
Annual medical check	May 23, 2008 at the medical office of Aeroflot-Nord, fit for flying as a pilot.
Pre-flight medical check, person in charge	Ground doctor of Aeroflot – Russian Airlines, September 13, 2008 at 19 hours 46 min.
Previous accidents or incidents	None.

The PIC<sup>2</sup> underwent transitional training for Boeing-737 in August to September 2006 in the Flight Training International (FTI), Denver, USA. During the course the co-pilot transition program was used. In 2006 the mentioned training centre was neither approved nor accepted by the Russian aviation authorities, which is required by Chapter 4 of FAR “Certification of Aviation Training Centers”, approved by the Federal Aviation Service Order No. 23 issued on January 23, 1999<sup>3</sup>.

**Note:**

*The investigation team obtained the "Individual Chief Pilot, Instructor and Pilot Training Program for Boeing 737-300/500" of Aeroflot-Nord Airline, approved by the Russian Aviation Authorities. The "General" Section states that "the present programs are to be used... after the transition training at the United, **Flight Training International Training Center (Denver, USA)**, approved by the civil aviation authority of Russia for this kind of training".*

In accordance with the Contract for B737 –300/500 flight crews/763-425-06 between Aeroflot-Nord and the FTI concluded on August 11, 2006, the FTI Centre was supposed to document all the training conducted using the approved documentation forms, accepted by Russian Aviation Authorities. All the training documentation was either to be sent to the airline by express mail within three working days after the end of the transition course, or given to the students (on the airline’s agreement). However the PIC’s personal file, apart from the transition

<sup>2</sup> In this section the terms PIC and Captain will be used to denote the PIC of the accident flight even with reference to the time when he was a co-pilot.

<sup>3</sup> This approval was only issued on April 02, 2007.

course certificate, contained only two more related documents: one regarding the ground training of 12 hours and the other regarding the Fixed Base Simulator (FBS) of 28 hours with a general comment of the instructor “Good job”. Later, among the PIC’s personal papers, a checkride certificate and the training schedule were found. It was not possible to reveal the cause of the lack of documents in the PIC’s personal file.

According to the FTI official information, copies of all papers related to the PIC’s training were kept for one year after the end of the course according to the FAA regulations and then destroyed. The FTI states that the amount of training was determined on mutual agreement with the airline and was different from the type rating course FAA.

Analyzing the aforementioned Contract between the airline and the FTI, as well as the training schedule with the PIC’s notes, it can be concluded, that the transition course included the following:

- CBT (number of hours unknown);
- EPI – 6 hours;
- Ground training – 12 hours;
- Fixed Base Simulator (FBS) – 28 hours;
- Full Flight Simulator (FFS) – 32 hours;
- Oral examination – 2 hours;
- Checkrides – 4 hours.

This course is longer than the FAA type rating course, which apportions only 24 hours for FFS training and does not include FBS training. However, one should take into account the difference in basic training level and previous experience on two-member crew aircraft, “glass cockpit” and western type attitude indicator between transitioning pilots from the US and from the CIS countries<sup>4</sup>.

Thus, because of substantial lack of documentation, it seems impossible to make a deep analysis of the amount of training received by the PIC during the transition course, the degree and quality of acquired skills and the instructors’ remarks.

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<sup>4</sup> In general, the FTI instructors noted that pilots from Russia experiences particular difficulties due to the general difference between western and eastern types of aircraft. Of special notice were problems with bank recovery due to different types of roll indication on the attitude indicators.

Before the transition course, from June 13 to July 12, 2006 the PIC took a course of “Technical English for Aviation” (208 hours) at METEK Ltd<sup>5</sup>, in St Petersburg. It was impossible to make an unambiguous assessment of the Captain’s mastery of the course materials and the English language in general, as there were no audio records or written works available. Records of radio exchange in several previous flights were analyzed though, where the PIC was maintaining the radio exchange partly in English. It should be noted that the PIC was rather fluent in using the standard phraseology, which assumes that he at least had ICAO Level 2. However the analyzed flights did not contain any abnormal situations, thus it is not clear if the PIC was able to use General or Aviation English beyond the standard phraseology. There was no information available if the PIC had passed any qualification testing that would meet ICAO Language Proficiency Requirements.

According to the available documentation, the PIC regularly took refresher courses in RTF phraseology in compliance with Instruction ДБ № 94. He passed the last refresher course from November 23 to December 06, 2007 (120 hours), which he completed with a “Good” mark.

The Captain did not have a permit for international flights (he was in the process of getting a permit for flying international routes).

Though the Certificate of transition training in Denver was issued on September 10, 2006, the PIC was commissioned as a co-pilot of Boeing 737 by an Order of the General Director only on January 09, 2007, which makes a break in transition of 4 months<sup>6</sup>. On the same day the PIC started his ground training Task 1, stipulated by Section 1 “Preparation for flights as co-pilot” of Program 1 “Co-pilot training”, FCTM-737 (later referred to as FCTM) of Aeroflot-Nord. This FCTM was developed by the airline and approved by the FTOA on June 26, 2006<sup>7</sup>.

**Note :** *The inconsistency of this FCTM’s provisions with the FCTM-92, CAFOM-85 and ROLRGA-87 will be tackled below.*

According to the airline FCTM, co-pilots who had a break in flights for more than 90 days after the transition training must receive additional FFS training of 4 hours before Task 2. This training was never taken.

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<sup>5</sup> Detailed information on METEK Ltd. and their courses of English for pilots is given in section 1.18.

<sup>6</sup> Meanwhile the PIC continued flying as a co-pilot of Tu-134. The CAFOM-85, p. 3.5.10 does not allow simultaneous operation of aircraft with different instrument indications. However there are no rules there regarding simulator training.

<sup>7</sup> In the course of the investigation, as a result of checks carried out in Aeroflot-Nord, flight crew training on the basis of the airline FCTM was suspended until it is changed to comply with the standard FCTM-92 (see Information on Flight Safety No.5 by the Russian CAA).

On January 11-12 the PIC performed 4 on-the-job training flights as an observer (Task 2). There is no order regarding his permission to fly (with the name of the assigned instructor) in the PIC's personal file. The flight time for Task 2 was 10 hours 35 min.

**Note:** *The order was submitted to the investigation team only on December 08, 2008 marked as Order No. 1-a dated January 10, 2007.*

On January 15-20 the PIC conducted 12 flights (Task 3) with pilot-instructors (3 instructors in all). The training task does not contain information whether he was pilot flying or pilot monitoring, nor any information on performing takeoffs and landings (FCTM-92, Program 1, p. 1.7).

**Note:** *The training task form approved by the airline FCTM does not provide for recording the number of flights performed as PF or PM (both takeoffs and landings), though the findings of the training flight include detected faults when flying as PF.*

Task 3 flight time was 33 hours 15 min. The instructors noted the necessity to pay more attention to "after takeoff" and "approach" procedures when flying as a PF.

On January 22 the PIC made a checkride as a co-pilot (Task 4). As a result of this checkride he was allowed to fly as a co-pilot with the weather minima of 60x550, takeoff 200. However, the same pilot-instructor both completed the training and checked if the PIC could be allowed to fly as a co-pilot, which is not in compliance with ROLRGA-87, p. 6.1.2.

The PIC's total flying time during his commissioning as a co-pilot was 47 hours 55 minutes.

The Captain's personal file does not contain the permit to fly as a co-pilot in an assigned crew with a fixedly assigned PIC in certain flight conditions. According to the airline FCTM, flight crews in the airline were not fixed, which contradicts CAFOM-85 p. 3.4.2 and ROLRGA-87 pp. 5.1.2, 5.1.4, 5.3.1 and 5.3.2.

In May 2007 the PIC was trained for CATII ICAO (Section 3 FCTM). There are no papers in the personal file regarding the checkride (Task 3). The PIC was allowed to fly CAT II ICAO (30x350 m, takeoff visibility 200 m) by Order No. 91 of June 25, 2007 issued by the flight division of Aeroflot-Nord.

From January 25 to October 21, 2007 the PIC was flying as a co-pilot. The flight time within this period was over 500 hours. Thus, the requirements of Task 1 "On-the-job flight



training for co-pilots” of Section 2 “Co-pilot on-the-job training” were followed in compliance with variant 2 (previous experience as Class II co-pilot). Based on the flight performance, on October 21, 2007 he was allowed to make a checkride before permission to commission as a Captain (Program 1, Section 2, Task 2).

However, according to the available documents, the checkride in question was conducted earlier, on October 04, 2007. Two flights were performed in real flight conditions, but the data regarding these flights (duration and time of the day) are *different* in the checkride test sheet and in the training task. There were no remarks on the checkride by the instructor.

Upon the Regional Qualification Board’s Decision No. 48 of December 28, 2007 the Company Order No. 269 of (date not specified) December 2007 was issued, according to which the PIC was allowed to fly as a trainee captain of B-737, assigned to a pilot-instructor for the training period (Program 2 “Captain training”, Section 1 “Training of captains for CAT I flights”, Task 3 “On-the-job training with a pilot-instructor”). By that time the PIC’s total flying experience as a co-pilot of B-737 was about 650 hours.

**Note:** *Order No. 289 without a specified date was present in the PIC’s personal file. On December 08, 2008 the airline submitted to the investigation team another order with the same content dated December 29, 2007.*

On January 14, 2008 the PIC passed ground training (Task 1). On the same day he was assigned for Training task 3 “On-the-job training with a pilot-instructor”. **Task 2 “Simulator training” was not conducted after the ground training.**

Instead, simulation training as a co-pilot on December 21, 2007 was reckoned for it. The pilot-instructor who was in charge for the training and check, made a conclusion that the PIC can be considered for being commissioned as a trainee captain. The training and check were conducted before the Regional Qualification Board’s consideration and before the issue of the permit to fly as a trainee captain.

According to Task 2, a trainee captain shall take simulator training in a fixed crew and the aim of the training is to acquire necessary skills to control the aircraft from the left captain’s seat, and to train emergency procedures. On the basis of its results it is concluded if the trainee can proceed to Task 3 (flight training). On December 21, 2007 the pilot-instructor did not make

such a conclusion, as the PIC was not yet a trainee captain and had not completed the previous tasks.

From January 16, 2008 to February 04, 2008 the PIC made 20 flights in compliance with Task 3. There are no remarks about 60x550 and 80x1000 approaches, takeoffs with visibility 400 and 200 m, and the used landing systems (CAFOM-92, Program 2, p. 1.8).

**Note:** *The standard task form, approved in the airline FCTM, does not provide for recording of weather conditions at takeoff and landing as well as the used landing systems and modes, which makes it difficult to assess the level of pilot's skills.*

Only the last two flights were performed under the guidance of the assigned instructor. The same instructor on February 04, 2008 allowed the PIC to proceed to Task 4 "Checkride for solo flight permission". The previous 18 flights were guided by another instructor. According to the FCTM, "flight training of a trainee captain is normally conducted by one assigned pilot-instructor or chief pilot". However, p. 1.3 of Program 2, FCTM-92 requires that the flight training of a trainee captain shall be conducted by one pilot-instructor.

The PIC's total flying time as a trainee captain was about 50 flight hours.

On February 05, 2008 two checkrides were made in compliance with Task 4, after which the PIC was allowed to fly a Boeing 737 with weather minima of 80x1000, TO visibility 400 m. There is no information on the weather conditions during the checkrides. The interview sheet and the weather minimum confirmation are not present in the personal file.

**Note:** *These documents were handed over to the investigation team only on December 08, 2008.*

By the time of the checkride no co-pilot was assigned for further flights with the PIC, which is against the FCTM-92, Program 2, pp. 1.3 and 1.4.

On the basis of Arkhangelsk Office of FTOA's RQB Protocol No. 3 of February 08, 2008 the PIC was approved as Captain of Boeing 737.

On the basis of Airline Order of February 08, 2008 the PIC was allowed to fly as Captain on Boeing 737 with the weather minimum of 80x1000, TO visibility 400 m.

The available documents show that by the time of getting his approval as Captain and weather minima of 80x1000 the PIC had not conducted 3 landings and 2 takeoffs in actual CAT I IMC (FCTM-92, Program 2, p. 1.8.b). He was allowed to perform takeoffs at visibility 200 m as

well as landings at 60x550 during his simulator sessions on December 19, 2007 when he was not yet a trainee captain. While the actual weather in which he conducted flights with a pilot-instructor when he was commissioned was 180x1800.

Though the PIC had not have any experience as a Captain he did not undergo captain training courses (FCTM-92, Program 2, p. 1.1: “Recommendation: Before being commissioned as a Captain, an applicant who has not flown as a PIC should undergo special courses for captains with approved syllabus (36 hours).”)

Though before transition the PIC flew a TU-134 (four-member crew), he did not get any CRM training.

When the PIC was commissioned, the requirements of p. 2, Section 5.6, Chapter 5, Aeroflot-Nord FOM were not complied with. (“When transitioning to new types of western aircraft at Aeroflot –Nord, *position of a captain can be normally taken Class I pilots with flying experience as captain on Class 1-2 airplanes of not less than 500 hours* who have not caused previous accidents or incidents, which factors shall be considered when selecting applicants for transitioning”).

On February 16-18, 2008 the PIC made 6 solo flights under the supervision of a pilot-instructor (Task 5: “Captain’s solo flights under the supervision of a pilot-instructor”).

From February 20, 2008 to March 22, 2008 he conducted 24 flights (Section 1, Task 6).

On March 22, 2008 the pilot-instructor wrote his conclusion in the training task sheet to allow the PIC to fly CAT I (60X550), TO visibility 200 m. However, the solo flight record does not contain any information on the weather conditions of landings made to confirm the minima (according to FCTM-92 not less than 15 flights shall be made with minima of 80x1000).

**Note:** *These data were submitted on December 08, 2008 as a separate document.*

On March 24, 2008 the PIC was allowed to fly CAT I ICAO (Airline Order No. 81).

**Note:** *According to FCTM-92, Program 2, p. 1.8 b, on aircraft with automatic landing equipment installed the weather minima of 60x800 is entitled to a captain who has an experience as captain on aircraft with the same systems and who has had a personal weather minimum of 60x800 or less for a year or more.*

The solo flight record does not contain any data on approaches and weather conditions to confirm the minima (60x550, TO visibility 200 m).

**Note:** *These data were submitted on December 08, 2008 as a separate document.*

On June 14, 2008 the PIC passed ground training for CAT II flights (30x350, TO visibility 200m) (Program 2, Section 3, Task 1).

On June 15, 2008 he passed simulator training. The pilot-instructor concluded that the PIC can fly CAT II. On the next day, June 16, 2008, after the semiannual simulator session the same pilot-instructor made a note that the PIC should be more accurate with his PIC duties.

On June 23, 2008 the PIC was allowed to fly CAT II ICAO (Airline Order No.167).

**Note:** *CAT II permission (30x350) was given in violation of the FCTM-92, Program 3, Section 1, p.2 requirements (3 approaches in actual CAT I conditions).*

*According to the available documents, the PIC conducted one automatic ILS approach on May 07, 2008 in Murmansk in actual weather conditions with cloud base 70 m and 3 approaches on a simulator on June 15, 2008.*

During the PIC's flights there was no order concerning the formation of the crew for the young captain who was flying as a PIC for the first time in his life and for the first year.

On August 13, 2008 the PIC made a checkride for International Flights Permit, with a positive conclusion of the pilot-instructor (Program 7, Task 3; there are no data on Tasks 1 and 2 in the personal file). By the time of the accident he had not yet received the International Flights Permit.

Total solo flight experience of the PIC on Boeing 737 by the time of the accident was less than 500 hours.

On the basis of the flight tasks No. 612 Flight No. 897/898 (Sheremetyevo – Chelyabinsk – Sheremetyevo) of September 11, 2008; No. 609, FN 729/730 (Sheremetyevo – Volgograd – Sheremetyevo) of September 11, 2008; No. 732 FN 885/886 (Sheremetyevo – Tyumen – Sheremetyevo) of September 13, 2008 as well as on the basis of Provisions on the Work and Rest Time Distribution for Flight Crews of Civil Aircraft, Russia (approved by Order 139 by the Ministry of Transportation, RF of November 21, 2005) and amendments to the abovementioned

Order (approved by Order 91 by the Ministry of Transportation of July 16, 2008) and also on the basis of Aeroflot-Nord FOM (Part 1, Chapter 7 “Flight, work and rest time of aircraft crews”) the following main conclusions were made:

- Duration of the flight shifts on September 11, 2008, September 11-12, 2008 and September 13 2008 was 7h40min, 8h19min and 8h29 min, which is lower than the maximum acceptable according to the Company FOM (Supplement 1, Part A, Chapter 7, Aeroflot-Nord FOM) and to Order No. 139 by the Ministry of Transportation. Taking into account the accommodation provided for crew rest by Aeroflot-Nord at the Volgograd Hotel in Volgograd, the rest time of the crews was not included into the work shift on September 11-12, 2008.
- Duration of the regular rest (rest between the shifts of September 11 and September 11-12, 2008 and September 12-13, 2008) was 5h56 min instead of the mandatory 12 hours<sup>8</sup>.
- Total time on duty within the 24 hours of September 11, 2008 was 12h24min instead of the maximum acceptable 10h30 min.
- Duration of the flight shift of September 13, 2008 and duration of the regular rest between the flight shifts of September 12-13, 2008 and September 13-14, 2008 are within the limitations.

**Co-pilot** received transition training for Boeing 737 at the Flight Training Centre of St Petersburg State University of Civil Aviation<sup>9</sup> in December 2007 – January 2008.

Before the transition courses, from September 03 to December 05, the co-pilot took a Basic English Course (512 hours) and Technical English for Aviation (288 hours) at METEK Ltd.<sup>10</sup>, St Petersburg. Thus, within 13 weeks the co-pilot had 800 hours of training, which makes over 10 hours of study a day, even including Saturdays. The opinions given by experienced teachers of English shows that it is practically impossible to acquire the course material properly at such a tempo, especially if the language is learnt from the beginner’s level. This is confirmed by the percentage of successfully completed tasks of the interim written tests, conducted at the training centre (74% of the first test and 36% (!) of the second. The final result was 70%). (Cf: the PIC had 92% of successfully completed tasks in his final test).

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<sup>8</sup> The FTOA inspection also revealed multiple violations of the work and rest balance requirements for the airline crews.

<sup>9</sup> On November 19-21, 2008 an FTOA commission made an inspection of this training center. Their general conclusion was that the initial, transition and refresher courses for flight crews did not comply with the FAR "Certification of Aviation Training Centers".

<sup>10</sup> Details on METEK Ltd. And their English language courses for pilots are given in Section 1.18.

At the end of December 2007 the co-pilot completed the theoretical part of his transition training with “Excellent” and was allowed to proceed with the simulator training.

The simulator training was conducted in January 2008 in Riga. During the simulator training the instructor wrote numerous notes saying that the co-pilot should pay more attention to SOP compliance, especially in terms of callouts, as well as to the CRM issues and PF/PM duties. It was also noted that he should get more training for flights with thrust asymmetry and pay more attention to attitude and speed during approach<sup>11</sup>.

On January 17, 2008 the co-pilot received Certificate of Completion of Transition Training for Boeing 737 and Certificate No. 126 of accepted state format.

The 5 final sessions on the simulator, the check and issue of Certificate were done by the same person, which is against FCTM, p. 6.1.2.

In compliance with Aeroflot-Nord Airline Order No. 63 of March 06, 2008<sup>12</sup> the co-pilot was allowed to proceed to the commissioning program according to Section 1, Program 1, Airline FCTM, and was assigned to a pilot-instructor.

The co-pilot resumed flying three months after he had received the Certificate of Transition Training (January 17, 2008 – April 17, 2008). Before he resumed flying, the co-pilot did not pass any recurrent training after the break in Boeing 737 simulator training<sup>13</sup>.

**Note:** *The Airline FCTM has provisions only for simulator training in case of break in flights of 90 days after the transition.*

Total break in flights (from September 2007) was 7.5 months.

When conducting flights in accordance with Task 3, the assigned pilot-instructor was not present. Within 14 flights there were 4 different pilot-instructors. The final flights were again conducted under the guidance of the instructor who had taught the co-pilot at the transition courses and issued the Certificate. The same instructor trained, checked (checkride on May 08, 2008) and made a conclusion allowing the co-pilot to fly in weather minimum of 60x550, TO visibility 200 m. The Chief Pilots and Managers of the airline practically did not take any part in the co-pilot's training quality assessment.

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<sup>11</sup> These drawbacks are typical for pilots who transition from Russian aircraft types to western ones and were also noted with other pilots involved in previous accidents (A-320, May 03, 2006 and A-310, July 09, 2006). It should be mentioned that all the abovementioned problems showed up during the accident flight.

<sup>12</sup> There are two orders with this number dated the same but slightly different in content.

<sup>13</sup> ROLRGA-87, p.6.4.1 determines the way of resuming flights after a break of 30 to 90 days. This item does not contain any direct reference that it can be applicable to pilots who are in the process of transitioning to a new aircraft type.

The training task sheet does not contain any information on the PF/PN flight distribution or the number of takeoffs and landings.

**Note:** *The training task form approved by the airline FCTM does not provide for recording of the mentioned information.*

Before the accident flight the co-pilot had a rest at a hotel for 15 hours. There were no violations of the work and rest balance requirements.

To conclude this section, it should be noted that it was the third flight of the crew in the same membership. Their first two flights together were the day before (Sheremetyevo – Tyumen – Sheremetyevo). There was no order regarding the crew formation. After the crew was formed there was no check flight on either aircraft or simulator, which was against p. 5.3.2 of CAFOM-87 (only ground briefing on September 10, 2008<sup>14</sup>).

**Note:** *CAFOM-87, p. 5.3.2 determines flight permits in case of crew member substitution:*

- *When one member is substituted flight permit is only given after ground briefing for the crew and a CRM check.*
- *When two or more crew members are substituted or a new crew is formed flight permit also demands a checkride on a simulator or on real aircraft.*

*It should be noted that concerning two-member crew aircraft this paragraph may be ambiguous in interpretation, but as within the rather short period of the PIC's flights as a Captain he has changed a significant number of co-pilots, the investigation team considers another change of a co-pilot as formation of a new crew.*

## **Upset Recovery Training**

There is no regular systematic upset recovery training in the airline. Some elements of this program are taught to the flight crews during simulator training concerning special cases, such as windshear or stabilizer hardover. The determination of approaching stall and stall recovery procedures are trained regularly during semiannual simulator training.

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<sup>14</sup> According to the submitted documents, on September 10, 2008 the PIC was formally still on vacation.

## Boeing 737 operation in Flight Management in the Airline - General

Aeroflot-Nord Airline was allowed to operate Boeing 737-500 aircraft by FTOA Flight Operations Oversight Department's Decision No. 234/OCЭ of September 01, 2006. The decision was issued on the basis of Airline Inspection conducted on September 01, 2006 on behalf of FTOA FOOD by a commission headed by Director of Operators Certification Centre MEGA with the participation of experts from Arkhangelsk Office of FTOA. At the time of the inspection there was no trained maintenance staff (a training session was planned); documentation and tools were being replenished. Although at the time of the inspection only two navigators were actually prepared for Boeing 737 (1 Captain and 3 co-pilots were passing flight training), the commission made a general conclusion that "the main data of the application provided by Aeroflot-Nord are consistent with its actual facilities and operational conditions of aircraft, Boeing 737-500 in particular". The inspection documentation does not contain any quantitative or qualitative assessment of the chief pilots and instructors' qualifications that entitle them to teach flight staff to fly Boeing 737 aircraft.

### 1.6. Aircraft information

Type	Airplane, Boeing 737-505
Registration	VP-BKO (Bermuda)
Manufacture number	25792
Manufacturer, date of manufacture	The Boeing Company, September 08, 1992
Owner	ARN 737 Limited, Clarendon House, 2 Church Street, Hamilton HM 11, Bermuda
Leaser	Pinewatch Limited, 25/28 North Wall Quay, Dublin 1, Ireland. Leasing Agreement of March 14, 2008.
Operator	Aeroflot-Nord Ltd.
FAA Type Certificate	A16WE, last revision No. 42 of July 01, 2008.
IAC Type Certificate	№ 19-737 of December 22, 1992, supplement № 19-737/Д-02 of January 15, 2002.
Certificate of registration	№ 1318 of April 07, 2008, issued by DCA Bermuda.



Airworthiness Certificate	№ 1211 of May 23, 2008, issued by DCA Bermuda, valid until May 22, 2009. Agreement on the basis of Article 83 bis, Convention on International Civil Aviation between the Government of Bermuda and Russian Federation concluded in 1999. The VP-BKO was entered into the relative Supplement to the Agreement dated March 07, 2008.
Time in service since new	44533 hours, 35104 cycles
Service life	Not specified.
Last D-Check	July 09, 2001, time in operation 23763 hours, 19240 cycles, performed by Taikoo Aircraft Engineering Co. Ltd, r. Xiamen, China.
Operating time since last D-check	20770 hours, 15864 cycles
Last 1C-Check (4000 flight hours)	Performed on March 04, 2008, by Taikoo Aircraft Engineering Co. Ltd, r. Xiamen, China, before being leased to Aeroflot-Nord.
Last base maintenance	1A+2A+4A Check, performed on September 07, 2008 at VARZ-400 maintenance base, Vnukovo. Task card No. 09-135.
Last line maintenance	Daily-check, performed on September 13, 2008 at VARZ-400 outside station at Sheremetyevo-1. Recorded in the log book.
Preflight check	Preflight Check done by the crew <sup>15</sup> .

## Engines

	left	right
Type	CFM56-3C-1	CFM56-3C-1

<sup>15</sup> The PIC was permitted to perform the preflight check on Boeing 737 by Order No. 341 issued by the Director General of Aeroflot-Nord of May 24, 2007 on the basis of Certificate No. 205-07-04 of January 29, 2007 on the completion of specialized courses at UAB Amikon (Lithuania). Flight Safety Information Sheet No. 5 issued by FTOA Head in the course of the investigation cancels the flight crew training program of Aeroflot-Nord with regard to Preflight Check on Boeing 737 and prohibits the crews trained by Aeroflot-Nord instructors to conduct Preflight Checks.

Manufacturer	CFM (France)	CFM (France)
Manufacturer's number	857313	856332
Date of production	June 17, 1992	August 09, 1992
Time in operation since new	35426 hours, 27364 cycles	41977 hours, 33041 cycles
Service life	Not specified	Not specified
Date and place of last overhaul	16.11.2004, at ST AEROSPACE ENGINES PTE LTD (Singapore).	24.09.2004, at MTU Maintenance Zhuhai Co. Ltd. (China).
Time in operation since last overhaul	14697 hours, 8442 cycles	11090 hours, 8074 cycles
Last base maintenance	1A+2A+4A Check, performed on September 07, 2008 at VARZ-400, Vnukovo. Task card No. 09-135.	1A+2A+4A Check, performed September 07, 2008 at VARZ-400, Vnukovo. Task card No. 09-135.

The aircraft takeoff weight was ~54000 kg (with a maximum of 60554 kg) and the CG was 20.61 % MAC, which was within the B-737-500 AFM limitations. The calculated landing weight was ~49700 kg (with maximum allowed 49895 kg), the landing CG was 21.9% MAC, which was within the B-737-500 AFM limitations.

The remaining fuel on board after the previous flight was 5800 kg. The aircraft was refueled with 11800 l (9333 kg) of fuel on the basis of Request No. 261982 from reservoir No. 4, fuel vehicle No. 130. Total fuel on board after refueling made up 13100 kg.

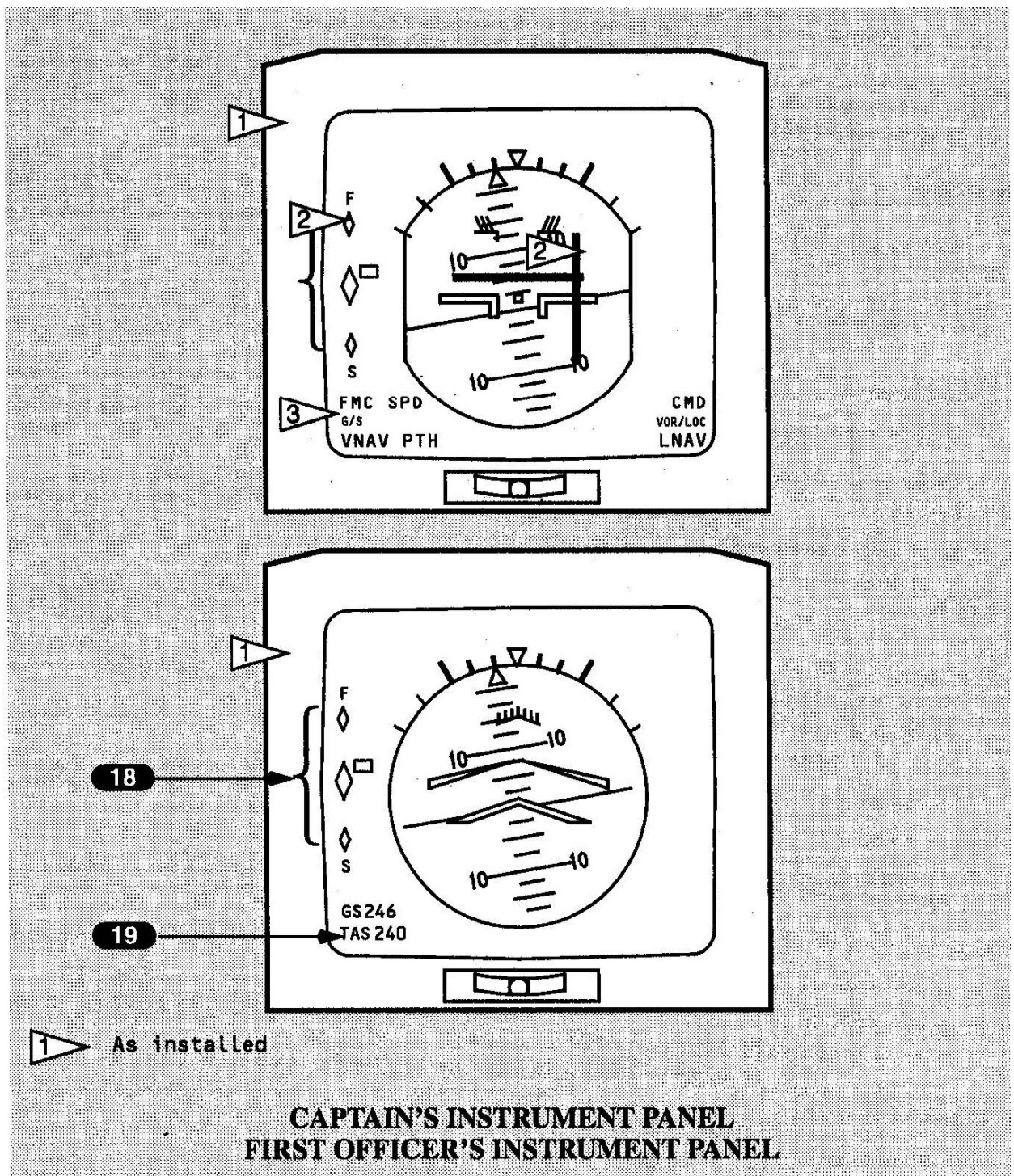
The laboratory analysis of the fuel from the refueling vehicle tank and the fuel reservoir showed that it complied with the specifications.

#### **Aircraft components of particular interest**

The aircraft was fitted with an integrated cue EADI. Ten out of twelve Boeing 737 aircraft operated by Aeroflot-Nord at the time of the accident, were fitted with conventional command bars (top EADI on the Picture below), while two of them, including the VP-BKO, had EADI with integrated cue (bottom EADI on the Picture below)<sup>16</sup>. In accordance with the provided data, before the accident flight, the Captain performed 20 flights on aircraft with the

<sup>16</sup> Changing the type of EFIS command bars is the program pin selections only.

integrated cue EADI, the last flight – on September 11, 2008, while the co-pilot performed 10 flights totally, the last one – on August 04, 2008.



After the accident the Russian CAA prohibited Aeroflot-Nord as well as other Russian airlines, “to execute flights on aircraft of foreign manufacture that have a different type of attitude indication on the EADI than the standard type used during flight crew training before they (crew members) are trained for this type of indication on aircraft or simulator.”

The VP-BKO had a U5 FMC with the NDB memory of 96 Kbytes. The database of the FMC did not contain the STAR of Perm Airport, but only 4 fixes: RWY-21 threshold, RWY-21 outer marker PX, FAF and FAP.

The FMS<sup>17</sup> (which includes the FMC) was used for navigation and flight control. The FMC determines the current position of the aircraft by use of IRS as well as raw data from the nav aids. The FMC computes current position as a mathematical combination of positions determined by the IRS and radio systems.

The IRS (two independent IRS are installed on the aircraft) provides navigation data, including aircraft position, to other aircraft systems. The IRS information does not depend on the raw data from the nav aids. Before the flight the IRS should be aligned, during which process the crew manually enters the aircraft current position. During the alignment the aircraft must be stationary. The accuracy of aircraft position in IRS decreases during the flight, due to its natural shifting. The accumulated error may reach up to 2 NM an hour. In case inaccurate coordinates are entered before the flight or if the aircraft moves during the alignment, the error may increase.

In order to correct the errors during the flight, the FMC aircraft position may be updated from ground based nav aids. The correction is done continuously, either automatically or manually. This correction can be made if signals from the following nav aids are available (decreasing priority):

- Two or more DME stations;
- one VOR with a collocated DME;
- one LOC with a collocated DME;
- one LOC.

The correction with two or more DME is the most accurate. The VOR/DME correction is less accurate due to inherent VOR bearing errors. The VOR/DME correction can be done only if the aircraft is within 25 NM of the beacon. The LOC correction is only possible in the aerodrome terminal area, if accompanied with manual adjustment of the relative ILS frequency.

When nav aid signals are unavailable, the FMC uses position data from the IRS as the primary approximation, and then uses corrections to calculate the estimated position. These IRS corrections take into account the errors related to the typical shifting of the IRS, and are calculated in advance, on those stages of flight when nav aid data are available.

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<sup>17</sup> The aircraft was not fitted with a GPS transceiver.

It should be noted that according to the FCOM, the FMC alone was not certified as a sole source of navigation system. The required accuracy of navigation is achieved during operations in accurate radio navaid environment. For the U5 FMC, an accurate radio navaid environment is such a condition when RNAV precision is provided in accordance with AC 90-45A FAA.

Thus, if there are not enough VOR and DME beacons along the flight route, the accuracy of FMC current position can be inadequate. The relative information is contained in the FCOM, with a description of various warnings in such cases. When such warnings appear, in order to achieve the required accuracy of navigation pilots should use all available onboard and ground aids.

During type certification of the aircraft it was noted that in the airspace of the former USSR the aircraft can fly only along international routes under constant monitoring by the ATC.

### **History of operation in Russia**

The actual operations of the aircraft by Aeroflot-Nord started on May 30, 2008. By that time its flight time was 43491 hours, 34619 flight cycles. Before that the aircraft had been operated in China. In 2005, within the framework of Rudder Control Improvement Program, in accordance with the AD 2002-20-07R1 FAA, the aircraft was fitted with a new main rudder PCU (see picture below).



## Main Rudder PCU

According to the information provided by the State of Registration (Bermuda), before the start of operations in Russia, all defects on the aircraft found out during the Bureau Veritas inspection were corrected.

Line and base maintenance of the aircraft and engines in Russia was performed by VARZ-400 maintenance base at Vnukovo, on the basis of and in compliance to Agreement No. 121-07/221/1058-H22-07 of November 01, 2007 between VARZ-400 and Aeroflot-Nord.

VARZ-400 at the time of the accident was certified as a maintenance organization (LINE and BASE maintenance) in accordance with the European Aviation Rules PART-145 (Certificate No. EASA.145.0321)<sup>18</sup>, and approved by the aviation authorities of the State of Registry (Certificate No. BDA/AMO/288)<sup>19</sup>.

Line maintenance is executed on an outside line maintenance station of VARZ-400 at Sheremetyevo-1 Airport, which was approved by the European Aviation Authorities (Letter 20298-T 132-0407 VARZ of October 15, 2007).

The engineering group has revealed that all maintenance was assigned in due time and executed completely. All required service bulletins and applicable airworthiness directives were complied with. There are no remarks regarding the record keeping.

Experts who did the maintenance of the aircraft had received training in organizations approved in accordance with European Rules PART-147 and were certified in compliance with EASA and FTOA requirements. There are no remarks regarding certificate formats or validity.

VARZ-400 maintenance base at Vnukovo Airport is provided with all necessary equipment, tools and appliances to perform all kinds of base maintenance. In accordance with Agreement No. 121-07/221/1058-H22-07 of November 01, 2007, it is the obligation of Aeroflot-Nord to provide the outside line maintenance station of VARZ-400 at Sheremetyevo-1 with equipment, tools and appliances, as the airline possesses a storage house there with the necessary equipment, tools and appliances for line maintenance.

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<sup>18</sup> This certificate was suspended in terms of base maintenance on September 30, 2008 due to serious defects found during EASA audit on September 23-27, 2008.

<sup>19</sup> This approval in terms of base maintenance was suspended on October 7, 2008 on the basis of the abovementioned EASA audit.

The aircraft was dispatched for the last flight with two MEL items<sup>20</sup>: autothrottle inoperative (deferred as per 22-4 MEL on September 12, 2008, Category C – 10 days) and TCAS inoperative (item 34-40 MEL, deferred on September 09, 2008, Category B – 3 days, extended deferral on September 12, 2008<sup>21</sup>).

**Note:** *The analysis of the DMI list for September 13, 2008 revealed that it is a common practice in the airline to extend the deferral period for MEL items (3 out of 11 MEL items in the whole Boeing 737 fleet were extended)<sup>22</sup>.*

The autothrottle was deferred as per MEL following a record in the flight logbook made by the crew who executed Flight AFL 824 on September 12, 2008 saying that the autothrottle was inoperative. This record was apparently made because the autothrottle disengaged several times during the flight<sup>23</sup>, which is confirmed by FDR data. The logbook does not contain any record if troubleshooting was done by the maintenance staff.

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<sup>20</sup> The Company MEL was developed on the basis of the MMEL approved by the FAA US, and was approved by Russian aviation authorities on July 21, 2008.

<sup>21</sup> The approval of the Russian aviation authorities for extension of deferral was given by Telegram 111252 dated September 11, 2008.

<sup>22</sup> See also the Final report on the Sibiria Airlines A-310 F-OGYP accident on July 09, 2006 at Irkutsk Airport

<sup>23</sup> See p. 1.16.1 for causes of autothrottle disengagement.



Delay codes: 1-Maintenance, 2-Flight Operator, 3-Attendant Service, 4-Passenger Traffic, 5-Weather, 6-Anticling, 7-Customers, 8-Frontier Guard, 9-Other Causes

AEROFLOT NORD		AIRCRAFT FLIGHT AND MAINTENANCE LOG		SAT	PR. ALT.	GR. WT	TAT	IAS	MACH	TAKE OFF
163053, RUSSIA, ARKHANGELSK, AIRPORT TALAGI PHONE/FAX: (8102) 21-85-55 MAINTENANCE CENTRE, PHONE: (8102) 21-85-07, FAX: (8102) 21-87-24		SHEET № * 0 1 6 9 9 7		051	815	420	027	274	0747	R+38
A/C REGISTRATION № VP-BKO		TYPE 735		ENG. №	N1	EGT	N2	FF	OIL PR.	OIL TEMP.
DATE OF ISSUE (UTC) 1106311235P				1	820	631	880	117	42	80
AFTER FLIGHT № 4P4829				2	820	630	880	117	42	80
HYD. FLUID RECORD		FUELING		PND/G/LTR		SIGN., LIC. №		ATTACHED DOCUMENTS		
UPLIFT (L QT GAL %) 0700		REMAIN 4100		4100		A014165		ADDITIONAL WORKS		
SIGN. LIC. № PAR-23		UPLIFT 8972		8972		A011030		SIGN., LIC. №		
ENGINE OIL RECORD		TOTAL 13072		13072		A011030				
REMAIN (L QT GAL %) 83 88		ADJUSTMENT APV-72		APV-72		A011030				
UPLIFT (L QT GAL %) 10 5		DEPART 13000		13000		A011030				
SIGN. LIC. № PAR-23		FUELING ORDER № 255318		255318						
ATA		ITEM INFORMATION		CORRECTIVE ACTION		P/N		S/N		ACCOM. LIC. №
1P		A/P is inop for over		A/P OISP. IAW MEL 22-4 c/w "C" D14 open EASA 145.0321.B6A/HNO.288 1208.08		OFF		OFF		
						ON		ON		
						OFF		OFF		
						ON		ON		
						OFF		OFF		
2		Gap check		Gap check has been performed IAW AD 2003-34-08. Found OK		ON		ON		
						OFF		OFF		
						ON		ON		
						OFF		OFF		
						ON		ON		
						OFF		OFF		
						ON		ON		
						OFF		OFF		
						ON		ON		
CHECK	Daily MEE		Daily AV		TIRE PRESS. CHECK, PSI		200 200 190 190 200 200		TIME/DATE 1106311235P	
SIGN., LIC. №	PAR-23		PAR-54		TIRE PRESS. ADDED, PSI		N1 N2 NL NL N3 N4		SIGN. LIC. № PAR-23	
FINISHED	1106311235P		1106311235P		H H M M D D H H M M D D		H H M M D D		H H M M D D	
AIRCRAFT IS FIT FOR FLIGHT/CRS*		EASA Part 145 0321 B6A/HNO/DCA 288		FROM		TO		TIME/DATE		
SIGN. LIC. № PAR-23		TIME/DATE 1106311235P		UUEE-UCPP		UUEE-UCPP		1106311235P		
GROUND DE-ICING		TYPE %		STARTED		SIGN. LIC. №		CAPTAIN'S SIGN.		LIC. № 001986

CRS\* means: Certifies that work specified except as otherwise specified was carried out in acc with Part-145 &amp; in respect to that work the aircraft is considered ready for release to service

Rev 1 (JUL15/2007)



However, according to the explanations given by the maintenance staff (2 persons: a shift supervisor and a technician of the outside station of VARZ-400 at Sheremetyevo-1) after the accident, they did the troubleshooting in accordance with AMM 22-31-00 and made a test of autothrottle in accordance with AMM 22-31-00 page 501. The test results identified a possible failure: "A/T computer and Synchro adjust". As there were no components for immediate maintenance while the aircraft was being prepared for the next flight, it was decided to defer the item as per MEL 22-4, "with which purpose the autothrottle was disengaged. The INOP tag was stuck to the autothrottle switch. The P-18 Panel AUTOTHROTTLE AC and AUTOTHROTTLE DC CBs were opened and collared".

The Captain (License 001966) who executed the following flight from Sheremetyevo to Perm<sup>24</sup>, put his signature in the logbook on the page with the record concerning the deferred autothrottle. However, both this crew and the crews on 5 more flights on September 12-13 (prior to the accident flight) used the autothrottle<sup>25</sup>.

**Note:**

*Three captains who executed flights on September 12-13, 2008 noted in their explanations, that the maintenance staff had not done the deactivation (the CBs were not opened or collared, there was no INOP tag on the switch). All the captains confirmed that before flight they were informed of the deactivated autothrottle as per MEL. There were no records in the logbook pertinent to these flights.*

The VP-BKO FDR history analysis revealed that starting with August 6, 2008 at part power with matching TLA the thrust split was up to 20%, and matching N1 caused a throttle stagger up to 15 degrees (there was no thrust split at idle and almost none at takeoff mode). When the autothrottle was engaged it maintained equal N1 by setting the throttles with a stagger.

On August 26 a crew made a record in the logbook: "In flight difference between thrust lever N1 and N2 ~ 60 mm". The Corrective Action section contains the following record: "TBS has been performed. Found: low idle out of limit Eng No.2. Adjustment has been performed IAW AMM 71-00-00/501 Rev."

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<sup>24</sup> The flight was performed on September 12. Please do not confuse with the accident flight.

<sup>25</sup> The crews did not make any comments in the logbook about autothrottle functioning in these flights..

On August 30 the crew wrote: “1. too big difference between thrust levers. 2. on GS (APP mode) RPM N1 left Eng 58%, right Eng 38-57%.” The Corrective Action runs: “1. TBS has been performed. Found high idle out of limit. Performed adjustment high idle IAW AMM 71-00-00/501. 2. See TLB 016315/1.” Then the engineer in charge of the troubleshooting made a record for the crew: “Please monitor in flight engine #1 vs engine #2 difference. Please report.” The analysis of the following pages in the logbook did not reveal any report of this kind.

It should be also noted that during each flight the crew have to fill in a special table which is later used by the maintenance staff to monitor the engines<sup>26</sup>. This table contains data about 8 parameters for each engine. According to the flight crews’ explanations, the engine parameters are recorded by any crew member in cruise flight, 5 minutes after reaching the cleared cruise flight level, if there is no icing condition or turbulence. The TLA is recorded both with engaged or disengaged autothrottle. In this case the No.1 engine TLA is virtually assumed as 50 % of the TLA range, and is supposed to be the basis. The No. 2 engine TLA is calculated virtually in relevance to its position (measured in percents). The available reports of this kind starting from August contained information about the throttle stagger.

However, despite the abovementioned, the maintenance staff did not perform the actions suggested in AMM 71-00-42 (Fig. 116, 117A, 117B, 117C) for throttle stagger. It should be also noted that despite the repeated notes of the flight crews about the throttle stagger, no FDR analysis was conducted during the troubleshooting.

After August 6 (when the stagger first appeared) the PIC who executed the accident flight, performed 10 flights on VP-BKO, the latest of which was on September 11. The co-pilot had never flown the VP-BKO before the accident flight.

### **1.7. Meteorological Information**

The weather at Perm on the night of September 13-14, 2008 was influenced by the north-eastern periphery of the non mobile occluded cyclone with the centre in Samara, minimum pressure in the centre 1004 hPa. The relevant warm front was passing via Neftekamsk – Krasnoufimsk – Nyasepetrovsk and was shifting from the south-west to the north-east with a speed of 10-15 km/h. The continuous rain area preceding the warm front was 200-250 km wide. The base of nimbostratus clouds in the warm front area fluctuated between 200 and 300 meters, the top of layered stratiform clouds was 8000 meters according to Perm weather radar.

The following weather conditions were forecast for Perm Airport (Bolshoye Savino) for the time of the accident:

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<sup>26</sup> This chart is a part of the standard logbook page.

TAF USPP 131940Z 132106 08007G12MPS 5000 -RA BKN015 OVC100 530001  
TEMPO 2103 1500 RA BR BKN004 TEMPO 0306 2000 RA BKN007 =

*From 2100 to 0600 – Surface wind 080 degrees 7 gusting 12m/sec, visibility 5000 m, light rain, clouds broken (5-7 oktas), cloud base 450 m, overcast (8 oktas), cloud base 3000 m, moderate turbulence out of clouds, frequent nearing layer from surface up to 300 m; temporarily from 21.00 to 03.00 visibility 1500 m rain, mist, clouds broken (5-7 oktas), cloud base 120 m; temporarily from 03.00 to 06.00 visibility 2000 m, rain, clouds broken (5-7 oktas), cloud base 210 m.*

Actual weather at the time of the accident at Perm Airport (Bolshoye Savino) measured after getting the accident alert:

*23.10: surface wind 060 degrees 5 m/sec, wind at 100 m – 070 degrees 7 m/sec, wind at 60 m – 100 degrees 15 m/sec, visibility 10 km, light rain, clouds overcast (8 oktas), cloud base 300 m, temperature 7 degrees, dew point 6 degrees, QFE 997 hPa, magnetic course 212, friction factor 0,50, forecast for landing – no changes.*

Actual weather at Perm Airport at the time of the accident was consistent with the forecast weather.

The weather forecasting equipment used to monitor the weather parameters at Perm Airport was operative. The installation and operation of the meteorological equipment comply with the standards of the AOS-92, MSM CA -95 and Instruction on meteorological Support at Perm Aerodrome.

The actions of the shift on duty of the Meteorological Office at Perm that provides meteorological support at the aerodrome and in the vicinity of Perm Airport, their cooperation with the ATC shift on duty before the accident and after receiving the accident alert were in compliance with the regulatory documents.

The professional level of the Perm Meteorological Office staff on duty and the frequency of their recurrent training are in compliance with the regulatory documents.

The meteorological support of the Boeing 737-505 VP-BKO operated by Aeroflot-Nord performing Flight AFL 821 from Sheremetyevo to Perm was in compliance with the regulatory documents.

## **1.8. Aids to Navigation**

The Aeronautical and Communication Equipment Operation Service (ACEOS) is a subdivision of Perm ATC Centre, a subsidiary of Ural Aeronautical Service, State ATM Corporation. The ACEOS operates and maintains navigation aids and radio communication aids at Perm Aerodrome.

The ACEOS has a Certificate of Compliance No. AHO.II000204, issued by the Federal Air Navigation Agency on April 22, 2008 and valid until April 22, 2013.

**List of ACEOS navigation and communication aids:**

Item	Abbreviation	Explanation
1	ASR-A combined with ADF	Aerodrome Surveillance Radar combined with Automatic Direction Finder
2	ESR-T	En-route Surveillance Radar combined with a SSR
3	ATCC	Air Traffic Control Center
4	LOM-212	Locator outer with marker
5	LMM-212	Locator middle with marker
6	LMM-32	Locator middle with marker
7	LOC-212	Localizer
8	GSL-212	Glideslope localizer
9	NDB "Mendeleyevo"	NDB "Mendeleyevo"
10	NDB "Kukushtan"	NDB "Kukushtan"
11	TMRS	Transmitting radio station
12	TCRS	Receiving radio station
13	MSC	Message switching centre

The maintenance of navigation and communication aids is performed by qualified staff in accordance with the RRTOP-2000 approved by the FATA Director's Order No. 250 of August 11, 2000, FAR "Aeronautical support of aircraft and aviation communication".

The landing heading 212 magnetic is ICAO CAT I and is equipped with the following nav aids:

**SP-90 landing system:**

Manufacturer's number 9556, manufactured in 1998, entry into service on January 05, 2001. Last maintenance: GSL – September 09, 2008, LOC – September 08, 2008, season maintenance in accordance with regulatory task cards. Last flight test on October 02, 2007, annual schedule, in accordance with certification requirements. At the time of the accident it was on and functioning properly.

**LOM-212 including:**

NDB PAR-10S MN 1006017, manufactured in 1992, entry into service on September 10, 1994. Last maintenance September 10, 2008, M-2, in accordance with regulatory task cards. Last flight test on October 02, 2007, annual check, in accordance with certification requirements.

Marker beacon E-615.5, MN 15099, manufactured in 1991, entry into service on September 30, 1996. Last maintenance September 10, 2008, M-2, in accordance with regulatory task cards. Last flight test on October 02, 2007, annual check, in accordance with certification requirements.

At the time of the accident the LOM-212 was on and operative.

**LMM-212 including:**

NDB PAR-10S MN 1006034, manufactured in 1992, entry into service on February 10, 1994. Last maintenance September 11, 2008, M-2, in accordance with regulatory task cards. Last flight test on October 02, 2007, annual check, in accordance with certification requirements.

Marker beacon E-615.5, MN 15147, manufactured in 1991, entry into service on September 30, 1996. Last maintenance September 11, 2008, M-2, in accordance with regulatory task cards. Last flight test on October 02, 2007, annual check, in accordance with certification requirements.

At the time of the accident the LMM-212 was on and operative.

Apart from the abovementioned aids the following were used:

**NDB “Mendeleyevo”:**

Locator PAR-10S MN 1005281, manufactured in 1992, entry into service on June 10, 1992. Last maintenance September 13, 2008, M-1, in accordance with regulatory task cards. Last flight test on November 11, 2004, annual check, in accordance with certification requirements.

At the time of the accident the NDB “Mendeleyevo” was on and operative.

**ASR-A combined with ADF including:**

Aerodrome Surveillance Radar ASR-85T, MN 9203, manufactured in 1991, entry into service October 21, 1994. Last maintenance September 12, 2008, M-1, in accordance with regulatory task cards. Last flight test on July 24, 2007, annual check, in accordance with certification requirements.

Automatic direction finder AT-75, MN 533, manufactured in 1984, entry into service February 25, 1985. Last maintenance September 07, 2008, M-3, in accordance with regulatory task cards. Last flight test on September 06, 2006, annual check, in accordance with certification requirements.

Automatic direction finder PLATAN, MN IJIT-018.07, manufactured in 2007, entry into service October 03, 2007. Last maintenance September 13, 2008, M-2, in accordance with regulatory task cards. Last flight test on October 02, 2007, annual check, in accordance with certification requirements.

At the time of the accident all aids were on and operative.

For Air Traffic Management, Automated ATM Complex was used: AATMC “Alpha”, MN 00112, manufactured in 2000, entry into service November 15, 2000. Last maintenance September 13, 2008, M-1, in accordance with regulatory task cards. Last flight test on October 02, 2007, annual check, in accordance with certification requirements.

The AATMC “Alpha” serves for transformation, formation and representation of primary and secondary analogue and digital information on the airspace conditions, that comes from en-route and aerodrome surveillance radars, landing radars and automatic direction finders and can be used at regional and aerodrome ATC centers with medium and high intensity of air traffic.

The sources of radar and direction finders information are: 1R-139, 1L118 (Lira), ASR-85T, AT-75, AT PLATAN.

The aircraft polar position is calculated with reference to a given fix and geographic coordinates of the aircraft position. The accuracy of azimuth calculation is within 1 degree, the accuracy of calculated distance is within 1 km, and the accuracy of coordinates’ calculations is within 1 minute.

The maps in the AATMC “Alpha” are aligned with the ARP.

The aircraft attitude in the AATMC “Alpha” is reflected in the tag in tens of meters (if preceded with a letter A – with reference to aerodrome level, without a letter A – with reference to a level with the pressure of 1013 hPa). The system automatically calculates height over aerodrome level. The pressure at aerodrome surface level is taken from the ATCC INFO box, where it is entered automatically (if the option USE CARMS is ticked) or manually (by a Controller). In case the altitude is automatically converted by the system, instead of the Letter A before the altitude an asterix «\*» appears.

At the time of the accident the AATMC was operable.

The recording system used was a multichannel sound and radar information recording – “Granit” recorder, MN 99302, manufactured in 1999, entry into service August 09, 1999, installed in the ATMC. Voice and radar data are stored on a hard magnetic disk, period of data storage 14 days, in accordance with Order No. 66 of the Ministry of Transportation, Russia issued on July 29, 1994. The “Granit” recorder contains three stations, and is a functional part of the AATMC “Alpha”, it is coordinated in time by the accurate time-metering system “Metronom”. The M1 and M2 stations (main and standby recorders) simultaneously record voice signals, as well as primary and secondary radar data. The third station (Readout station) serves to playback the recorded data directly from the hard disks of M1 and M2 stations and also from a removable hard disk followed by readout and printing of the data on paper. Last maintenance was performed on September 13, 2008, M-1, in accordance with the regulatory task cards.

The “Granit” recorder was operative. The records of voice as well as primary and secondary radar data of the accident flight were used in the course of the investigation.

### **1.9. Communications**

During the descent and approach the crew of the aircraft in turns maintained radio communication with the Regional ATCC of Perm (Sector “North”), Approach control and Ground Control of Perm Airport at VHF 135.1, 127.1 and 124.0 MHz respectively. There are no remarks on the quality of the communication.

### **1.10. Aerodrome data**

The Perm Aerodrome (Bolshoye Savino) is a joint base aerodrome, is included into a Class II Airport and can accept aircraft of Categories A, B, C, D, E.

The Perm Airport has a status of an airport of federal importance and is approved for international flights.

Aerodrome services are carried out on the basis of FAR “Certification requirements to legal entities who are engaged at aerodrome activities such as aerodrome service for civil aircraft” approved by Order No. 121 issued by FATA, Russia on May 06, 2000.

FSUE “Perm Airlines” has Certificate of Compliance No. ФАБТ А.00901 issued on September 14, 2007 and valid until May 04, 2010 for airport activities such as aerodrome support.

The aerodrome has Certificate of State Registry and Operational Acceptability valid until February 08, 2013 and IAC Certificate No. 073 A-M, valid until February 14, 2013.

The aerodrome is permitted for operations of IL-76T(TD), TU-154, TU-204, TU-214, IL-18, AN-12, YAK-42, TU-134, AN-32, AN-26, AN-30, AN-24, UL-114, B-737-300, B-737-400, B-737-500, B-737-800, A-319-100, A-320 and helicopters of all types, as well as aircraft of lower class.

It is a Class B aerodrome, having only one runway with artificial surface, 3200 by 49 meters. The runway entered into service in December 2005. Takeoff headings 212° M (RWY-21) and 32° M (RWY 03). Magnetic declination +14° east. Runway surface classification PCN 55/R/C/W/T.

**Note:** *Aerodrome class is determined by the runway class, while the runway class is determined by the length of the runway in normal conditions in accordance with Table 2.1 of the AOS-92.*

The runway condition on September 13, 2008 was checked at 1545 hrs before the accident. A record was entered into the Log of Airfield Condition of Perm Airport (Bolshoye Savino) The aerodrome was acceptable for flights, runway braking action was 0.5 on each third of the runway.

In order to perform the assigned tasks of managing the air traffic at Perm Airport the ATS consists of the following centers:

- Approach Control
- Ground Control;
- Subsidiary Ground Control-03;
- Aerodrome Control.

The combination of Control centers is in compliance with p. 5.14.1 of AOS-92 and p. 6.4.1 of CAFOM-85.

These are the borders of control transfer:

- To the Air Traffic Control of Perm (sector “North”) – at 5100 meters, over NDB “Mendeleyevo”.
- To the Ground Control when approaching RWY-21 – near base turn at 600 meters (distance and azimuth depend on the approach pattern).



The ATC procedures and duties are developed in accordance with the requirements of Standard Procedures for ATS in Russian Airspace approved by Order No. 108 issued on November 14, 2007 by the FTOA.

The Procedures for ATC, Ground Control, Approach Control and Subsidiary Ground Control at Perm ATCC were approved by the Head of Perm ATCC on February 05, 2008. The job description of the shift supervisor at the Approach and Ground Control and the job description of the ATC, Ground Control, Approach Control and Subsidiary Ground Control staff were approved by the Head of Perm ATCC on April 18, 2008.

The ATC stations are in the ATCC building: the Approach Control is in the joint ATC room, the Ground Control is in the Tower. The Subsidiary Ground Control is located with a landing course 32° because the Tower Controller cannot observe the airfield in this direction. The Shift Supervisor's station is on the Tower near the Ground Controller's station.

The Controllers' and Shift Supervisor's stations are fitted with equipment and manuals in accordance with p. 5.14.3 of the AOS-92 and List of Documents, Manuals, Visual Aids and Standard Equipment for ATC Personnel No. 6/II issued on September 21, 1998.

The Approach and Ground Controllers' stations are equipped with light and aural warnings for landing systems with landing course 032° – 212° M, locators and lighting system.

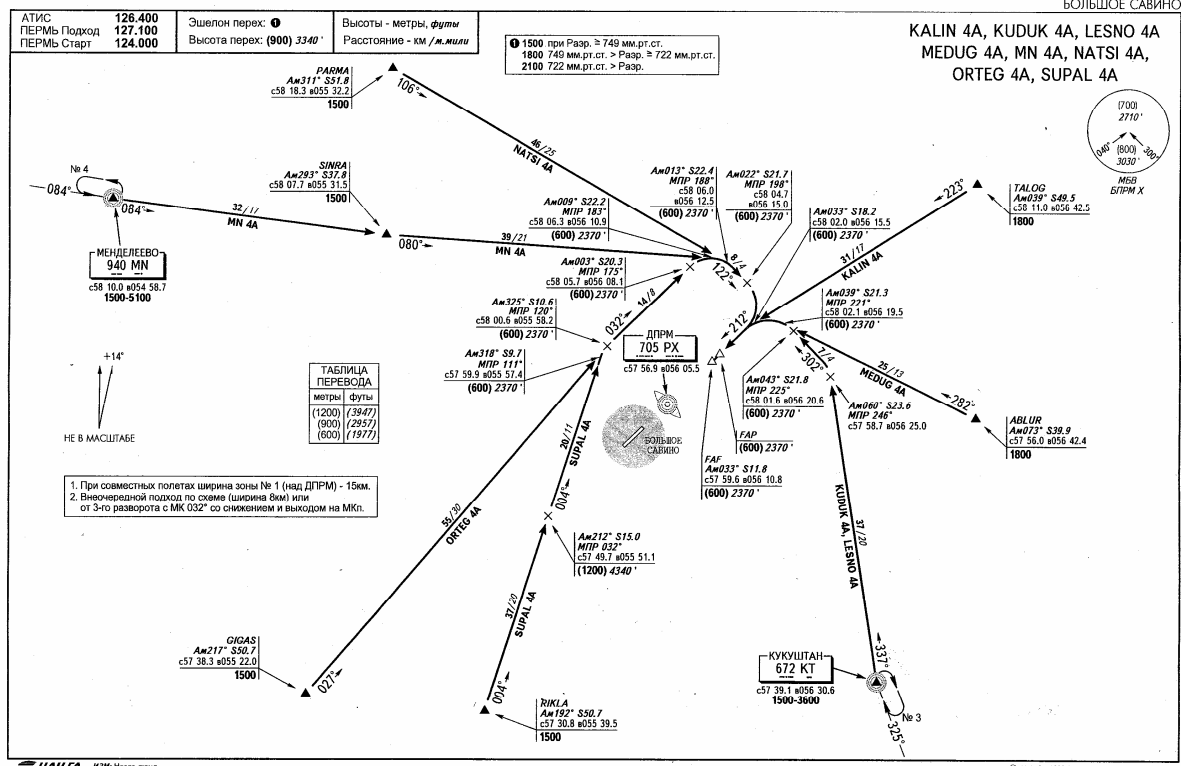
Below are approach patterns from the NDB "Mendeleyevo": MN 4A and MN 4B, as well as ILS approach pattern to RWY-21. It should be noted that there is a misprint in magnetic azimuth of FAF in the approach pattern, 45° instead of 32°. Similar misprint is made on the other approach pattern (outer marker for RWY 21).

ПОДХОД (По приборам с РЛК)  
ВЛГ: 21

14 фев 08

Б-3

ПЕРМЬ, РОССИЯ  
БОЛЬШОЕ САВИНО

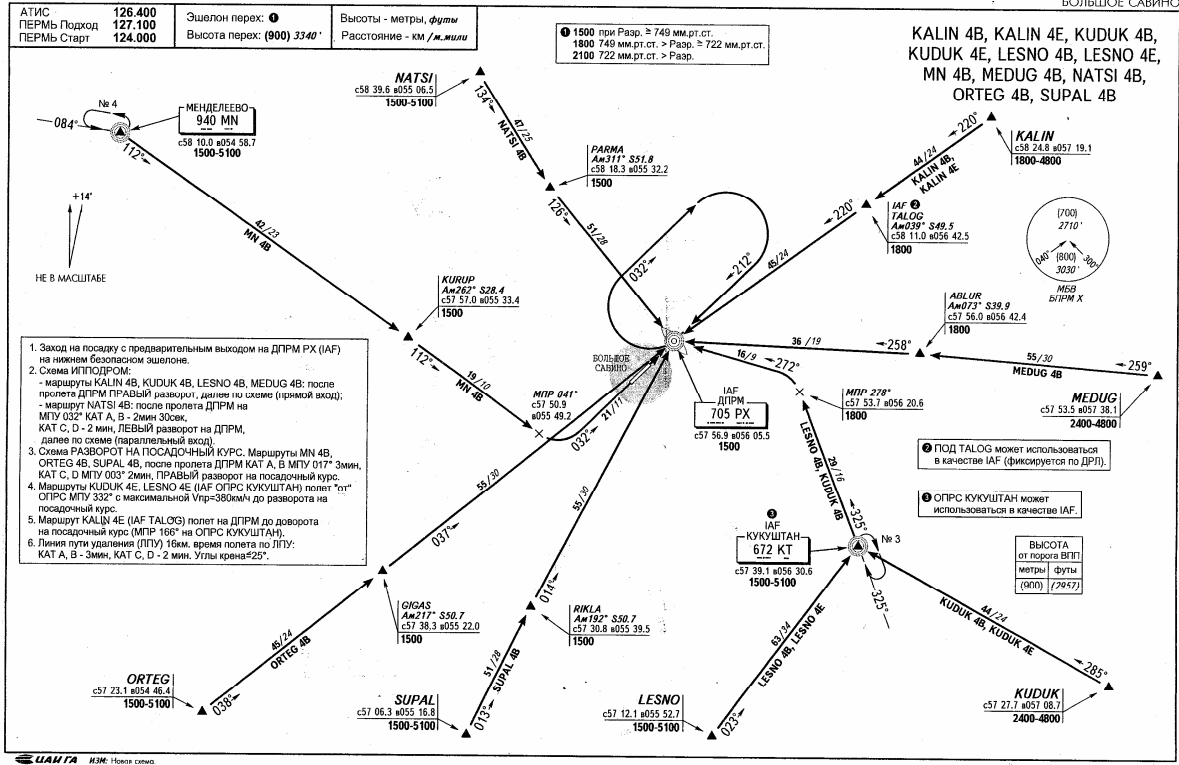


ПОДХОД (Стандартная схема)  
ВПП: 21

14 фев 08

Б-4

ПЕРМЬ, РОССИЯ  
БОЛЬШОЕ САВИНО



## ПОСАДКА

14 фев 08

И-1

АТИС 126.400  
 ПЕРМЬ Старт ② 124.000

ПЕРМЬ, РОССИЯ

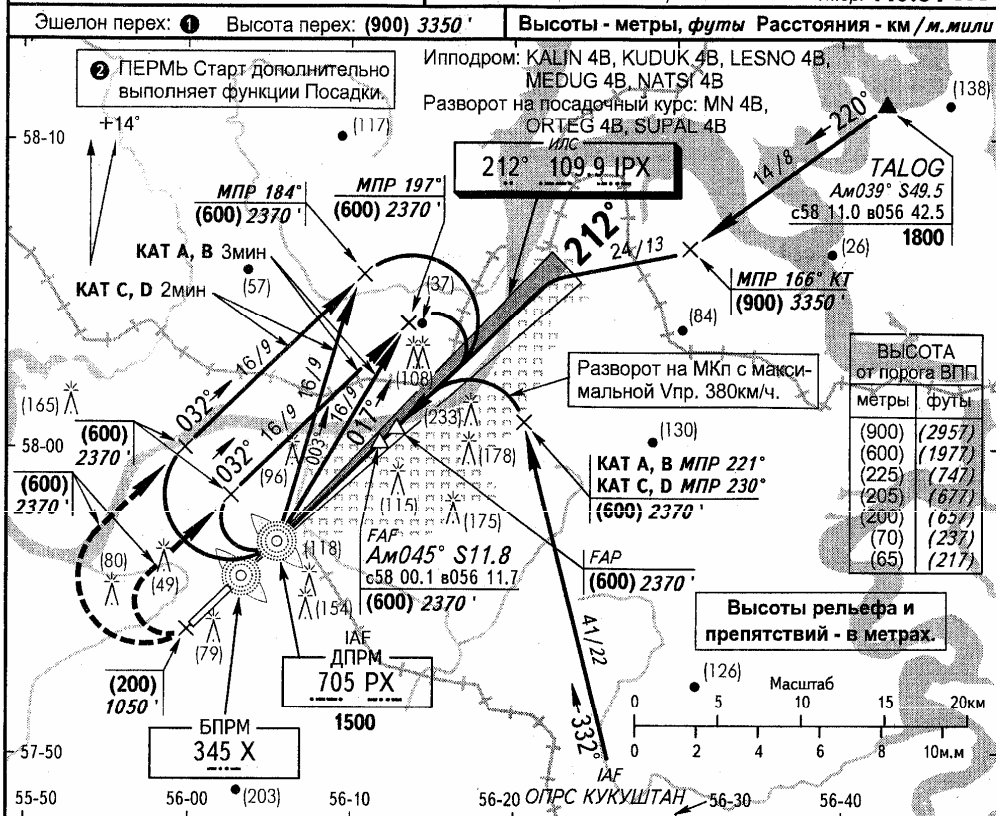
БОЛЬШОЕ САВИНО

ИЛС ВПП 21

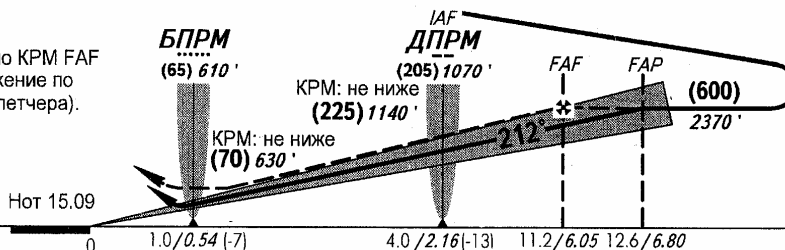
КРМ 109.9 IPX

① 1500 при Разр.  $\geq 749$  мм.рт.ст.  
 1800 749 мм.рт.ст.  $>$  Разр.  $\geq 722$  мм.рт.ст.  
 2100 722 мм.рт.ст.  $>$  Разр.

МБВ БПРМ X Назр. 123.0 404' Нпор. 119.81 393'



При заходе по КРМ FAF по ДРЛ (снижение по команде диспетчера).



УХОД НА ВТОРОЙ КРУГ: Набор (200) 1050'; ПРАВЫЙ разворот с набором (600) 2370' на МПУ 032°, далее по схеме захода.

Кат. ВС	ПОСАДКА ВПП 21															
	РМС 1	Нмб	КРМ		Нмб											
A	60x800	42	100x1500 721'		98											
B	593'	44														
C	70x900	47														
D	623'	50														
Верг.	60x600	42	100x1000													
Путевая скорость , км/ч		120	150	180	210	240	270	300	330	360	390	420	450			
FAF-МАРг 10190м , мин:с		5.10	4.05	3.24	2.55	2.33	2.16	2.02	1.51	1.42	1.34	1.27	1.21			
Вертик. скорость снижения градиент 5.2% , м/с		1.7	2.2	2.6	3.1	3.5	3.9	4.4	4.8	5.2	5.6	6.0	6.5			

ИЛС ВПП 21

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## 1.11. Flight Recorders

### Flight Data Recorder

The FDR installed on the aircraft was a crash-protected Sundstrand magnetic tape FDR , model 4100, that stores data for the latest 25 hours. When it was recovered from the accident site, the recorder was highly damaged, so it was necessary to use special readout devices, therefore the readout (copying) was done at BEA France. The analysis of the record was done at the IAC Russia.

The readout showed that the FDR was operative and it recorded all analogue parameters and ON/OFF signals in accordance with the established list. The only exception is the channels of control wheel and control column inputs. The channel for the control wheel input was faulty from the time of the aircraft's entry into service at Aeroflot-Nord<sup>27</sup>. The analysis of the record of control column inputs and comparison of the recorded values with the simulation results (see p. 1.16.2) showed that this recording channel recorded the control column inputs with a shift. The shift could be caused by the sensor case rotating in its mounting bracket, which could lead to the new zero reference of the recorded values. This defect had been revealed on Boeing 737 type previously<sup>28</sup>, and is connected with a structural feature of the sensors used. These sensors are hermetic and have a sealant between the rotating shaft and the sensor case. As time passes, the sealant loses its flexibility and leads to the increase of efforts needed to rotate the shaft above the limitations. If the shaft is rotated abruptly (the control wheel is deflected abruptly) and the sealant is not flexible it can lead to the case rotating in the mounting bracket, which can result in a new zero reference. This defect is only related to the parameter record and does not affect the flight control of the aircraft (such as CWS mode). This defect appeared on the VP-BKO long before the accident flight.

**Note:** *According to the Maintenance Procedures Guide of the aircraft (Task card 31-024-00-05), the record quality assessment shall be done during every IC-check.*

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<sup>27</sup> The earliest of the flights with a record available for the investigation group was dated May 29, 2008 (ferry flight from China to Russia).

<sup>28</sup> The same defect in recording control wheel position was revealed during the investigation of a Flash Air Boeing 737 accident (Egypt) of January 03, 2004.

The tape contains data on all the 8 tracks concerning the flights of the aircraft from September 11, 2008 to September 14, 2008 including the accident flight from Moscow to Perm, which is on track 4. The quality of the record is satisfactory.

### **Cockpit Voice Recorder**

Installed on the aircraft was a crash-protected Loral Fairchild CVR, model A100, which is a 4-track tape recorder (channels for the PIC, the Co-pilot, the area mike, and the time channel) and stores record of the last 30 minutes of the flight. When recovered from the accident site, it was highly damaged and demanded special readout equipment, therefore it was sent to the BEA facilities in France for the readout (copying). The transcript of the record and its analysis was done at the IAC. Total time of record is 31 minutes. The quality of the record is good. The voice identification was done by the flight personnel of Aeroflot-Nord.

### **Flight Data and Voice Data Synchronization with the ATC records**

In order to synchronize the data the ON/OFF radio exchange signals from the FDR were used as well as the corresponding phrases on the CVR and ATC recorder. UTC time on the ATC record was taken as basic<sup>29</sup>. The error in synchronization is not more than  $\pm 1$  sec. The synchronization revealed that the FDR record was 2-3 sec shorter than the CVR record, which includes the moment of the crash. The last seconds of the FDR record were not possible to readout due to heavy damage of the tape portion in contact with magnetic heads at the time of the ground collision.

## **1.12. Wreckage and Impact Information**

The accident site lies within the City of Perm, azimuth 60° magnetic, at a distance of 12.4 km from the ARP of Bolshoye Savino Aerodrome. The accident occurred on the railway almost perpendicular to the aircraft heading at the last phase of its flight (see Picture and plots below). The first impact was on a group of trees at the left embankment of the railway if viewed in direction of the station called "Ferma". The next impact was the upper ray of the pillar to which overhead cables were attached, which resulted in distorted ray and broken cables. The pillar was not damaged. The upper cable was not torn.

Lower on the embankment there is a track from the wing impact on the ground. An element of the left stabilizer was found closer to the rail line, and further, between the lines, were fragments of the cockpit with the window frame. The rails were distorted perpendicular to the aircraft track. One of the rails was thrown onto the opposite embankment. The heavier parts of the aircraft are cast over with a course of 45°-55°, including the main landing gear, one of the engines, etc. The second engine was lying below, near the rail line.

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<sup>29</sup> The FDR time is 9 seconds ahead of the ATC recorder time which was taken as a basis for synchronization.

The greatest number of structure elements was spread along the rail lines, in the sector with the azimuth of 28-40°, max distance from the spot of first impact ~150 meters, and in the sector with the azimuth of 55-85°, max distance ~175 meters from the spot of first impact.

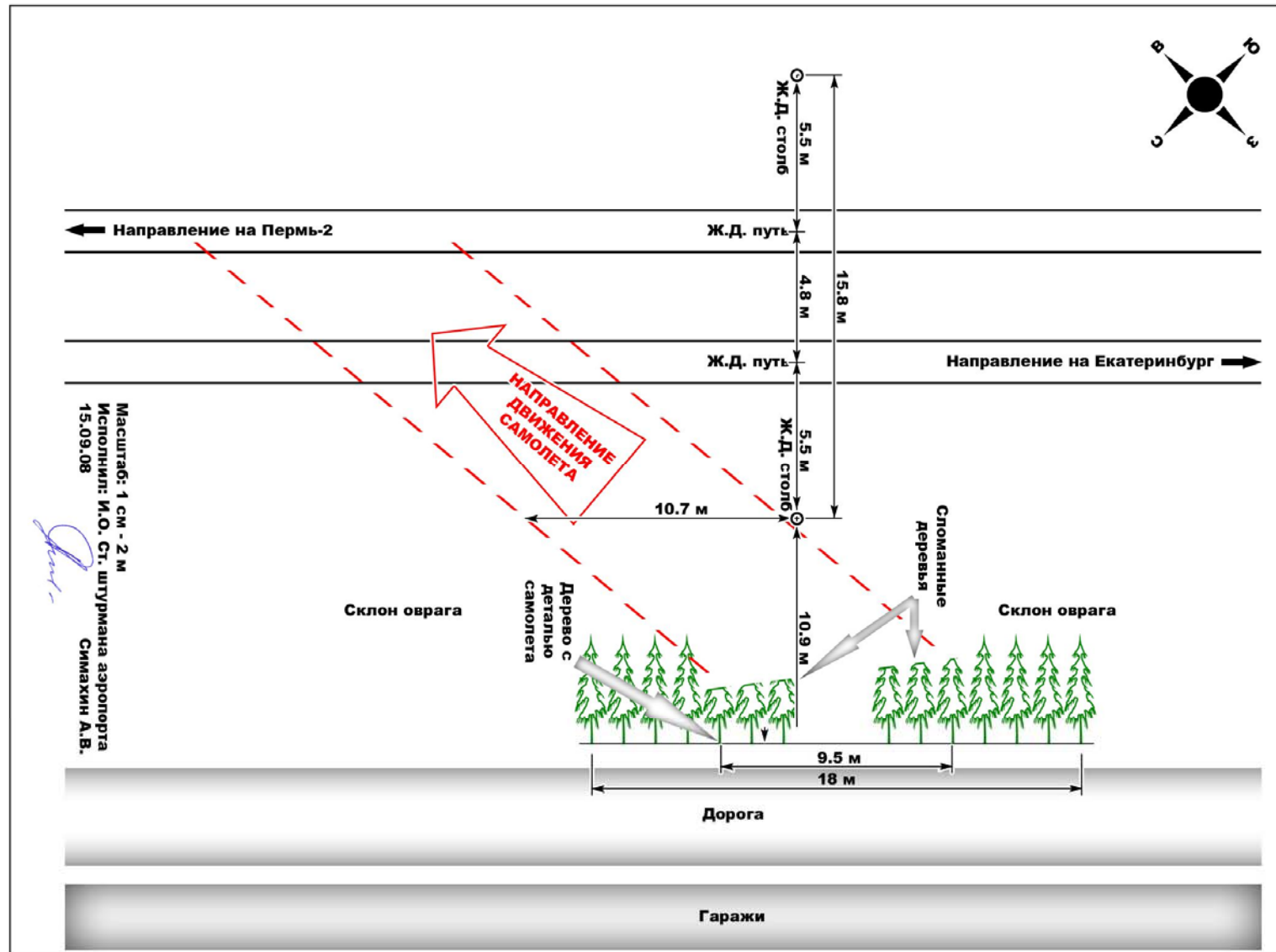
As a result of the accident, the airframe, engines and systems of the aircraft were totally destroyed. The wreckage was highly fragmented and partly burnt in the ground fire.

The aircraft was complete until the impact, judging by the absence of debris before the impact site along its track, and also by the closed outflow valve of the pressurization system.

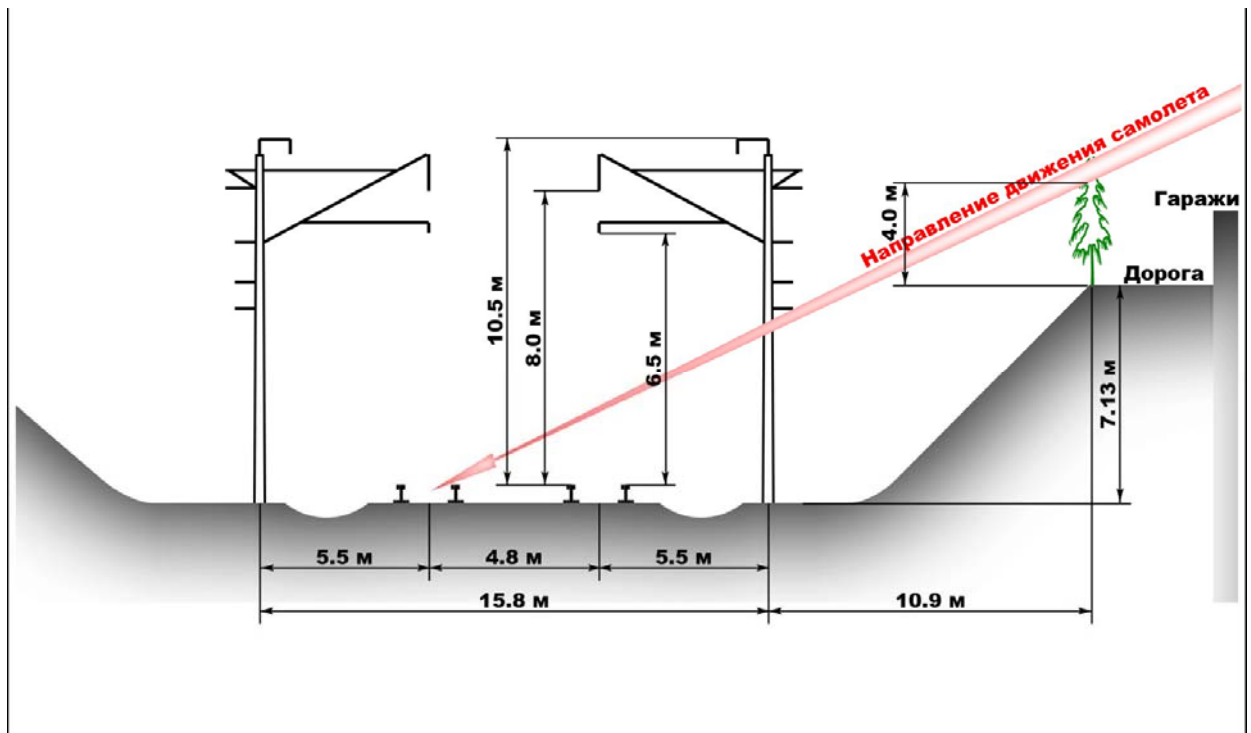
As the tree tops were not burnt and there was no evidence of fire in the air, it can be concluded that the fire started on the ground from the spilt fuel.











As it was important to recover the rail lines as soon as possible to resume the transportation, after the wreckage plots were drawn all the debris were evacuated to a guarded site on the territory of Perm Airport.

The study of the remaining fragments showed:

### **Fuselage**

The fuselage was highly fragmented. There were 14 identifiable large fuselage skins and sections (see Picture below). Eleven of these panels are located on the right side of the airplane and three are lower (belly) panels. There were no identifiable fuselage structures found for the left side of the fuselage.



### Remaining parts of the fuselage

Left and right wing boxes and the center section were shattered and fragmented. Upper and lower wing surfaces, ribs, rear spar and front spar were broken into individual parts. Landing gear beams were separated from the airplane. The picture below shows the damage of right wing box to center section attachment.



Right wing box to center section attachment

The lower 12 feet portion of vertical fin wreckage remained after the accident. The upper half was ripped and twisted almost 90 degrees to the right in relation to the lower half. All rudder hinges were ripped off except one on the upper portion. The vertical fin has evidences of severe burn in ground fire.



Remained portion of vertical fin



The only structure found on the left horizontal stabilizer was its tip.



Tip of left horizontal stabilizer

The right horizontal stabilizer was ripped in two pieces (see the pictures), which were twisted and crumbled from post-impact. Trailing edges were ripped off.



Inboard section of right horizontal stabilizer



Outboard section of right horizontal stabilizer

All the fuselage damage was caused by the impact forces.

### **Landing gears**

Nose gear assembly was separated from the fuselage. Left wheel was destroyed and ripped off the strut, the attaching nut was locked. Right main landing gear was deformed and had evidences of ground impact. The left wheel was separated; the right wheel had traces of ground fire. The left main landing gear was totally destroyed, the wheels and brakes ripped off, the shock strut inner cylinder was broken off in the lower portion, the damper is missing, the inclined strut was destroyed and ripped off. At the time of the impact the landing gears were extended.





Nose gear



Right main gear



Left main gear

All the damages of the landing gears resulted from the impact forces.

### **Flight Controls**

The flight controls and control linkages were totally destroyed; the central cockpit panel was damaged. The control wheels were destroyed.



Portion of a Control Wheel



All four outboard flap drive screws as well as all four inboard flap transmission assemblies were identified. The distance from the up-stop to the top of the gimbal was measured for each, which showed the Flaps 30 position.



Outboard flap tracks

The slat control system was totally destroyed. According to the identified right wing box fragments with the slat spindle carriages, the slats were completely extended.

Besides, the following fragments were identified:

- The two aileron power control units;
- Both aileron autopilot actuators;
- The two elevator PCU's;
- The two elevator autopilot servos;
- The elevator feel and centering unit and the feel computer;
- The stabilizer electric drive motor;
- 5 of the 10 spoiler actuators;
- The main and standby rudder PCU.

There is no evidence of failure of any of these units.

## Engines

**The left engine** was broken into two major sections:



- The fan containment case;
- The core of the engine including the fan disk, the LPC, the HPC, the combustor, the HPT and the LPT.



Left engine's fan case

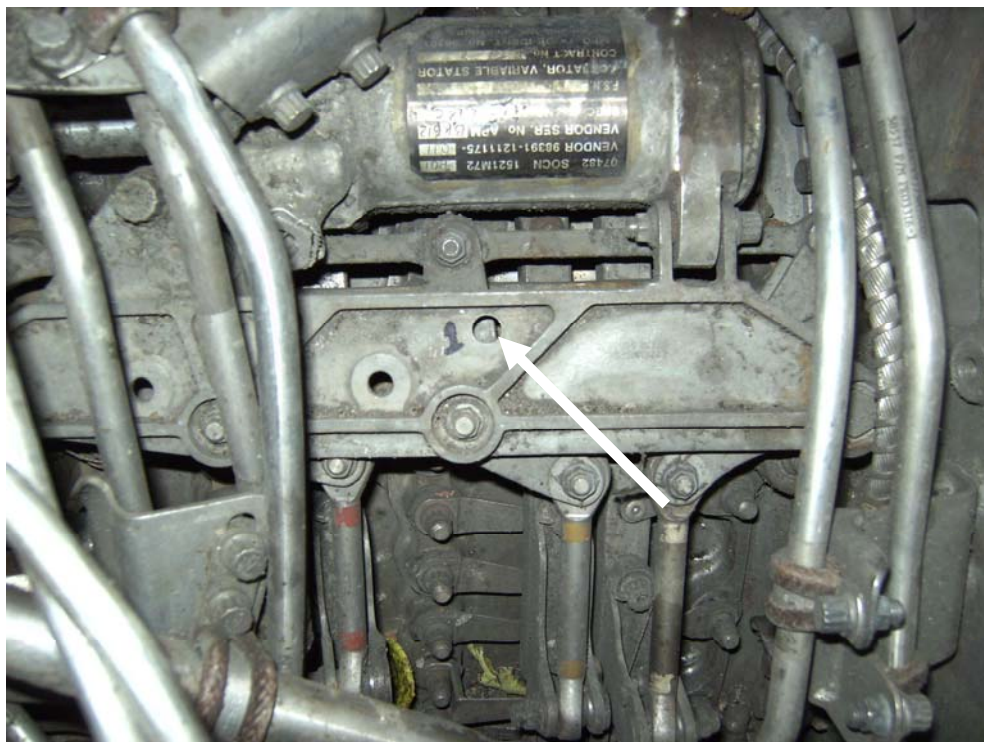


Left engine's core

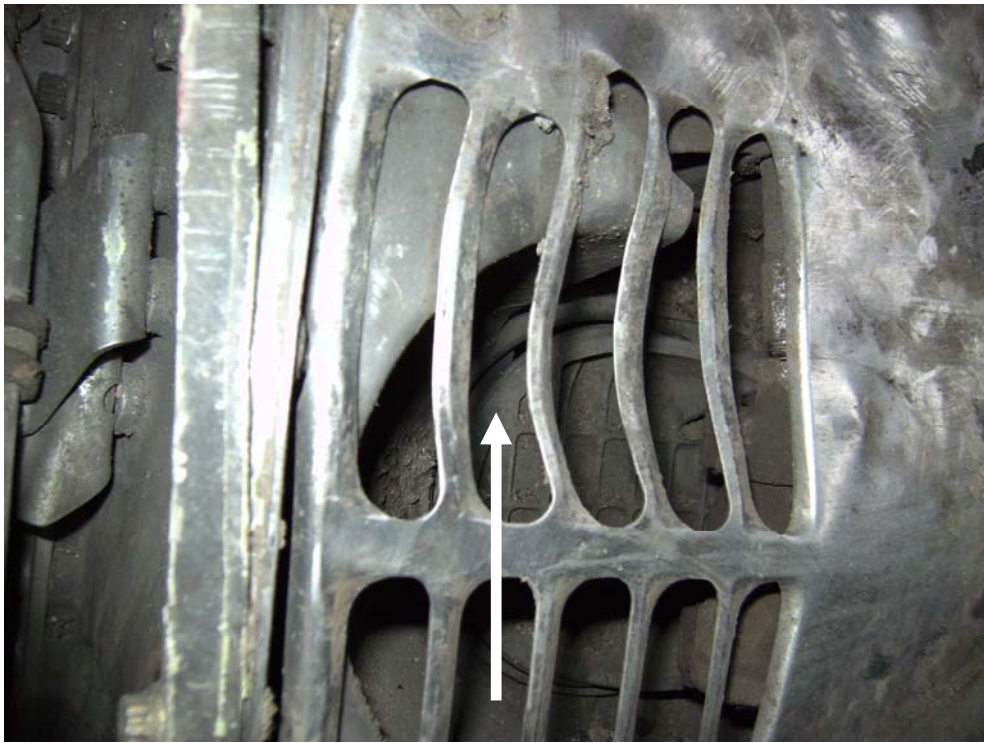
The fan case was separated from the engine, broken into two portions, deformed, no traces of fire, the stator blades were fractured or missing and had soot from ground fire. The pipes were destroyed, but the wiring had no evidence of in-flight fire.

The fan disk, LPC, HPC, combustor, HPT and LPT were not separated. Six fan blades were fractured and bent opposite the direction of engine rotation; the other thirty blades were separated at the root. The vanes and blades of the first, second and third stages of the LP compressor, were either separated at the root or were damaged and bent.

On the basis of the slight offset of the stator vane actuator lever arm rig pin hole and the inner rig pin hole in the synchronization rings, and also on the basis of the bypass valve in partly closed position (see pictures below) it can be assumed that this engine was operating at high power at the time of the impact.



Left engine - stator vane actuator lever arm rig pin hole



Left engine – bypass valve position

The rotor and stator blades of the 3<sup>th</sup> and 4<sup>th</sup> stage of the LP turbine are distorted, partly missing or fractured at the root.

The nozzles were distorted, crushed and fractured.

The gearbox, generator, MEC, hydraulic pump, ignition boxes, starter, heat exchanger were separated from their mounting brackets, distorted and fractured.

There were no evidences of thermal distress, in-flight fire or uncontainment or bird residue on the examined parts of the left engine.

**The right engine** was recovered in four sections:

- The fan case;
- The fan and compressor;
- The combustor and the high pressure turbine;
- The low pressure turbine and the exhaust duct.





Right engine's fan case



Right engine's fan and compressor



Right engine's combustor and high pressure turbine



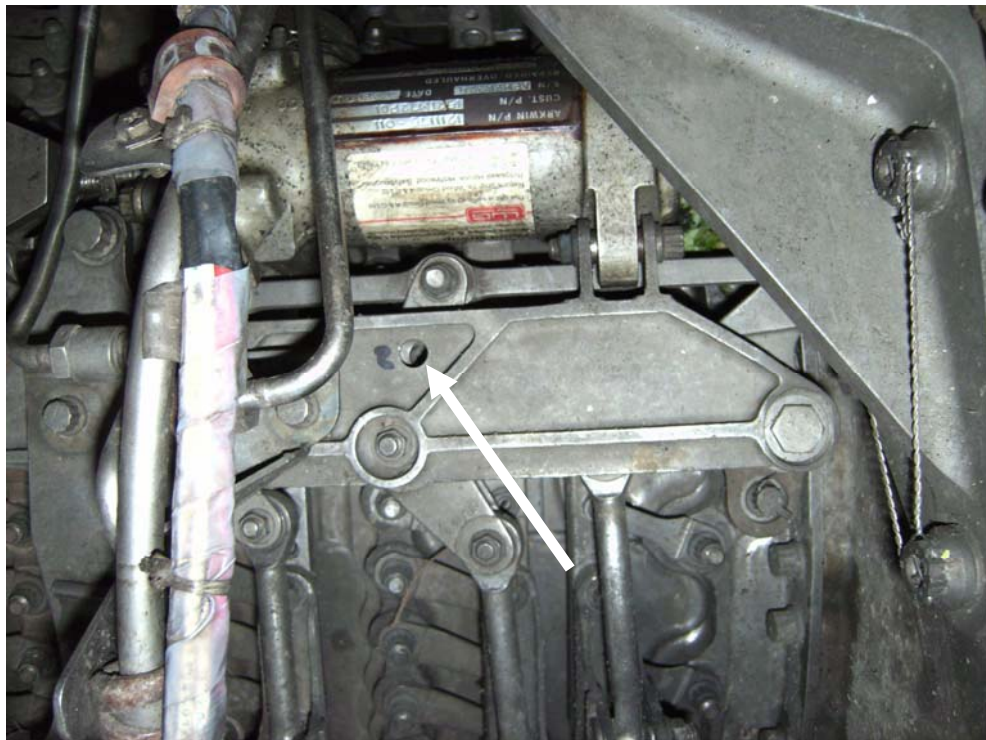
Right engine's low pressure turbine, exhaust duct and exhaust cone

The fan case was crushed and distorted. Twenty-two stator blades were separated. The remaining blades were deformed and some were sooted by the ground fire. There was evidence of thermal damages on fan acoustic panels, the fracture surfaces were also affected, which means they were burnt after the ground impact. The wiring insulation on the outside of the fan case did



not have any traces of burning. The units on the fan case were separated from their mounts except the oil filter and two ignition boxes. The ducts and wiring on the fan case are distorted and torn.

The fan and compressor were highly damaged. Thirteen fan blades are totally separated. The remaining 23 blades are either broken or crushed and bent in the same direction opposite to the engine rotation. The variable stator vane actuator arm rig pin hole was aligned with the other rig pin hole. On the basis of this alignment and also of the bypass valves position (fully closed – see pictured below), it can be concluded that at the time of the impact the right engine was operating at almost full thrust.



Right engine - stator vane actuator lever arm rig pin hole



Right engine – bypass valve position

Some low pressure compressor first stage stator blades were disengaged at their roots and bent. The engine shaft was twisted and fractured. The ducts around the HPC compressor were bent and partly separated, the wiring insulation did not have any evidences of fire or thermal distress.

The combustor case and the high pressure turbine case were buckled, but there were no signs of thermal distress of the stator or rotor blades. Most of the blades fractured about 3 cm from the blade root platform due to the impact. The fuel lines and fuel nozzles were distorted and crushed.

The low pressure turbine and the nozzles were distorted, with tears on the nozzles. The drive shaft was crushed and twisted, its roller bearing was crushed and the rollers missing.

All the low pressure turbine first stage rotor blades were crushed, but had no thermal distress. The turbine case was crushed, the ducts torn and crushed.

The gear box, CSD generator, oil tank, MEC, hydraulic pump, air starter and heat exchanger were separated from the engine, crushed and distorted.

The right engine did not have evidences of thermal distress, fire, in-flight uncontainment or bird residue.

The examination of the powerplant fire protection system showed that the engine fire extinguishers were crushed, the cartridges were not discharged, and the membranes are intact.

The aircraft hydraulic, fuel and other systems as well as the avionics were totally destroyed. The FDR data show no ON/OFF signals or parameters that would indicate any failure of engines or other aircraft systems.

### **1.13. Medical and Pathological Information**

#### **Medical Information (according to medical logbook)**

**The PIC passed:**

- Medical examination at the Main Medical Office of Aeroflot-Nord – November 23, 2006, November 27, 2007. In accordance with Article 52 Group II CAFARMS-2002 was accepted fit for flying as a pilot.
- Semiannual medical examination by an aviation doctor of the Aeroflot-Nord Medical Office on June 21, 2007, May 22, 2008 (conclusion expertise): allowed to fly.
- Examination by an ophthalmologist of the MMO on June 21, 2007, May 22, 2008: allowed to work as a pilot.

The examinations revealed the following: myopic astigmatism (0.5 D, OD) with a vision of 1.0. Hypermetropic astigmatism (0.5 D, OS), with a vision of 0.9 corrected to 1.0. Overweight (Article 52, Gr. II of CAFARMS-2002).

The terms of the annual and semiannual medical examinations, as well as the completeness of the examinations and the dynamic medical observations are in compliance with the CAFARMS-2002. Within the two last years no negative dynamics in the PIC's health was noticed.

Psychological status<sup>30</sup>:

- January 10, 1995: the level of professionally essential qualities lies within Group I, recommended for transition in the first place.
- According to the expertise of June 21, 2006 (with the purpose of transitioning to a new aircraft type): positive professional motivation, medium level of basic cognitive functions. Stable psyche, sufficient level of compensation and adaptation capabilities. The expert did not reveal any psychopathological changes.

Bad habits – smoking. Did not abuse alcohol or medications.

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<sup>30</sup> These data were given by the medical group after analyzing the pilot's medical logbook. The findings of the independent expertise made on the basis of the psychological examinations of the PIC are given in the investigation file.



Within the last two years did not have any diseases or injuries, suspension from flights due to the medical examinations, or changes in health and physical condition. He did not consult any medical centers for medical aid.

**The co-pilot passed:**

- Medical examination at the Main Medical Office of Aeroflot-Nord on May 23, 2007: according to Article 38.2 Gr. II CAFARMS-2002 was admitted fit for flying as a pilot; on May 23, 2008: Gr. II CAFARMS-2002 fit for flying as a pilot (conclusion expertise).
- Semiannual medical examination by an aviation doctor of the Aeroflot-Nord Medical Office on November 27, 2007: allowed to fly.

On November 14, 2007 during a semiannual examination, the ECG first showed slight distortion of the repolarization phase. On November 29, 2007 he was allowed to fly after the extra examination (test taken with potassium chloride). No negative dynamics was found at the ECG made on May 20, 2008 and the veloergometry test made on May 20, 2008. The annual medical examination expert concluded on May 23, 2008: "Fit. Dispensary Observation Group I".

The terms of the annual and semiannual medical examinations, as well as the completeness of the examinations and the dynamic medical observations are in compliance with the CAFARMS-2002. Within the two last years no negative dynamics in the co-pilot's health was noticed.

Psychological status<sup>31</sup> on the basis of the psychological expertise conducted on November 15, 2007: positive professional motivation. Medium level of the main cognitive functions. Psychologically stable, sufficient level of compensation and adaptation capabilities. The expert did not reveal any psychopathological changes.

The co-pilot did not smoke and did not abuse alcohol or medications.

Within the last two years did not have any diseases or injuries, suspension from flights due to the medical examinations, or changes in health and physical condition. He did not consult any medical centers for medical aid.

**Preflight medical examination**

All the crew members passed complete preflight medical examination at the Medical Office of Aeroflot – Russian Airlines at Sheremetyevo Airport on September 13, 2008 at 1948 hrs, gave no complaints and were allowed to fly without any limitations.

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<sup>31</sup> These data were given by the medical group after analyzing the pilot's medical logbook. The findings of the independent expertise made on the basis of the psychological examinations of the PIC are given in the investigation files.

**Note:** *During the preflight medical examination the following is checked: pulse, blood pressure, mouth cavity, general condition, presence or absence of any complaints.*

### **Pathological, Toxicological, Biochemical and Other Investigations**

A copy of the Forensic Medical Expertise Conclusion No. 285 of November 07, 2008 was attached to a letter from the Investigator for Cases of Special Importance, Prosecution Investigatory Committee, Russian Federation. The expertise was executed at the State Health Care Institution of Special Type “Perm Regional Board of Forensic Medical Expertise”.

On September 15-16, while the body fragments were examined, probes were taken and put into penicillin bottles which were sealed hermetically with aluminum caps. At the same time the forensic chemical test was conducted to check 16 of the fragments for alcohol content (including 15 adult body fragments). In all of them no ethyl alcohol was contained.

The main forensic chemical investigation of the body fragments was conducted in October 2008, when the genetic expertise findings were received concerning the belonging of the body fragments to the people who died in the accident.

As a result of the accident the bodies were highly fragmented and suffered abrupt loss of blood, it was not possible to conduct the conventional chemical analysis of blood and urine. Therefore alternative material – muscular tissue – was taken for the examination. Muscles are quite resistant to decomposition and the content of alcohol in them is considered more stable than in other organs or tissues. Typically, more reliable results are received from examinations of body portions with significant amount of muscular tissue, such as hips.

Statistical assessment methods were used in the course of the examination to study the dynamic processes (new growth or splitting) and toxicodynamics of ethanol both in isolated samples (those in penicillin bottles) and in larger body fragments.

The examination included the following stages:

1. Examination of the sample pilots’ body fragments taken in September.
2. Comparative examination of some of these fragments taken in October.
3. Examination of the sample flight attendants’ body fragments taken in September and comparative examination of part of these fragments taken in October.
4. Comparative examination of the sample eight children’s body fragments taken in September and October.

5. Secondary examination of sample adult passenger's body fragments (primary examination was on September 15-16).
6. Analysis of the findings, conclusions.

The following conclusions were drawn on the basis of the examination:

- The absence of ethyl alcohol found by the chemical analysis of 15 adult body fragments made on September 15-16 assumes that there was no outside contamination of the fragment samples with ethanol.
- The average level of endogenous alcohol that appeared in the body fragments of passengers who did not consume alcohol before the flight during the storage period was 0.62 ‰ in isolated samples and 0.23 ‰ in other fragments.
- The average level of ethanol in isolated fragments (1.08 ‰) and fragment parts (1.19 ‰) of the PIC's body are significantly higher (by 0.46 ‰ and 0.96 ‰ respectively) than the abovementioned average values, which confirms the presence of ethyl alcohol in his body before death.

According to the data in medical manuals, such content of alcohol (0.46 ‰ and 0.96 ‰) in the muscular tissue which was not subject to evident postmortem processes (autolytic, bacterial or thermal), is correspondent to the content of 0.53‰ (0.52 ‰ - 0.55 ‰) and 1.12 ‰ (1.09 ‰ - 1.14 ‰) in human blood.

- The average content of alcohol in isolated samples and in body fragments of other crew members (the co-pilot and the flight attendants) did not exceed the average level of newly generated alcohol, which assumes the absence of ethyl alcohol in their bodies before death.
- The forensic chemical examination of the crew members' body fragments (pilots and flight attendants) did not reveal any narcotic, psychotropic or hard substances.

#### **1.14. Survival Aspects**

On board were 82 passengers, 2 pilots and 4 flight attendants. At the time of the impact the IAS was ~470 km/h, with nosedown pitch attitude of ~60°. As a result of the impact the aircraft was totally destroyed. It was impossible to survive in this accident.

#### **1.15. Fire and Rescue Operations**

At 0511 hrs local time the aerodrome shift supervisor raised an alarm with regard to the loss of communication with the aircraft and its disappearance from the radars. At 0512 hrs the search and rescue team and freelance rescuers were called for. All the rescue groups arrived on

time. While the search and rescue group was gathering, and after the shift supervisor had determined the supposed accident site, it was decided to use the search and rescue aircraft on duty. At 0513 the RSRB group on duty started loading the Mi-8 RA-24706 helicopter operated by Gelix Airline. At the same time the search and rescue group was being formed to go to the search area. While the group was formed, information was received from the Emergency Service about the accident site – TransSib Railway in the vicinity of a dwelling house (56 Samoletnaya Str.). On the basis of the received information and after consulting the shift supervisor, it was decided against using the helicopter for the search and rescue operations. The RSRB group on duty was included into the search and rescue group.

The SRG included:

1. RSRB team:
  - chief paratrooper-instructor;
  - rescue paratrooper;
  - rescue paratrooper group doctor.
2. Fire brigade on a AA-8-55 truck registered o279TH including:
  - SR team;
  - fire fighter;
  - driver.
3. AMB team on a mobile communication vehicle WAZ 3909 registered 0914xy including:
  - AMB shift supervisor;
  - shift engineer;
  - technician.
4. Security team on a WAZ Patriot registered x551ky including:
  - security shift supervisor;
  - security inspector;
  - driver.
5. Transport police officers (2 persons).
6. A group on an off-road KAMAZ 43101 registered c653ar, including:
  - driver;

- rescuer;
- ground SR team;
- load master.

At 0537 hrs the search and rescue group left the airport for the accident site. At 0557 hrs they arrived at the accident site and started searching the area trying to find probable survivors to help them and also in search of the flight recorders. By that time, rescuers from the regional rescue service, fire fighters from the Russian Emergency Service and police officers had already been present at the accident site. During the search and rescue operations the weather was cloudy with slight drizzle, there was no natural lighting. The search and rescue group searched the accident site and adjacent area of 300x500 meters. During the search they found numerous aircraft debris and body fragments. No survivors were found. The flight recorders were not found. During the search and rescue operations they used the intra-airport radio stations at the frequency of 164.150 MHz. The seats on fire were located and extinguished by the fire fighters from the Emergency Service and there was no need to apply to the fire brigade of the FSUE “Perm Airlines”. After the supervisor of the Emergency Service headquarters decided to stop the search operations until it gets lighter and until the prosecutors arrive, it was decided that the fire brigade, the search and rescue group and the PTS group and the AMB team should return to their normal locations to resume their service. The accident place was cordoned off by the police, guaranteeing the custody of the flight recorders in case they were found.

## **1.16. Tests and Research**

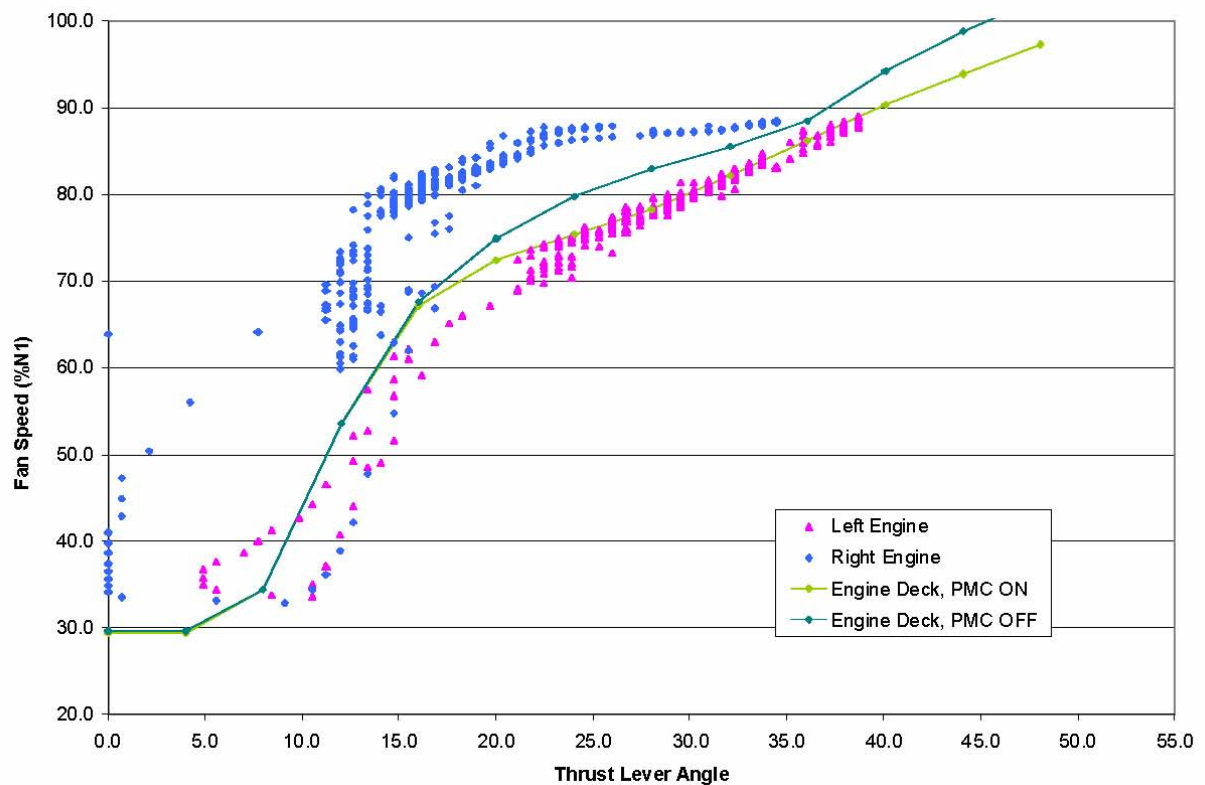
### **1.16.1. Powerplant and Autothrottle**

With regard to the difference in engine trimmings (see Section 1.5) and the record in the logbook concerning the autothrottle failure, the investigation team had to analyze the joint operation of the powerplants and autothrottle.

The examinations conducted revealed that the throttle stagger was the most significant at part power. At takeoff mode there was virtually no stagger while at idle there was no stagger at all.

The thrust split in the accident flight peaked at approximately 4700 lb (~2130 kg).

The chart below shows the nominal N1 to TLA function for the PMC ON and OFF, and also the actual values for the left and right engine. It is clear from the chart that the left engine was working within the operational limitations (compared to the nominal PMC ON), while the right engine N1 (and thrust) were significantly higher than standard for the part power TLA.



The TLA analysis showed that the trim of engine control linkage was within the service limits. The idle and takeoff stops were within the established limits.

The engines' history revealed that this kind of N1 split (throttle stagger) had been noticed before. Below are some data from the left and right engines' history, according to which staggering was adjusted twice on the left engine (1993 and 2003) and once on the right engine (in 2004). The troubleshooting consisted in replacement or adjustment of the MEC and also in replacement of the temperature sensor.

Event Date	AC Tail No	Pos	PSE Cause	ETSN	ECSN	AIRLINE
9/9/1992	LN-BRW	2	Engine delivery	0	0	SAS NORWAY (BRAATHENS)
9/27/1992	B-2591	2	Engine delivery	0	0	XIAMEN AIRLINES
5/8/1993	B-2591	2	Fuel filter clog light; replaced filter	0	0	XIAMEN AIRLINES
8/25/1993	B-2591	2	<b>Throttle stagger</b> ; MEC replaced	2890	2160	XIAMEN AIRLINES
8/31/1993	B-2591	2	<b>Throttle stagger</b> , T2 sensor was faulty	2813	2097	XIAMEN AIRLINES
12/25/1994	B-2591	2	MEC leak, installed SN 80048	6083	4377	XIAMEN AIRLINES
3/3/1995	B-2591	2	No start; replaced ignition lead	6749	5036	XIAMEN AIRLINES
3/23/1995	B-2591	2	Engine removed for engine stagger program	6712	5136	XIAMEN AIRLINES
8/30/1997	B-2592	2	Engine removed for customer convenience	10025	8180	XIAMEN AIRLINES
11/13/1997	B-2975	2	Fuel pump leak	0	0	XIAMEN AIRLINES
7/30/1999	B-2975	2	No start; replaced ignition lead	7511	5885	XIAMEN AIRLINES
10/28/2000	B-2975	2	HPC blade damage; removed for performance restoration	17502	13563	XIAMEN AIRLINES
9/13/2003	B-2656	1	Pilot squawked that throttle stagger 1.5 knobs at 50%-60% N1 speed, left thrust lever advance. Performed engine diagnostic ground test, with PMC off part power run, left engine N2% was 92.4%, which was lower than the target 93.4%. Did Part Power adjustment one turn clockwise on MEC, engine run test showed no throttle stagger. No more pilot squawk in flights the next day.	22073	17390	XIAMEN AIRLINES
9/28/2003	B-2656	1	Slow start; replaced CIT sensor	22213	17512	XIAMEN AIRLINES
4/26/2004	B-2656	1	Start EGT high; performed water wash	24023	18985	XIAMEN AIRLINES
7/1/2004	B-2656	1	Fuel leak from HPTCCV	24636	19484	XIAMEN AIRLINES
7/14/2004	B-2656	1	Start EGT high, troubleshooting performed NCF	24760	19578	XIAMEN AIRLINES
8/5/2004	B-2656	1	Start EGT high, replaced MEC; installed WYG80281	24958	19740	XIAMEN AIRLINES
8/31/2004	B-2656	1	Removed for LLP and performance restoration	25203	19948	XIAMEN AIRLINES
7/26/2005	B-2529	1	No start; replaced igniter	27121	21452	XIAMEN AIRLINES
4/30/2006	B-2529	1	Fuel leak from HPTCCV	29537	23238	XIAMEN AIRLINES
8/15/2006	B-2529	1	Start EGT high, replaced MEC; installed ?	30504	23968	XIAMEN AIRLINES
10/27/2006	B-2529	1	No start; replaced ignition lead	31082	24420	XIAMEN AIRLINES
12/15/2007	B-2529	1	Engine removed for customer convenience	34508	26649	XIAMEN AIRLINES
3/18/2008	B-2591	1	Aircraft lease returned	34383	26879	XIAMEN AIRLINES
9/14/2008	VP-BKO	1	Aeroflot event	36400	27353	AEROFLOT-NORD

### Left engine history

Event Date	AC Tail No	Pos	PSE Cause	ETSN	ECSN	AIRLINE
10/8/1992	B-2591	1	Leaking starter pad oil seal	0	0	XIAMEN AIRLINES
10/23/1992	B-2591	1	No start; replaced igniter	0	0	XIAMEN AIRLINES
7/16/1995	B-2591	1	Fuel pump leak	7621	5521	XIAMEN AIRLINES
10/28/1995	B-2591	1	Leaking starter pad oil seal	8434	6140	XIAMEN AIRLINES
2/28/1996	B-2591	1	Vibration, fan trim balanced	9110	7010	XIAMEN AIRLINES
3/11/1996	B-2591	1	Fuel pump leak	9320	7171	XIAMEN AIRLINES
3/26/2000	B-2591	1	Engine removed for performance restoration	20200	16501	XIAMEN AIRLINES
2/18/2002	B-2529	1	Vibration, replaced AVM	23835	19322	XIAMEN AIRLINES
6/4/2003	B-2529	1	High EGT on start, <b>MEC replaced; WYG80131 installed</b>	27322	22183	XIAMEN AIRLINES
1/23/2004	B-2529	1	Pilot reported <b>throttle stagger</b> during descent with left throttle advance. Post flight, the QAR data confirmed throttle stagger at 74% N1. Performing Part Power engine run test, left engine Part power was found slightly beyond the manual limit. Adjust part power on MEC, engine run test OK. No more pilot squawks.	29307	23746	XIAMEN AIRLINES
4/4/2004	B-2529	1	Vibration, installed FFCCV sensor	29880	24193	XIAMEN AIRLINES
4/27/2004	B-2529	1	High EGT on start, MEC SG adjustment	30091	24367	XIAMEN AIRLINES
7/20/2004	B-2529	1	Engine removed for performance restoration	30829	24941	XIAMEN AIRLINES
6/2/2005	B-2656	2	No start; replaced igniter	32910	26485	XIAMEN AIRLINES
8/7/2005	B-2656	2	Replaced ignition lead due to burnt tip	33482	26927	XIAMEN AIRLINES
8/27/2005	B-2656	2	EGT indication, chaffed EGT wire	33668	27057	XIAMEN AIRLINES
12/16/2005	B-2656	2	Vibration, relubed fan blades	34633	27788	XIAMEN AIRLINES
4/23/2006	B-2656	2	Vibration indication erratic, replaced indicator	35756	28598	XIAMEN AIRLINES
5/2/2006	B-2656	2	No start; replaced igniter and exciter	35837	28663	XIAMEN AIRLINES
8/2/2006	B-2656	2	High EGT on start, <b>MEC replaced; WYG80228 installed</b>	36526	29195	XIAMEN AIRLINES
9/15/2006	B-2656	2	Frequent no starts; replaced start switch	36923	29496	XIAMEN AIRLINES
8/5/2007	B-2656	2	HPTCCV leaking; replaced	39781	31667	XIAMEN AIRLINES
8/22/2007	B-2656	2	High EGT on start, MEC SG adjustment	39917	31763	XIAMEN AIRLINES
9/26/2007	B-2656	2	Bird strike; no damage	40143	31938	XIAMEN AIRLINES
10/17/2007	B-2656	2	High EGT on start, rerigged VSV	40293	32067	XIAMEN AIRLINES
3/18/2008	B-2591	2	Engine removed and installed on aircraft B-2591	41341	32499	XIAMEN AIRLINES
3/18/2008	B-2591	2	Aircraft B-2591 lease returned	40935	32556	XIAMEN AIRLINES
9/14/2008	VP-BKO	2	Aeroflot event	41951	33030	AEROFLOT-NORD

### Right engine history

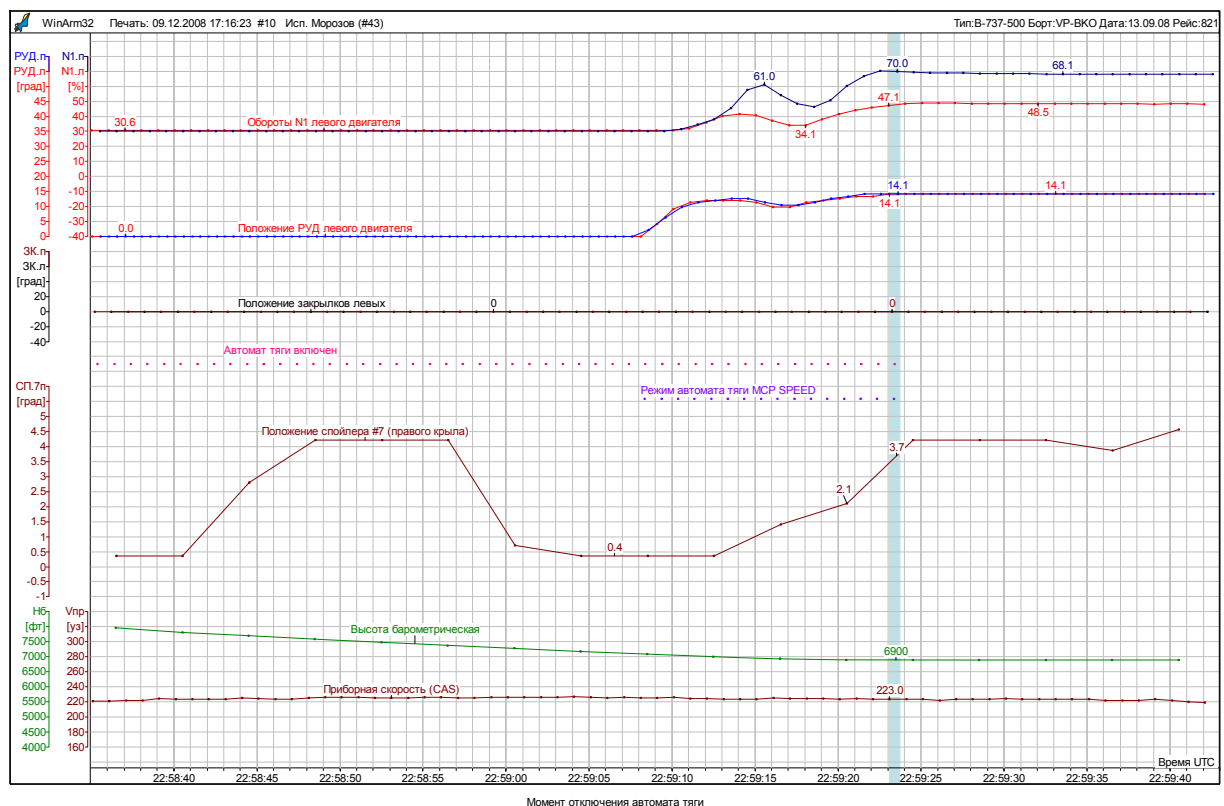
Thus, the probable cause of the split could be faulty power trim adjustment of the MEC or a faulty temperature sensor (for example T2).

The autothrottle operations analysis showed that it was operative and before the disengagement it adjusted the required engine thrust as per design. The autothrottle has specific design features to provide its operation in the conditions of thrust split. After 40%N1 is reached by both engines the autothrottle matches the N1 by staggering the throttles, in order to reduce the required rudder trim and consequently to reduce the aircraft drag. This function does not work below 40%N1.

**Note:**

*In accordance with AMM 71-00-42 the limit for a throttle stagger with the matched N1 and PMC ON is one knob, which makes 1.2 inches or 6° TLA. The accuracy of TLA adjustment at part power is normally 0.06 inches.*

During cruise flight the autothrottle is controlled by the Cruise Split Monitor. The autothrottle is automatically disengaged if all of the following occurs simultaneously: flaps are less than 12.5°, the thrust split is more than 700 lb and any wing spoiler is extended more than 2.5°. These conditions were met at 22:59:23, when the autothrottle was disengaged automatically.





### 1.16.2. Flight Simulation

In order to compare the stability and controllability of the aircraft in the accident flight with the aircraft type parameters, and also to assess the external forces affecting the aircraft, a simulation match of the flight and a kinematical analysis of the FDR data were executed. The principle patterns of both methods are below:

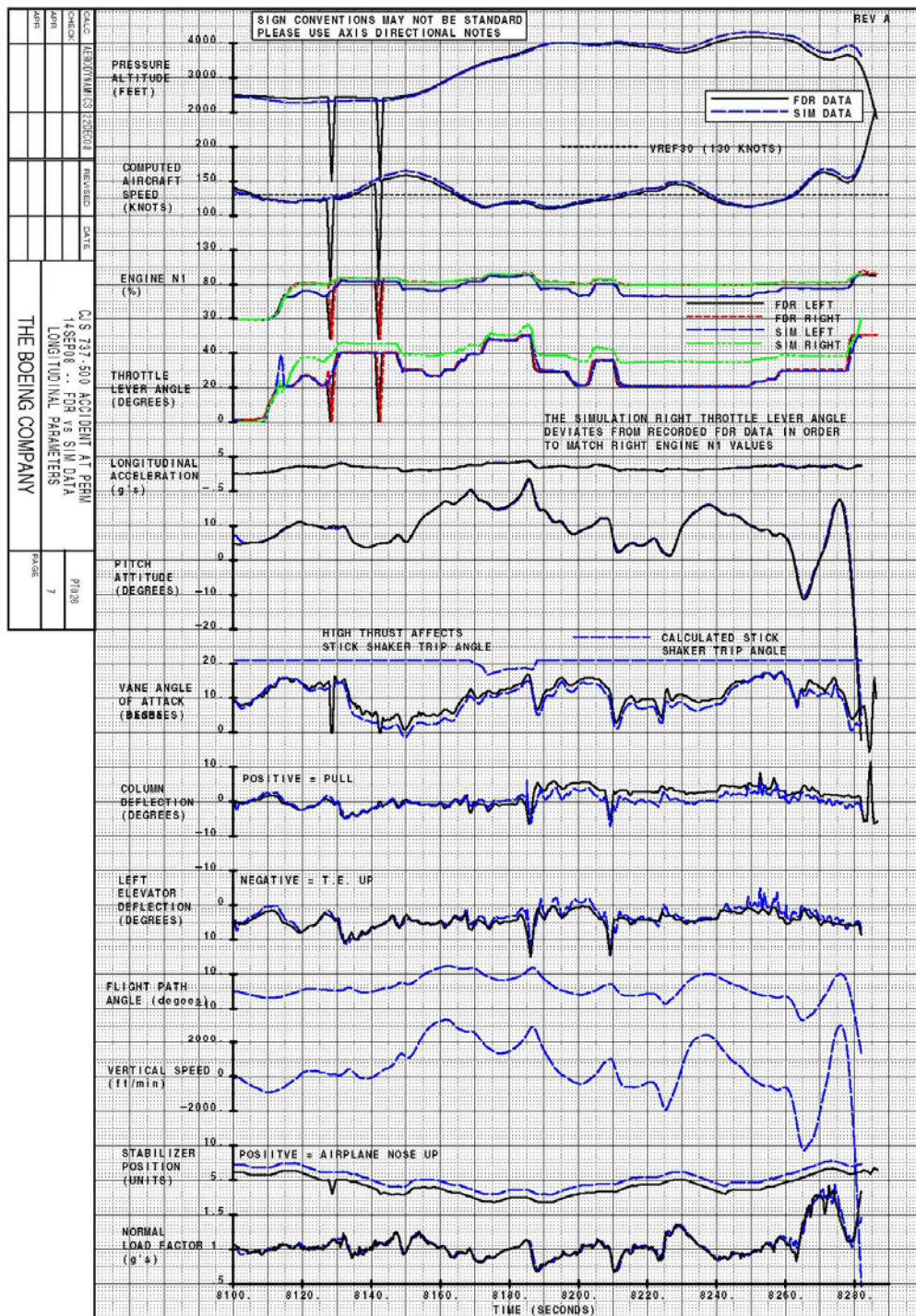
	Simulation Match	Kinematical Analysis
Input	Rudder and elevator deflection and engine thrust	Aircraft movement parameters, controls deflection and engine thrust
	Calculation of forces and moments	Accelerations
	Calculation of accelerations	Calculation of forces and moments
Output	Aircraft movement parameters compared with FDR data. Required and recorded controls deflection comparison.	Assessment of difference between the calculated and base aerodynamic coefficients.

The engineering simulation was done to recreate the last three minutes of the accident flight. The simulation was setup in the following manner:

- Pitch math pilot drives column position to track pitch attitude and pitch rate.
- Roll math pilot drives wheel position to track bank angle and roll rate.
- N1 math pilot drives thrust lever angles to track N1.
- Simulation rudder driven directly by FDR rudder.
- Simulation stabilizer driven directly by FDR stabilizer. The basic stabilizer value was calculated on the basis of longitudinal stability of the aircraft at the beginning of integration. Thus, a slight difference in the FDR and simulation stabilizer could be caused either by errors in the measurement/recording system or by inaccurate data on weight and CG.
- Weight, CG, temperature, flaps and landing gear position were actual data taken from the investigation materials.

The charts below compare the simulation and FDR parameters (the timeline shows relative time). On the basis of these charts and also of the kinematical analysis, the investigation team arrived at the following conclusions:

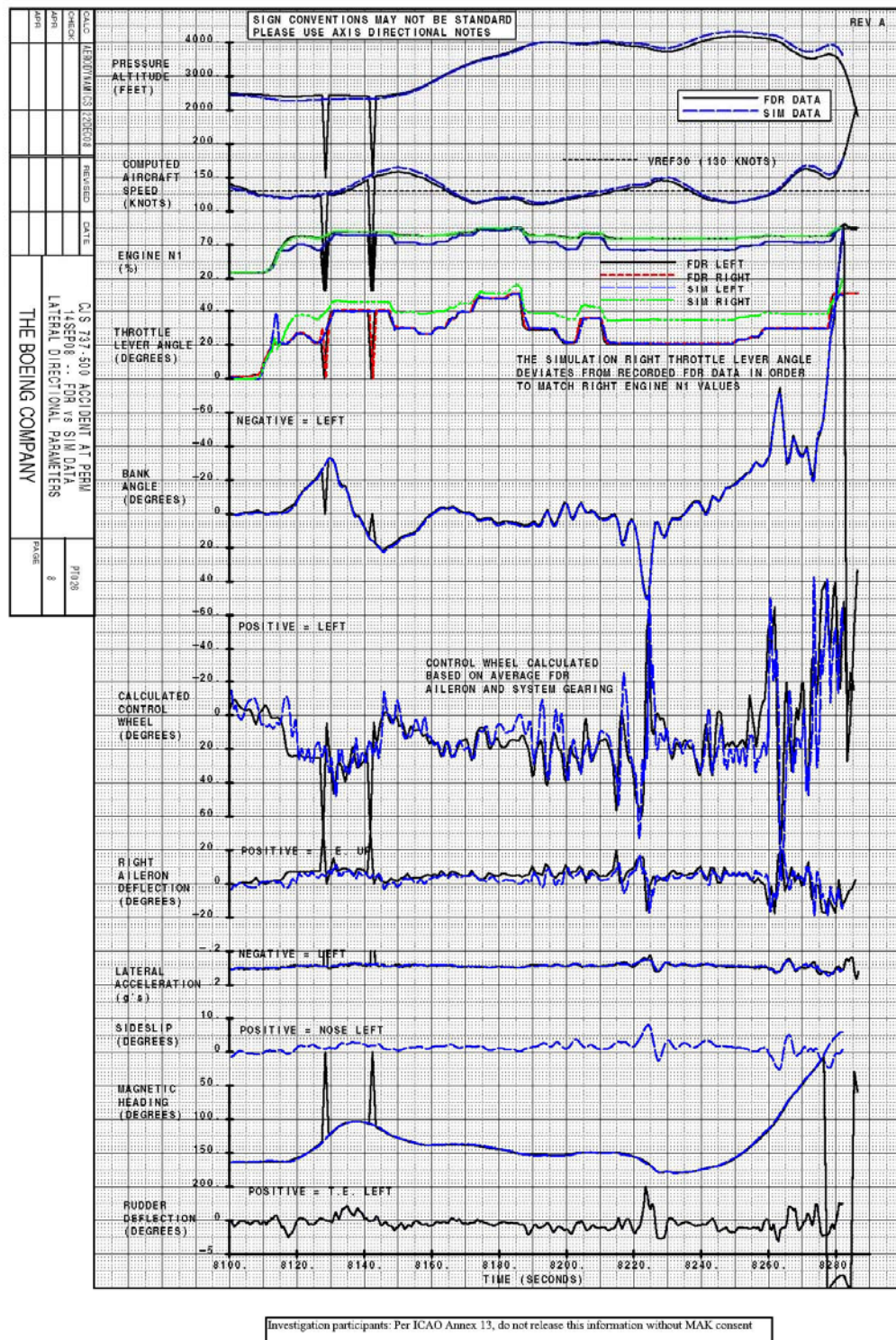
- The stability and controllability characteristics in the accident flight matched the aircraft type characteristics;
- There was no indication of external forces (turbulence, windshear, etc.) that would affect the aircraft;
- As the IAS decreased, the thrust split required greater wheel to stabilize the aircraft position, however the required wheel was significantly lower than the available;
- During the upset situation no angles of attack were recorded that would exceed the stick shaker AOA.



Investigation participants: Per ICAO Annex 13, do not release this information without MAK consent

## FDR and Simulation Pitch





## FDR and Simulation Roll

### 1.16.3. Speed Trim System

The Speed Trim System automatically (without pilot inputs) deflects the stabilizer to increase aircraft speed stability. This system is only operative in manual flight and under the following conditions:

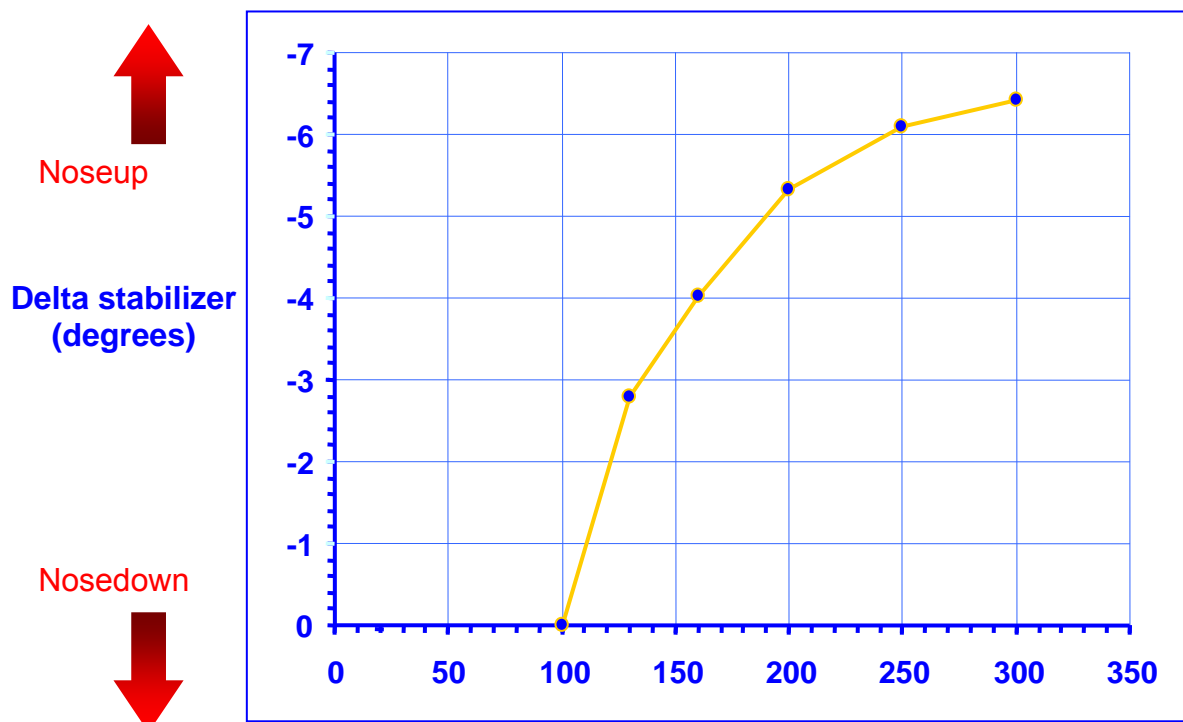
- Middle and aft CG;
- $N1 > 60\%$ ;
- Low flight speeds ( $Mach < 0.6$ );
- AOA lower than the stick shaker AOA.

The system is armed 10 seconds after the liftoff or 5 seconds after the crew applies manual stabilizer trim. The system trims the stabilizer nose up if the airspeed increases and nose down if the airspeed decreases. The magnitude of the trim is determined on the basis of the pre-computed tables stored in the FCC memory (see picture below), as well as the aircraft vertical speed (extra damping of the long-period process). When the climb vertical speed increases, it trims the stabilizer nosedown, and if it decreases the stabilizer is trimmed noseup.

Depending on the flaps position the vertical speed coefficient is:

- Flaps retracted – 0.011 degrees of stabilizer/(ft/sec);
- Flaps extended – 0.022 degrees of stabilizer/(ft/sec).

The mentioned algorithms were used to assess the operation of the Speed Trim System on several portions of the flight after the autopilot was disengaged. This assessment showed that the system was working as per design.



#### **1.16.4. Independent Flight Test**

In the course of the investigation a working group was formed to conduct an independent analysis to assess the conditions of the accident flight and the pilots' actions. The working group consisted of two test pilots from the State Civil Aviation Research Institute and the Gromov Flight Research Institute, a representative of the FTOA (a pilot who had flying experience on western aircraft), as well as three experienced line pilots from the leading Russian airlines that operate Boeing 737 aircraft.

The materials of the analysis are used in the Analysis section of this Report. This section contains the main conclusions of the assessment as well as the opinion of the working group regarding the issues of transitioning from eastern type attitude indicators to western type and of CRM in two-member crew.

The working group concluded that the probable cause of the accident was spatial disorientation, mainly by the PIC, due to lack of training. The crew was formed without taking into account the actual level of the pilots' training.

#### **Attitude Indicators – Working Group Conclusion**

“Undoubtedly, the main cause of the accident was the pilot's low level of training concerning to determine the direction of roll upset recovery, which they fail to determine in a stressful situation. The skills of operating with eastern type EADI that remained even after transitioning to a Boeing 737 with a western type EADI did not allow the pilots to determine the required wheel direction to recover from the bank. This problem is well-known and the only way to solve it is by training flight crews to recover from the upsets set by the instructor at flight simulator sessions”.

“Western types of civil aircraft are fitted with western type EADI. Both during their initial training and transition training pilots in western airlines encounter only one type of EADI with the western type indication. This kind of EADI is used for initial training of western pilots:



Russian airlines operate aircraft with three types of indication: eastern, western and mixed. Therefore, during their flight career the pilots when transitioning to a new type of aircraft often have to break the settled stereotypes.

Provided aircraft with eastern type of attitude indication are going to be operated by Russian airlines for a significant period of time ahead, the problem will persist”. “Therefore, when pilots transition to western types of aircraft or Russian aircraft with western type of attitude indication (RRJ-95, TU-204, Il-96...) <sup>32</sup>, special attention should be paid to the formation of steady skills of flying the aircraft with a new (for a particular pilot) indication type. Extra simulator training should be provided, including upset recovery training.”

“We assume that it would be practicable for the colleges of initial flight training to use aircraft fitted with western type of EADI. While Russian training aircraft models with this type of indication are being designed, it could be practicable to consider buying western aircraft suitable for initial training, or, as an alternative, to consider installing western type EADI in the Russian training aircraft.”

### **Two-member Crew Flights**

“Throughout the world crews on all modern aircraft, including Boeing 747-400 and A-380 are two-member. On Russian aircraft types, even the most modern ones, like Tu-204 and Il-96, at least one more crew member is present (flight engineer). Unfortunately, an extra crew member does not always guarantee increased flight safety. For example, numerous landing gear

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<sup>32</sup> Western type of attitude indicators are installed also on Tu-154, Yak-42, Il-86 and other aircraft.



retractions on An-24, a belly landing of Il-86, a Tu-154 landing on a taxiway as well as numerous CFIT's occurred when a navigator was on board.

A pilot who is used to working on a multi-crew aircraft, where every crew member has a limited number of specific duties, and all the crew member work for the Captain, will face difficulties when transitioning to a two-member crew aircraft. In a optimum situation, an inexperienced pilot is assigned during the transitioning to an experienced pilot, who will be able to work for two in complicated situations. This does not refer to instructors, who are expected to act like this due to their status, but only to line PIC's who fly regular flights. In such a situation, as this transitioning pilot gains experience, he will turn into a skillful pilot. Unfortunately, it is not possible to perform flights with an instructor until 100% safety is reached. Therefore, the crew should be well-balanced, i.e. a skillful Captain with not less than 1000 hours flying experience can guide an inexperienced co-pilot. And vice versa. At first sight it seems trite, but nowadays, when there is intense lack of experienced pilots, this principle is violated. The price of such violations is too high. It was noticed that when co-pilots with significant flying experience first become captains, after an experience of 350 to 800 flight hours they often start to overestimate their skills and start making errors when the flight conditions get slightly more complicated. It is also unacceptable to speed up the commissioning as captains of pilots who had never been captains before, especially when they transition to a new type. It is necessary to set up a standard flight time for such pilots of not less than 1500 hours as co-pilot on new type; and for those pilots with experience as captains (except Class IV aircraft Captains) who had not operated a two-member crew aircraft, a standard of 1000 flight hours; and for pilots who had operated two-member crew aircraft with same type of attitude indication, a standard of 500 flight hours. Under no conditions should pilots who do not have experience as captains be commissioned as Class I aircraft Captains. Also the previous standard of 4000 flight hours for transitioning to Class I aircraft should be restored, with a minimum of 1000 flight hours as captain.

During the checkrides instructors should require strict compliance with the prescribed duties. If serious errors are noticed, pilots who make them should be suspended, and then should pass the required tests and another checkride. Instructors at simulator sessions should require that their trainees strictly adhere to their duties and follow the QRH procedures with accuracy.”

#### **1.16.5. Expert Conclusion on the Psychological Examinations of the Crew**

For the purpose of analyzing the findings of the psychological examinations, the investigation team involved independent practicing medical psychologists. The expert conclusions were drawn on a “blind” basis, i.e. the psychologists were not informed about the



conditions of the accident or the pilots' actions. The only information submitted to them included the findings of psychological tests, medical logbook data and the report of the aviation medicine working group.

The analysis of the psychological documentation related to the PIC and the Co-pilot made it possible to assess their individual psychological traits and their probable influence on the professional activity, including abnormal situations<sup>33</sup>. In particular, the experts noted that the PIC's character type accounted for his "easy adjustability in communication, flexibility and adaptability in situations when he plays secondary roles", as well as the fact that in stressful situations the PIC could only apply simple highly automated skills and actions.

The experts also noted that "the set of psychodiagnostic methods used for identifying individual traits of the PIC's personality was very limited and requires a highly qualified diagnostician to assess the individual traits and their possible impact on the pilot's behavior in a non-standard situation".

#### **1.16.6. Instrumental Speech Analysis**

In order to get more objective assessment of the psychological status of the pilots in the accident flight, instrumental tests of the crew's speech were conducted, in particular the analysis of the main tone frequency. As experience shows, this human speech characteristic can vividly reflect the dynamics of pilots' psychological stress during the flight. Statistical data received experimentally were used for the test assessment. There are five levels of emotional stress:

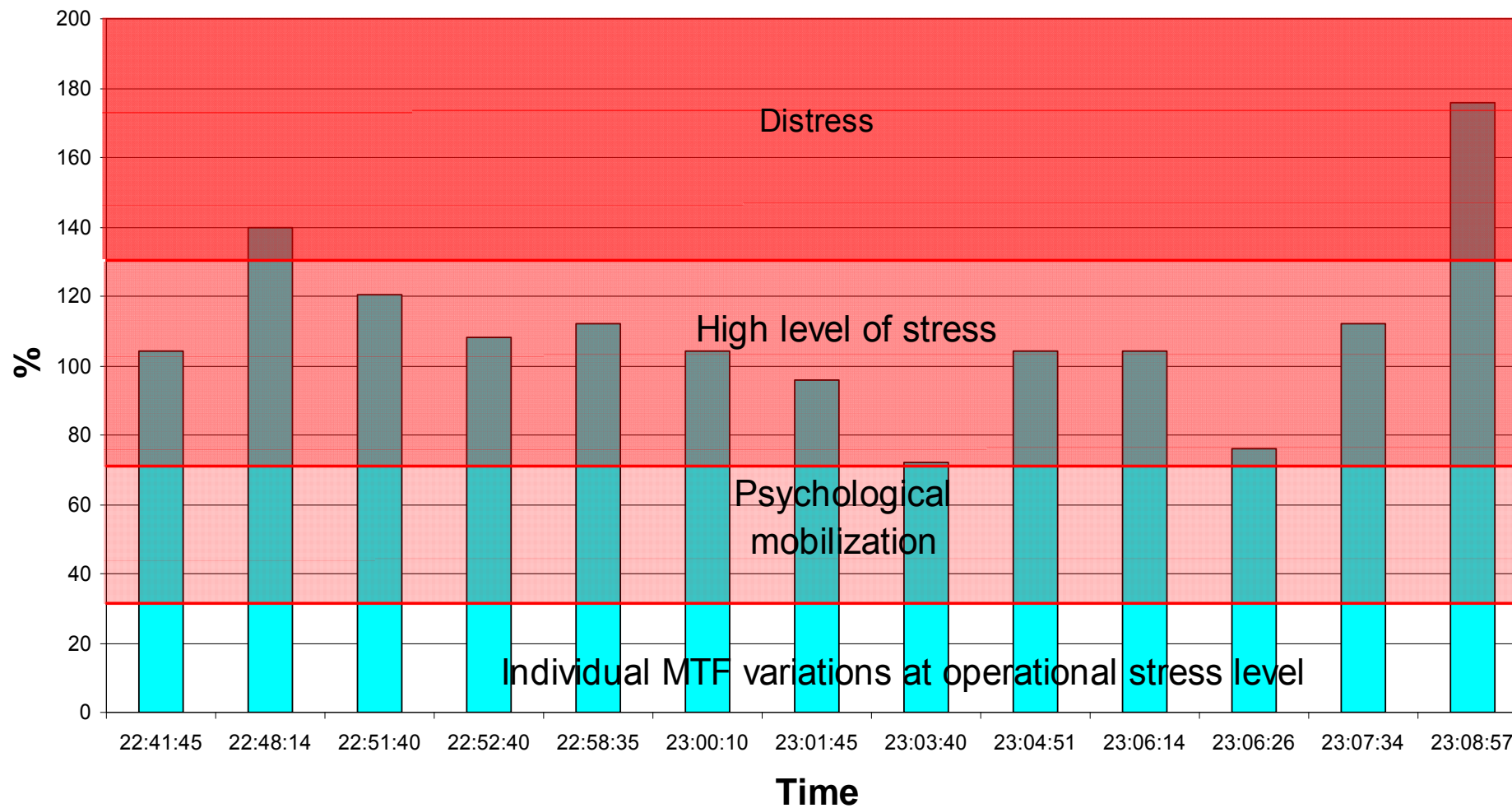
- Quiescent status (initial level, 100%);
- Operational stress (25-30% higher than initial);
- Psychophysiological mobilization (30-70% higher than initial);
- High level of stress (70-100% higher than initial);
- Distress (higher than operational (not quiescent) by 70% and more).

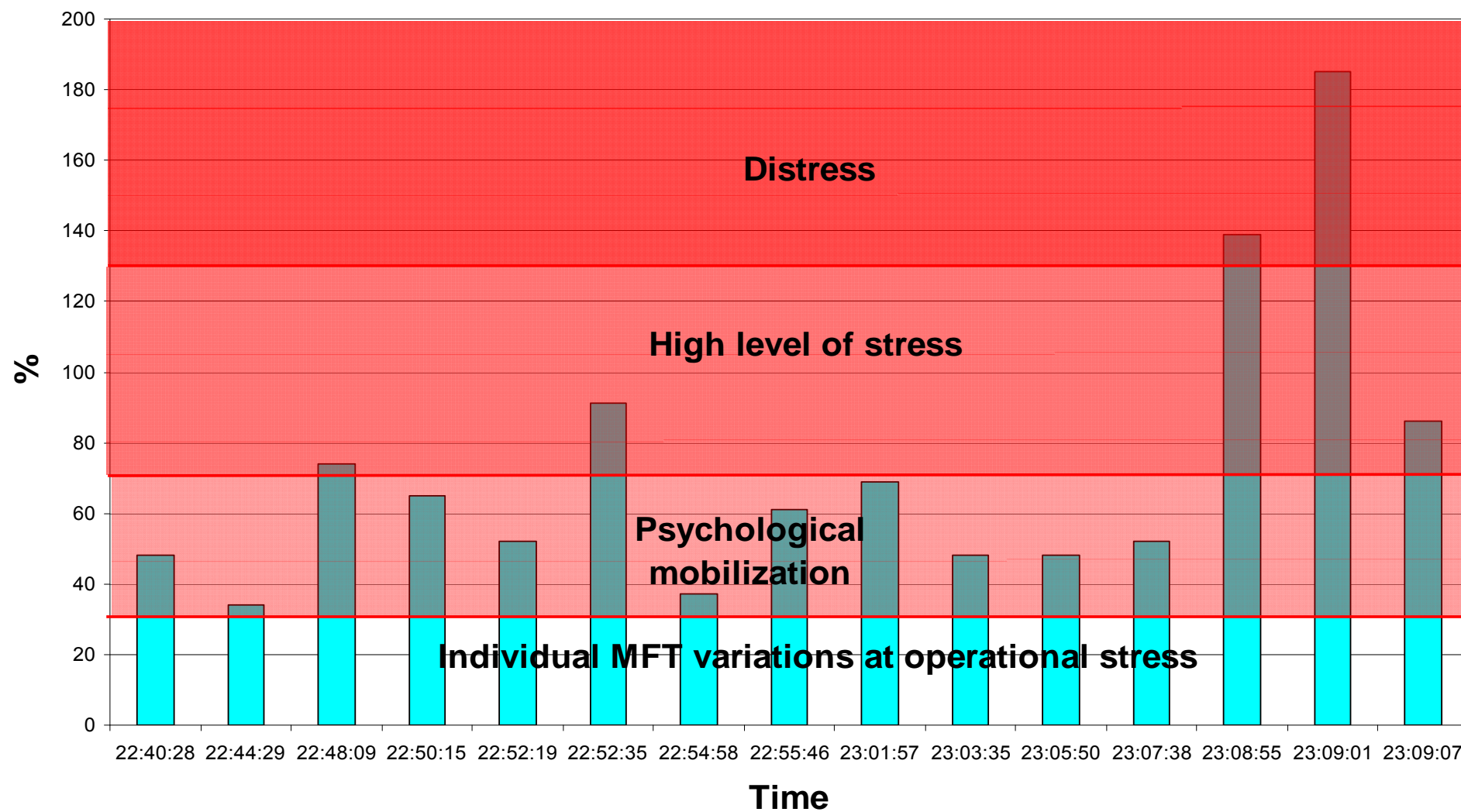
The main tone frequency analysis of both pilots showed that within the last 30 minutes the PIC level of stress was higher than operational and was equivalent to the high level of stress (see the bar chart below). Such a state inevitably affects the airmanship in a destructive way.

As for the co-pilot, his state of mind until 23:08:55 was within the mobilization level, and only after that (30 seconds before the crash) it changed to reach the high level of stress.

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<sup>33</sup> The Expert conclusions are in the investigation file.





### **1.17. Organizational and Management Information**

#### **Aeroflot-Nord Airline**

Full name: Aeroflot-Nord LTD.

Established by PLC Aeroflot – Russian Airlines and Aviainvest LTD.

Aeroflot-Nord LTD was registered as a legal entity and, in accordance with Federal Law “On the State Registration of Legal Entities” was included into the Common State Register of Legal Entities with the registration No. 1042900018908, Certificate Series 29 No. 001084455, issued by the Arkhangelsk Inspection of the Ministry of Taxation.

Location: 163053, Russia, Arkhangelsk, Talagi Airport, Aeroflot-Nord LTD.

Aircraft Operator Certificate No. 466 issued September 08, 2004. Extended on August 27, 2008 by the Federal Air Transport Agency.

Aeroflot-Nord performs domestic and international commercial air transportation on the territory of the Russian Federation and abroad.

Aeroflot-Nord operate the following aircraft types: Boeing-737-500/300, TU-154Б-2, TU-134A, AN-24, AN-26.

The operation of Boeing 737-500 was permitted by a Decision of Flight Operations Oversight Department, FTOA issued September 01, 2006.

#### **PLC VARZ-400**

Full name: Public Limited Company “Vnukovo Aircraft Maintenance and Repair Plant No. 400”, abbreviated name: PLC VARZ-400.

Legal address: 119027, Russia, Moscow G-27, Zavodskoye Motorway, 19. Site of base: Vnukovo Airport, Moscow.

At the time of the accident VARZ-400 had a valid Certificate of Approval EASA.145.0321 as a line and base maintenance organization of B737-300/400/500 and a Certificate of Approval No. BDA/AMO/288 issued by Bermuda as the State of Registry. These certificates were suspended on September 30 and October 7, 2008 respectively.

VARZ-400 executed maintenance of aircraft and engines on the basis of and in compliance with the Agreement No. 121-07/221/1058-H22-07 concluded on November 01, 2007 between VARZ-400 and Aeroflot-Nord.

#### **Flight Training Center of St. Petersburg State University of Civil Aviation**

The Flight Training Center (FTC) is a structural division of the Aviation Training Center (ATC) of the Federal State Institution of Higher Professional Education “St. Petersburg State

University of Civil Aviation, registered OGPU 1047796301002 on July 01, 2002 by the Registry Chamber of St. Petersburg Administration.

The St. Petersburg State University of Civil Aviation was established by the Russian Government, the establisher's functions are performed by the Federal Air Transport Agency.

The ATC is headed by the Chancellor of St. Petersburg State University of Civil Aviation.

One of the main activities of the ATC, in accordance with the available Certificate of ATC No. 036 which entitles the holder to train civil aviation personnel, is transition training, refresher training and simulator training of flight crews for Boeing 737. The training makes use of multimedia programs (State Contract signed December 29, 2006) and simulator training in simulator training centers of Lufthansa Flight Training (Berlin) and GCAT Flight Academy Sweden AB (Riga Airport), which is defined by the State Contracts concluded on February 21, 2008 and December 20, 2007.

On November 19-21, 2008 a FTOA commission made an inspection of the training center. The general conclusion was that the initial, transition and refresher training of flight crews did not comply with the FAR "Certification of Aviation Training Centers".

### **Flight Training International**

The FTI Training Center where the PIC had his transition training is located in 3401 Quebec Street, Suite #9150, Denver, Colorado, USA.

### **METEK LTD.**

METEK LTD (St. Petersburg) was registered according to the Decision of St. Petersburg Registry Chamber No. 81587 issued on August 27, 1997, Certificate of State Registry No. 53414, OGPU 1027810226729.

According to the submitted Letter of Information No. 823829 of June 18, 2003 about including into the Common State Register of Legal Entities, the identification code of METEK LTD includes code 80.42 of the Russian Classification of Commercial Activities (Education of adults and other kinds of education, not included into other groups). METEK LTD does not hold a license for training.

## **1.18. Additional Information**

### **1.18.1. Photographs of the Actual Throttle Stagger in Flight**

The investigation group received the following photographs taken by the crew who had performed one of the flights preceding the accident flight on the same aircraft on September 12, 2008. The photos were taken during cruise flight, with the autothrottle engaged.



### 1.18.2. English Language Proficiency of the Crew

#### General

In accordance with the documents submitted by Aeroflot-Nord, the PIC and the Co-pilot both passed English language courses at METEK LTD. The PIC took a course in Technical English for Aviation (208 hours) from June 13, 2006 to July 12, 2006 and completed the course with an “Excellent” mark. The Co-pilot from September 03, 2007 to December 05, 2007 took a course in Basic English (512 hours, “Excellent”) and a course in Technical English for Aviation (208 hours, “Good”).

#### Language Training Organization

METEK LTD (St. Petersburg) was registered according to the Decision of St. Petersburg Registry Chamber No. 81587 issued on August 27, 1997, Certificate of State Registry No. 53414, OI PH 1027810226729. According to the Organization Exposition, the range of activities of the organization is rather wide, including trade; electronic equipment design, manufacture, installation and repair; research and design activities with regard to medical and other special equipment; design of heat monitors; establishing leisure and health centres; medical services; tourism; food supply via retailers; construction works; transport maintenance and repairs; real estate, etc. (only part of the activities are mentioned here, just to show their dispersed range.) Among the abovementioned activities the Exposition indicates “arranging recurrent training courses and professional training for technical staff and flight crews of airlines and aviation industry of Russia and CIS countries.”

According to the submitted Letter of Information No. 823829 of June 18, 2003 about including into the Common State Register of Legal Entities, the identification code of METEK

LTD includes code 80.42 of the Russian Classification of Commercial Activities (Education of adults and other kinds of education, not included into other groups).

These are the only documents regulating the activities of METEK LTD with regard to training. They explain the absence of educational license with reference to p. 2 of the Provisions No. 796 issued by the Russian Government on October 18, 2000 (Approval of Provisions for Educational Licensing), according to which “training in the form of single lectures, probations, seminars and other kinds of training not followed by final assessment and issue of certificates of training and/or qualification”. However, as the pilots had certificates of training at METEK LTD, it assumes that this kind of training should be licensed. Besides, the Exposition claims that they “arrange refresher courses and professional training courses”, therefore their activity should be regulated by Order No. 610 issued by the Russian Government on June 26, 1995 (Approval of the Standard Provisions for institutions of additional professional education (recurrent training) of specialists) and Order No. 213 issued by the Russian Government on March 10, 2000 (Amendments to the Standard Provisions). According to p. 8 of the Standard Provisions, refresher courses are included into educational institutions of recurrent training. And according to p. 14, “the right to engage in educational activities... is entitled to an educational institution of recurrent training as soon as it is given a relative license”. Though it should be also mentioned that the Standard Provisions are exemplary for private educational institutions of recurrent training (p.16).

The educational activity of METEK LTD with regard to Aviation Technical English training was neither certified nor approved by any national authority of Russia.

METEK LTD have trained aviation personnel of airlines in Uzbekistan, Kazakhstan and Georgia. Since 2002 they have taught specialists from the following Russian airlines: Volga-Dnieper, Orenburg Airlines, Pulkovo Enterprise, Samara Airlines, Dalavia, KDavia. At present they are training staff in State Transportation Company Rossiya, KDavia and Orenburg Airlines.

The head of the company referred to a contract concluded between METEK LTD and Boeing, in accordance with which METEK LTD translated training manuals for Boeing 737, 757, 767 and 747. According to the Letter of Reference from Boeing on February 2006, Boeing “rely heavily on METEK English language classes (both basic and Aviation English) they conducted for the pilots, mechanics and CAA personnel of Uzbekistan, Georgia, Azerbaijan, Kazakhstan and Russia”.

### **Teachers’ Qualifications**

The courses of Aviation Technical English were read by teachers of METEK LTD. Both teachers have internal Qualification Certificates of METEK LTD, which state that the

abovementioned specialists have “necessary professional skills to teach English for specific purposes in groups”. As these documents are internal, they cannot serve appropriate evidence of the teachers’ competence. These certificates and diplomas of higher education are the only documents that confirm the teacher’s qualifications.

The higher education obtained by both teachers was not connected with aviation, linguistics or pedagogy. One of them graduated from Leningrad Electrical Institute in 1974 and specialized in automatic machinery and telemechanics, was qualified as an electrician engineer and worked at the State Optical Institute for 20 years. The other teacher graduated from Leningrad Mechanical Institute, specialized in automatic gears and was qualified as an electromechanical engineer. His further work was connected with design of automated spectral and optoelectronic devices for medical purposes.

For several years, starting with 1994, both teachers were involved in translating training manuals for Boeing aircraft, both have worked as interpreters at the Boeing Training Center in Seattle for groups of aviation personnel studying “airframe and powerplant mechanics”, “avionics”, and “aircraft flight operations”.

According to the explanation given by the Director of METEK LTD, their experience of cooperation with Boeing became the basis for developing their own Technical English courses for the abovementioned qualifications.

Since 1996, both teachers have taught many Technical English training cycles for aviation personnel (mechanics and pilots) in the abovementioned CIS countries.

However, as was stated above, the teachers of Aviation Technical English do not have any aviation, linguistic or pedagogical education.

### **Training**

In 2006 (June 13 – July 12) and 2007 (November 04 – December 05) teachers of METEK LTD read the courses of Technical English for Aviation for pilots of Aeroflot-Nord. The main objective of the course was to prepare the pilots in terms of the language to the first stage in their transitioning to Boeing 737. As the teachers explained via e-mail, the priorities were reading skills and ability to adequately understand the FCOM, FCTM, QRH Checklists and SOPs for the Boeing 737, and also listening comprehension of the voiceover in the Boeing CBT.

The classes were held in the Aeroflot-Nord training Center in a standard classroom. The teachers characterized the classroom environment as quite comfortable. In accordance with the basic syllabus, the course is supposed to take 240 academic hours (5 weeks of 8 academic hours a day, 6 days a week). As the classes finished at 1600 hrs every day, there should have been



enough time for homework and self-teaching. It was also noted that the PIC and the Co-pilot (as well as other students who came from other towns) were staying at a hotel, 5 minutes away from the training center.

However, according to the Certificates of Training, in 2006 (PIC's group) the number of hours for the course was reduced down to 208. According to the teachers, such course reduction is done by reducing the amount of training materials. However, the materials that concern the navigation system, automatic flight, cockpit warnings, flight controls, engines, fuel and electrical systems are of special priority and cannot be excluded. The materials to be reduced may refer to the general structures of the aircraft, like doors.

In 2007, on the contrary, the amount of materials to study should have been increased, but when the classes started some circumstances (that came from the top management of Aeroflot-Nord) changed and the time-frame of the course had to squeeze to 4 weeks (it was connected with the further CBT training of the pilots in St. Petersburg), so the syllabus had to be reduced while the workload was increased, with classes lasting up to 9 or 10 academic hours a day.

It should be noted that according to experienced teachers of Aviation Training Center "CompLang" (authorized by the Ministry of Education and Science, RF and certified by the FTOA and the Moscow Department of Education), the optimum length of classes of intensive courses for adults should not exceed 6 academic hours. Even the most motivated and committed group will suffer problems with material acquisition after 5 or 6 academic hours. If the workload of 8 (even more so 9 or 10) academic hours a day persisted within several weeks with only one day off after every 6 days, the complete and due acquisition of the course materials can be highly doubted (provided the students also had to do their homework and study on their own every day after the classes). When we talk of the group of 2007 (the Co-pilot's group), this is enhanced by the fact that before the course in Technical English the group had had a course in Basic English, levels Elementary and Pre-Intermediate (almost from the beginning) of 512 hours (not less than 8 academic hours a day, 6 days a week). There was no break between the two courses. It can be assumed that the accumulated fatigue could hamper the language acquisition, especially during the more complicated Technical English course.

### **PIC's Language training**

It is difficult to adequately assess the PIC's level of English for a number of reasons. Records of radio exchange from several previous flights were analyzed where the PIC partially maintained the exchange in English. The PIC was quite confident with the RTF phraseology, so he at least could show ICAO Level 2. However, there were no abnormal situations during the

analyzed flights, so it is unclear if the PIC could use Aviation and General English that would lie beyond the frames of standard phraseology in normal situations.

According to the available documents, the PIC regularly took refresher courses in RTF phraseology, in compliance with Instruction ДБ No. 94. The last of them was from November 23 to December 06, 2007 (120 hours), which he completed with a “Good” mark.

From June 13 to July 12 the PIC took a course of Technical Aviation English at the Aviation Training Center of Aeroflot-Nord in Arkhangelsk. According to his teacher’s reference, the PIC’s level of English was in full compliance with the pre-requisites for CBT training. In the group rating list he was the fourth among 15 students of the group (on the basis of assessment results). The teacher only noted that the PIC had constraints while using speaking skills. However, he never missed classes, did all the required exercises with diligence and a wish to comply with the required level of skills. The PIC completed the course with an “Excellent” mark.

According to the submitted scale of marks, “Excellent” is given, when the student “easily understands an unfamiliar text from the abovementioned reference books. Strictly follows grammar rules. Errors are insignificant. Easily corrects themselves and does not repeat the errors in future speech. Has good vocabulary. Can use synonyms. Successfully paraphrases terms and expressions. Can work with documents and training materials successfully on his own. When listening to the CBT course gives a correct interpretation of the essence, after the second listening can reconstruct the details. Can work with an English-speaking instructor with moderate speech tempo.”

However, there are no objective data (audio record or written works of the PIC) that would allow assessing the PIC’s level of acquiring the course material and the English language in general. It is not exercised in METEK LTD to keep the written works of the students or to conduct an oral examination. The total mark for the course is the average of written test results (mainly lexical tests), the teachers’ assessment of FCOM, FCTM, QRH and SOP reading skills and the assessment of CBT listening comprehension. The two last marks were determined during the course. Thus, the assessment of the PIC’s level of English is subjective to a certain degree.

### **Co-pilot’s Language Training**

According to the available documents, the Co-pilot’s English language training started when he took initial training courses for pilots and navigators who perform international flights as a co-pilot of Tu-134 from October 24, 2004 to April 6, 2005. Among other subjects he studied a course in radiotelephony in English (“Good” mark). His language proficiency was assessed as “Elementary”, ICAO scale.

The next document that related to the Co-pilot's language training was Certificate No. 1390 issued by METEK LTD. The training lasted from September 03 to December 05, 2007. First he completed a course in Basis English of 512 hours (Elementary and Pre-Intermediate) with a "Good+" mark. Provided the initial training of the English language and Radiotelephony English had been taken 3 years before and had neither been maintained or used (the Co-pilot only made internal flights on a Russian aircraft), most likely he was taught again at METEK courses virtually as a beginner. Moreover, taking into account the high tempo of training (over 8 academic hours a day, 6 days a week), the workload was rather heavy. Right after the basic course was completed, the Co-pilot proceeded to a course of Technical English for Aviation within the framework of his transition to Boeing 737. As was mentioned above, the workload was even more intensive (9-10 academic hours a day, 6 days a week). Experience allows assuming that such workload (taking into consideration the already accumulated fatigue after two months of intensive training of Basic English) would significantly reduce the quality of material and skills acquisition.

According to his teacher's reference, the Co-pilots level of English was in full compliance with the pre-requisites of Boeing CBT training. However the teacher also noted that when speaking, translating or listening to records the Co-pilot needed more time to understand the content of utterances and to formulate replies than other students. Among 16 pilots in his group he was the sixth in the progress rating list. However, in the first intermediate written test he completed 74% of the tasks and only 36% in the second. The final test was completed 70%. (Cf. The PIC completed 92% of his final test correctly.)

The Co-pilot completed the Technical English course with a "Good" mark. According to the given rating scale, this mark is given if a student "understands an unfamiliar FCOM, FCTM, QRH and SOP text well enough. Sometimes makes grammar mistakes. Corrects the mistakes on his own, tries not to repeat them further. Vocabulary is enough to work with manuals successfully on his own. Can paraphrase terms and expressions. When listening to CBT voiceover, usually gives an adequate translation of the gist after the first listening, may need several extra listenings to reconstruct the details."

Just the same as with the PIC, it seems impossible to adequately assess if the mark was adequate, as there are no written works or sound records available.

### **Final Remarks**

It should be mentioned that as neither of the pilots performed international flights nor had a permit to make international flights, the language proficiency requirements cannot be applicable to them. According to Russian regulations, such requirements exist only for flight

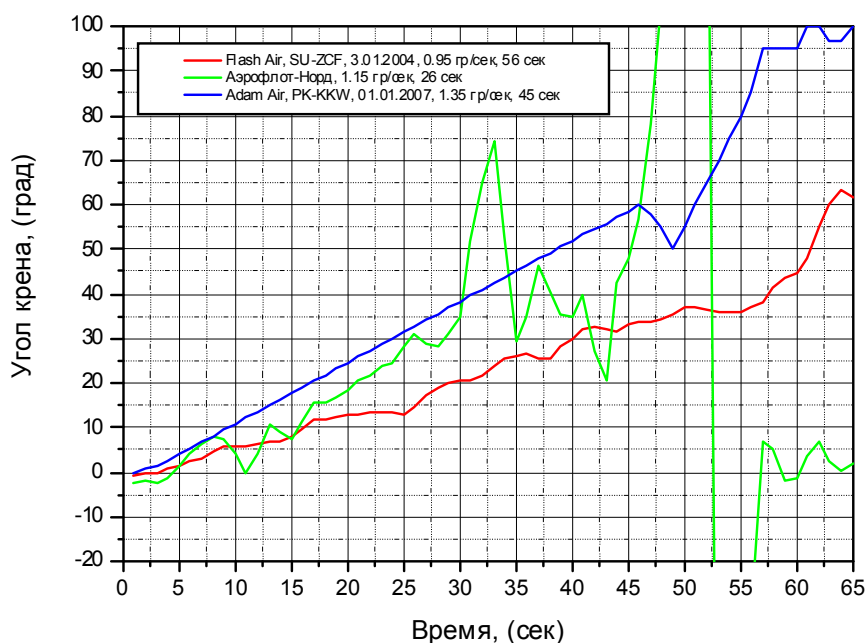
personnel who are involved in international flights (Order No. 90 by the Ministry of Transport, RF of July 09, 2007). Analysis of the co-pilot's communication during the accident flight and the way he failed to understand the FMS and Autoflight logics assumes that he had a low level of English.

### 1.18.3. Text Message (SMS) Sent from the Aircraft Before the Flight

Via the AAIB UK the investigation team got access to a text message (SMS) sent from the aircraft by one of the passengers to her friend in UK. The message was sent before the engine startup (approx. at 20:59) and said that the sender was very scared, because when the PIC addressed the passengers his voice sounded “like he is totally drunk”. According to the message, the passengers were worried, but the flight attendants said everything was all right.

### 1.18.4. Previous Cases of Spatial Disorientation

In the course of the investigation the investigation team studied several previous cases of spatial disorientation in flight. The chart below shows comparative data regarding slow banking of Boeing 737 type aircraft during the upset (with reference to average rate of banking), followed by more rapid banking as the crews reacted (all the cases ended up in accidents). For convenience, absolute values of bank angles are given in the charts and the initial magnitudes of bank angles are taken as zero references.



Apart from the abovementioned occurrences with the Boeing 737 type aircraft, there have been numerous incidents and accidents due to spatial disorientation with other types of aircraft,

both in Russia and other countries. Aviation experts distinguish between three main theories that can explain the spatial disorientation:

- Increased workload of the crew due to multiple tasks;
- False sense of aircraft motion (which can be explained in terms of physiology);
- False interpretation of attitude indication.

Detailed description of all these theories can be found in special literature and lies beyond the framework of this report. It should be noted though, that most often it is a combination of several of these factors that leads to spatial disorientation.

#### **1.18.5. Flights Performed on the Accident Aircraft after August 06, 2008**

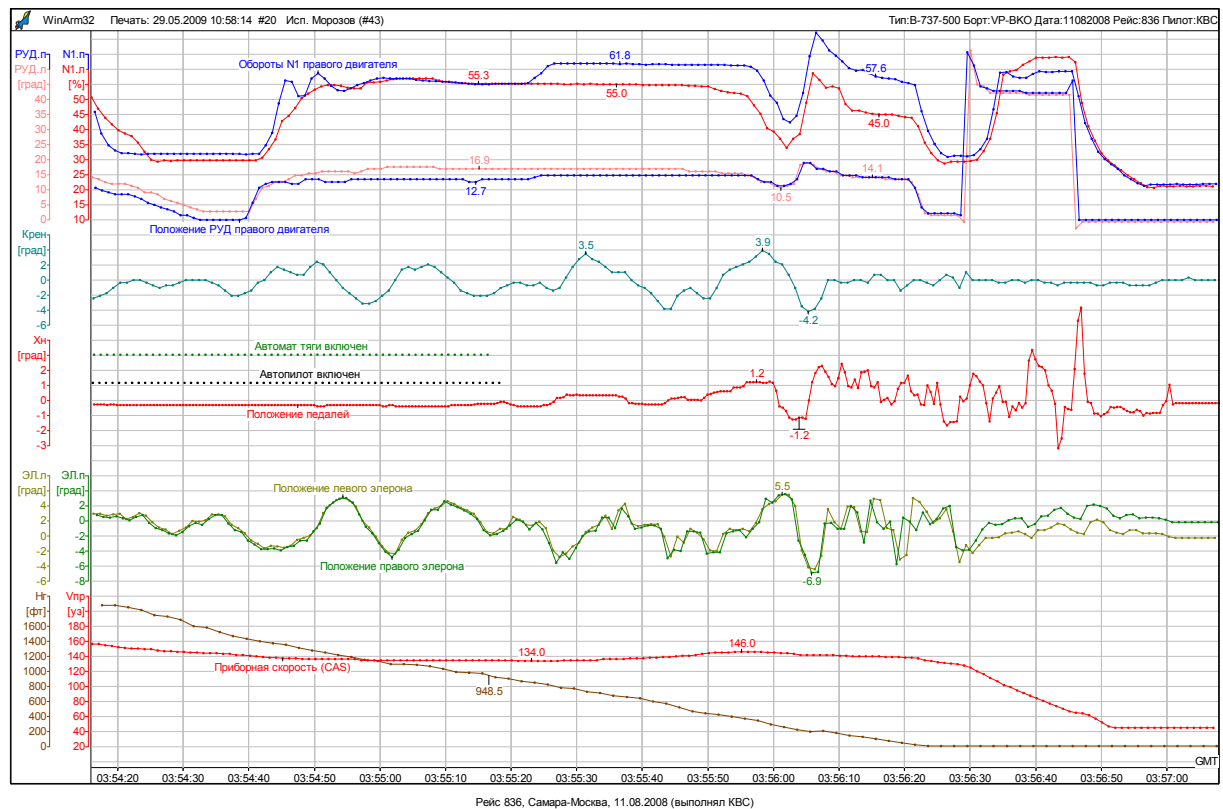
In the course of the investigation, the investigation team analyzed previous flights performed on the accident aircraft after August 6, 2008 (the day when the throttle stagger first appeared) both by the PIC and other pilots<sup>34</sup>. The purpose of the analysis was to assess the crew inputs applied to balance the aircraft with the autothrottle disengaged.

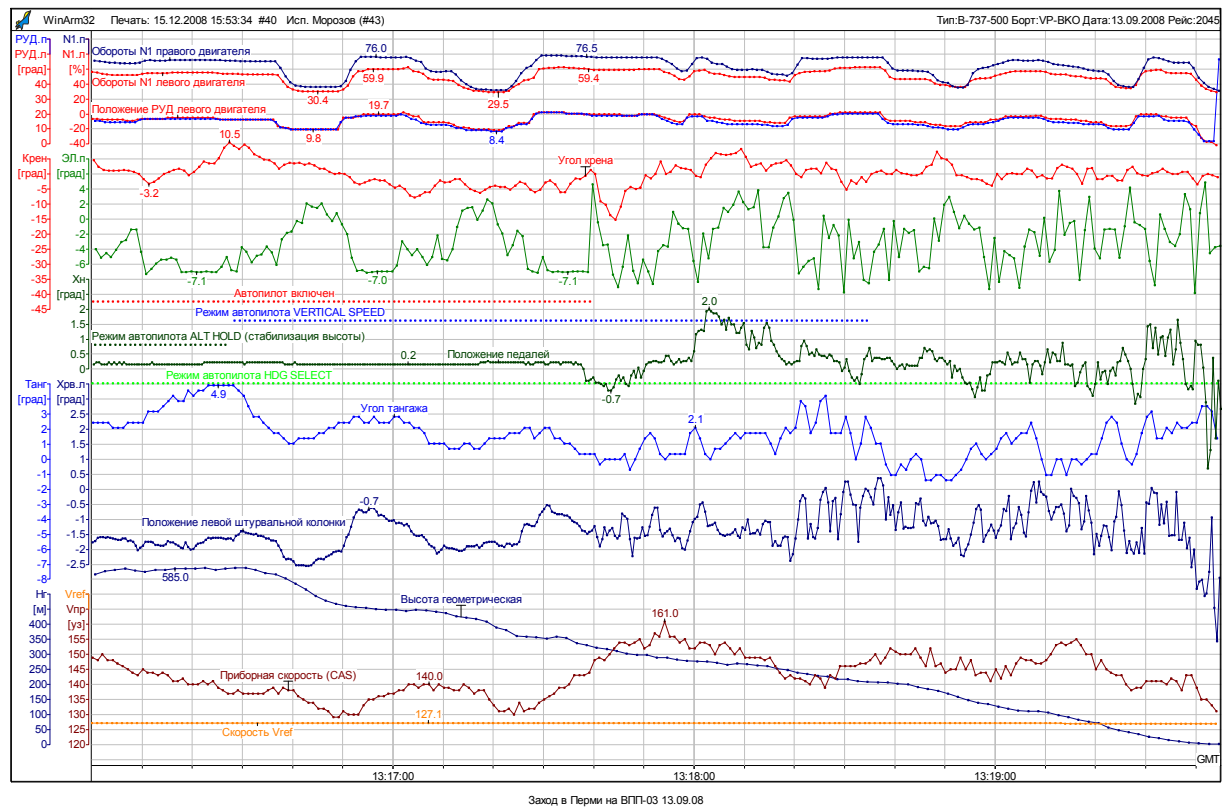
The FDR records available for the investigation team showed that during the flights performed by the PIC the autothrottle was engaged before the takeoff roll, and it was disengaged just before the touchdown, at 60 meters and lower, which does not allow assessing the pilots' input. A slight exception was noticed during one flight on August 11, 2008 from Samara to Moscow<sup>35</sup>. The plot of this flight is given on the chart below.

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<sup>34</sup> As was mentioned before, the Co-pilot did not fly this aircraft after August 6.

<sup>35</sup> The throttle stagger at this stage was smaller than in the accident flight. It was impossible to define who was the pilot-flying.





### 1.18.6. Pilot Training at the FTI Center

The Interstate Aviation Committee is now investigating the accident of a Boeing 737-300 EI-DON operated by KDavia airline that occurred on October 1, 2008 at Kaliningrad airport. During the landing in a non-landing flap configuration ( $2^\circ$ ) due to flap asymmetry the crew forgot to extend the landing gear and made a belly landing. The investigation revealed significant violation of SOP by the crew (like skipping checklists) and lack of understanding of QRH emergency procedures.

The co-pilot in that crew took transition training for Boeing 737 at the FTI Center in autumn 2006. The transition directly followed the co-pilot's graduation from the flight college, thus he did not have any solo flight experience. The analysis of training documents showed that in the course of 7 FBS sessions and 8 FFS sessions the FTI instructors did not reveal any fault and did not make any remark to the transitioning pilot, which seems strange, taking into account the usual number of instructors' remarks during transition to an absolutely different type of aircraft. This, and also the actual low level of the co-pilot's skills as well as the errors he committed in the accident flight assume low level of training at the FTI Center.

### 1.19. New Investigation Techniques

No new techniques were used in the course of the investigation.



## 2. Analysis

On September 13, 2008 a Boeing 737-505, registration VP-BKO (Bermuda) operated by Aeroflot-Nord was making a scheduled domestic passenger flight AFL 821 from Moscow (Sheremetyevo) to Perm (Bolshoye Savino).

Apart from the two flight crew members, on board were 4 flight attendants and 82 passengers, including 66 citizens of the Russian Federation, 8 of Azerbaijan, 1 of Byelorussia, 1 of Germany, 1 of Italia, 1 of China, 1 of Latvia, 1 of Turkey, 1 of Uzbekistan, 5 of Ukraine and 2 of France.

The Boeing 737-505 VP-BKO serial number 25792 was manufactured by the Boeing Company in 1992 and was owned by ARN 737 Limited (Bermuda).

The actual operation of the aircraft by Aeroflot-Nord airline started on May 30, 2008. By that time its total time in operation was 43491 hours, 34619 cycles. Before that the aircraft had been operated in China. In 2005 within the framework of rudder control improvement program, in accordance with AD 2002-20-07R1 FAA USA, the aircraft was fitted with a new main rudder PCU.

By the time of the accident the aircraft was in operation for 44500 hours (total). All the checks required by the regulations was performed in due time and to a full extent. All the applicable service bulletins and airworthiness directives were complied with.

The last line maintenance (Daily-Check) was done on September 13, 2008 at the outside maintenance station of VARZ-400 at Sheremetyevo-1. The engineers and mechanics doing the maintenance have valid certificates.

The study of maintenance documents revealed that by the time of departure 2 items were deferred as per MEL: the TCAS and the autothrottle were inoperative. According to the Boeing MMEL as well as the MEL of Aeroflot-Nord, approved by the FTOA on July 21, 2008, it is permitted to fly with the abovementioned defects within the period determined for each item.

The reason why the autothrottle was deferred was a record in the flight logbook after Flight SU 824 on September 12 about the inoperability of the autothrottle. This record was apparently caused by the fact that the autothrottle disengaged several times during the flight.

The study of the VP-BKO history on the basis of the FDR records showed that starting from August 6, 2008 at part power there was a thrust split up to 20% with matching TLA, or a throttle stagger of 15 degrees TLA with the matching N1 (there was no thrust split at idle and

almost none at takeoff mode)<sup>36</sup>. The analysis showed that the right engine N1 (and thrust) was significantly higher than nominal at part power TLA<sup>37</sup>, while the left engine N1 was within the normal conditions.

Despite the numerous records in the technical log, this defect was not troubleshot by the maintenance staff. The relative AMM troubleshooting procedures were not followed. The FDR was not readout for troubleshooting.

**Note:** *The analysis showed that the right engine trim was within the limitation. The idle and takeoff stops did not exceed the limitations. Thus, the most probable cause of this defect could be mistrim or some fault of the MEC or a temperature sensor (for example T2).*

The fact that the defect was not rectified for a long period, the troubleshooting procedures were not followed and there were many prolonged deferred MEL items (in the whole Boeing 737 fleet), reveals the low level of Boeing 737 maintenance in the airline and the low level of training of VARZ-400 staff.

All the aircraft and engine systems, except the TCAS and the mentioned defect in the right engine trim, were operative when the aircraft was departing from Moscow. The investigation team did not reveal any evidences of aircraft systems or engine failures in the accident flight.

Aeroflot-Nord was permitted to operate Boeing 737 type aircraft by Decision No. 234/OCЭ issued by the FOOD FTOA on September 01, 2006. The analysis of the available information as well as the findings of inspections conducted by the FTOA and the Russia CAA after the accident revealed that the permit to operate Boeing 737 was issued without checking the actual level of training and amount of flight and maintenance personnel, which later affected the flight operations and maintenance. As the number of Boeing 737 aircraft in operation was rapidly increasing (by the time of the accident there were 12 aircraft), rapid commissioning of new flight crews was accepted, despite serious drawbacks in professional training of some of them<sup>38</sup>. While the new flight personnel was committed the instructors were not duly controlled, and provisions of the ROLRGA-87 regarding the training flights quality assessment and the training quality assessment were violated. There were serious violations in the flight operation management, work and rest management, and control of flight operations. The general level of flight operation management in the airline is low.

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<sup>36</sup> See Section 1.6 for details.

<sup>37</sup> See Section 1.16.1.

<sup>38</sup> Similar shortcomings were highlighted by the investigation team for the A-310 F-OGYP operated by Sibir Airlines that crashed on July 9, 2006 at Irkutsk.

The professional training of flight crew was conducted on the basis of the FCTM developed by the airline and approved by the Russian Aviation Authorities. The analysis revealed that this FCTM has serious deviations from the civil aviation regulatory documents (CAFOM-85, FCTM-92, ROLRGA-85) in terms of flight crew training, crew formation and documentation. The incompliance of the Company FCTM with the current standards and the low quality of flight operations management at the time of the accident were confirmed by the findings of the FTOA and CAA inspections.

The PIC took transition training to Boeing 737 in the FTI Center (Denver, USA), which at the time of the training (August-September 2006) was not approved by the Russian Aviation Authorities. The program used for the training was designed for co-pilots. The PIC's personal file does not contain all the training documentation, which does not allow adequate assessment of the PIC's progress and the instructors' remarks.

The PIC's previous experience was on AN-2 (in the flight college) and Tu-134 (co-pilot, 2700 flight hours). Thus, he did not have any experience on aircraft with spaced-apart engines, when the thrust split leads to a significant yaw disturbance moment. The PIC also had no experience of flying a two-member crew aircraft with glass cockpit, FMS and western type of attitude indication.

While the PIC was commissioned and trained (first as a co-pilot and then as a captain), there were serious deviations from the FCTM, and violations of the tasks order<sup>39</sup>.

The PIC had no experience as captain and he did not pass the captain training courses. Although he transitioned from a Tu-134 (with 4 crew members), he did not pass a CRM training.

**Note:** *The investigation team for the A-310 F-OGYP accident at Irkutsk on July 9, 2006 recommended "to develop and implement a universal course for improving the qualifications of flight crew specializing in crew resources management (CRM) on aircraft with two-man crews. To ensure that crews undertake it obligatory at transition from aircraft with three or more crew members". Despite the recommendation implementation plan approved by the Vice-Minister for Transport, RF gives ground for the development and implementation of such a program, it has not been developed so far.*

The total PIC's experience on Boeing 737 by the time of the accident was 1190 hours, 477 of them as a captain.

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<sup>39</sup> See Section **Ошибка! Источник ссылки не найден.**1.5 for details.

The Co-pilot took transition training for Boeing 737 at the Flight Training Center of St. Petersburg State University of Civil Aviation<sup>40</sup> in December 2007 – January 2008.

The Co-pilot's previous types were the An-2 (over 7000 flight hours, over 3400 of them as a captain) and Tu-134 (co-pilot, 1600 hours). Thus, just like the PIC the Co-pilot had not had any experience on aircraft with spaced-apart engines, glass cockpit, FMS and western type of attitude indication.

During the simulator training there were numerous instructors' remarks that the co-pilot should pay more attention to the SOP, especially regarding the callouts, and to the CRM and the distribution of the PF/PM duties. These problems connected with the transition from Russian aircraft to western ones have been noticed before with regard to other flight crews involved in previous accidents (e.g. the A-320 accident on May 03, 2006 and the A-310 accident on July 09, 2006). As will be indicated below, all the mentioned problems that the co-pilot experienced were revealed in the accident flight.

The instructors also noted the co-pilot's insufficient level while making flights with thrust asymmetry and recommended that he should pay more attention to the attitude and speed control during approach.

During the commissioning and training of the co-pilot the FCTM<sup>41</sup> was also not fully complied with. For example, the final training flights during the commissioning were executed with the same instructor who did the training and issued the Certificate. The same instructor also trained and checked the Co-pilot and allowed him to fly as a co-pilot.

By the time of the accident the Co-pilot had experience of 236 flight hours on Boeing 737.

It should be noted that the analysis of the co-pilot's English language training revealed that it was insufficient to operate an aircraft with all documentation published in English<sup>42</sup>.

It was the third flight of the PIC and Co-pilot together.

The operating procedures and the distribution of duties in a two-member crew differ significantly from those in a crew that also include a flight engineer and a navigator. Flight operations on a two-member crew aircraft with modern avionics requires that the pilots should

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<sup>40</sup> On November 19-21, 2008 a FTOA commission inspected the training center and made a general conclusion that the initial, transition and recurrent training of flight personnel does not comply with the FAR "Certification of Aviation Training Centers".

<sup>41</sup> See Section 1.5 for more details.

<sup>42</sup> See chapter 1.18.2 for analysis of the English proficiency of the crew members.

have theoretical knowledge of how this equipment works and practical experience of such operations.

When applicants are selected for transitioning, one of the main issues to consider should be professional skills of the pilots and their ability to properly operate the aircraft instruments and cooperate in abnormal situations.

As was mentioned before, neither the PIC nor the Co-pilot had previous experience in flying a two-member crew aircraft with modern avionics. Besides, the PIC had not had any experience as captain before he transitioned to Boeing 737. Thus, an inexperienced co-pilot was assigned to a captain without sufficient experience in this position, both being accustomed to multicrew operations.

***On the basis of the conducted analysis, the investigation team concluded that the crew formation was made without considering the actual level of the pilots' training and skills.***

According to independent psychologist experts, the psychological traits of the pilots were also not taken into account when the crew was formed. Experts assume that the PIC's character accounted for his "easy adjustability in contacts, flexibility and adaptive behavior in situations when he is *playing secondary roles*".

The departure was scheduled for 2112 hrs. The crew arrived at the airport around 1930 hrs, which is in compliance with the airline's requirements. The Co-pilot and three flight attendants were brought to the airport from the hotel by bus, while the PIC and one flight attendant came there on their own.

**Note:**

*The PIC's and Co-pilot's rest before the flight was around 15 hours which is in compliance with the standards. However, within the previous three days the PIC made 6 flights (two night flights) with significant violations of rest and work balance on September 11-12 and had almost no night rest. Thus, the PIC could suffer from fatigue during the pre-flight preparation and the accident flight.*

The crew passed medical examination at the medical office of Aeroflot – Russian Airlines at 1948 hrs, and all of them were permitted to fly.

On the basis of the dispatch information (aircraft condition, aeronautical information, weather information, load data, operational flight plan) the PIC took a decision to fly at 1955 hrs and the crew boarded the aircraft.

The aircraft was standing on Stand 22 D at Sheremetyevo-1. At 1945 the mobile stairs were attached to the aircraft. According to an Aeroflot – Russian Airlines’ mechanic who was refueling and releasing the aircraft, the crew walked to the aircraft.

From 2008 hrs to 2017 hrs the catering was loaded.

The aircraft was refueled at 2025 hrs. Total fuel on board (including the fuel remaining from the previous flight) made up 13.1 tons with the calculated flight fuel of 5.3 tons.

The Preflight Check was performed by the crew. The personnel of VARZ-400 were not present during the Preflight Check. Thus, there was no actual transfer of the aircraft from the maintenance staff to the flight crew and therefore no check of autothrottle deactivation (no check if the AC and DC CB’s were opened and collared, and if the autothrottle was tagged INOP).

**Note:**

*As the flight crew use the autothrottle in flight (see below), the AC and DC CB’s were activated. It was impossible to identify if the autothrottle was tagged INOP, as the cockpit was totally destroyed. It should be also noted that all the other crews flying the 6 flights on the accident aircraft after the autothrottle was deferred as per MEL, used the autothrottle in flight as well.*

The passenger embarkation and baggage loading were completed at 2049 hrs and 2052 hrs respectively. The payload of the aircraft (cargo and passengers) according to the load sheet was 8079 kg. the takeoff weight was ~54000 (with a maximum of 60554 kg) and the CG was 20.61 % MAC, which was within the B-737-500 AFM limitations.

When the passengers were on board the PIC informed them about the flight details. The investigation team was reported about an SMS sent from the aircraft at approximately 2059, in which the sender expressed his fear of the flight, as the PIC sounded as if he was drunk. The forensic medical expertise of the PIC’s body residue revealed **“the presence of ethyl alcohol in his body before death”**<sup>43</sup>. No alcohol was found in the bodies of other crew members.

The analysis of the available data showed that the Co-pilot was the PF and the PIC was the PM in the accident flight.

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<sup>43</sup> See Section 1.13 for details.

When the FDR was switched off after the previous landing (at approximately 1640 hrs), the FMS recorded position was N55° 58.6' and E037° 24.1'. The aircraft spend more than 4 hours on the ground, unpowered.

Most probably the crew made a complete alignment of the IRS before the flight. In accordance with the SOP this should be made by the co-pilot. During the alignment the aircraft position entered into the FMC should be as accurate as possible. In this case the most accurate would be the published coordinates of Stand 22 D: N55° 58.9' and E037° 25.0.

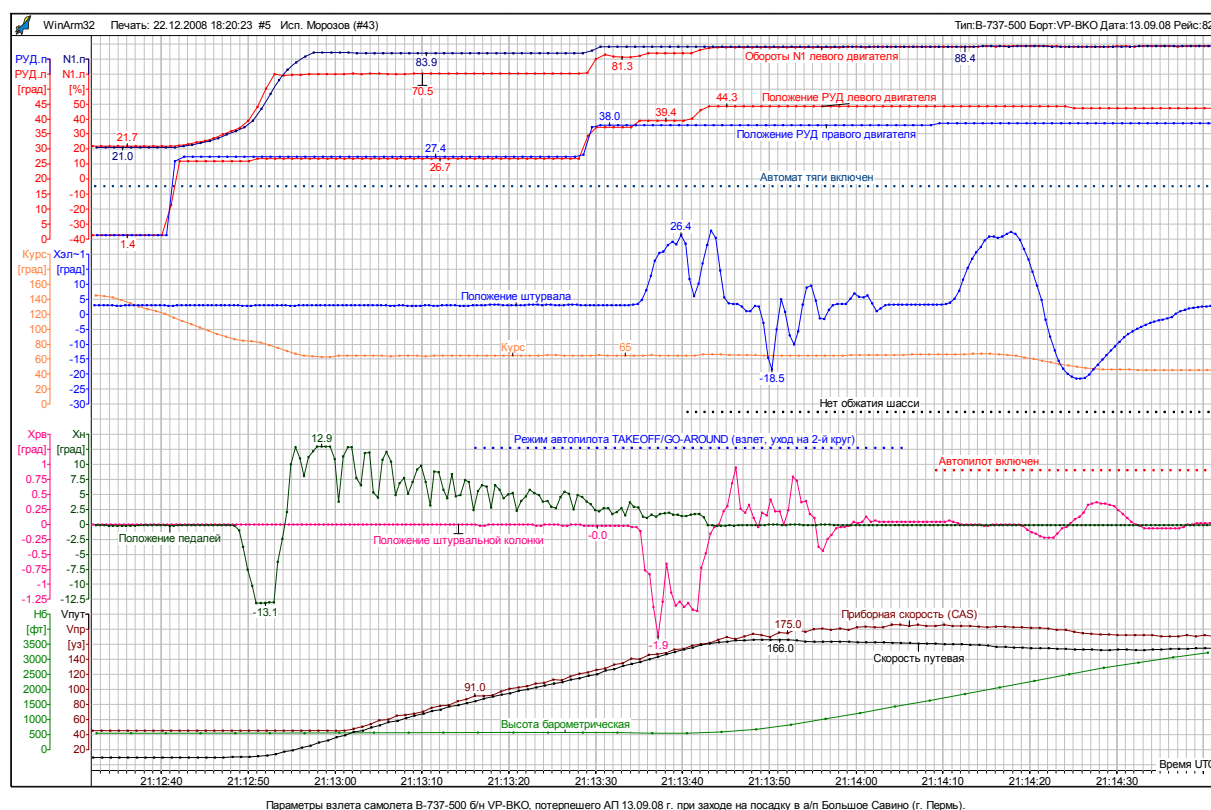
The FDR record concerning the accident flight starts at approximately 2103 hrs during the right engine startup. At that time the recorded aircraft position converted to FMS was N55° 59.9' - E037° 24.8'. Comparing the given position with the stand position it can be assumed that the latitude was entered with an error of 1 minute (approximately 1 nm). As the difference between the entered position and the ARP was within the acceptable 4 nm, the VERIFY POSITION warning was not displayed. The FMC usage section of the SOP states: “During the preflight preparation the co-pilot usually enters data into the FMC under constant oversight by the PIC who should call out the data from operational documents (OFP, LOAD SHEET, RW ANALYSIS, etc.) Thus, the error made while entering the aircraft position into the FMS is an evidence that the PIC did not properly monitor the Co-pilot’s actions during the preflight preparation.

The aircraft started taxiing at 21:06:40. According to the SOP taxiing is performed by the PIC. The autothrottle was armed at 21:11:53 (confirmed by the On/Off signal on FDR), though it was deferred as per MEL. Further, until the autothrottle automatically disengaged at 22:59:24, it was operating without any deviations in accordance with the design logics and the flight mode inputs.

As the Co-pilot was to be the PF, the PIC (who was taxiing) was to transfer control to the Co-pilot after taking the takeoff course (in case of rolling start). Then, in accordance with the SOP the Co-pilot was to increase thrust to 40 – 60% N1 and press the TO/GA button after matching the N1. The SOP recommends completing the takeoff thrust adjustment before 60 knots (~110 km/h). After the takeoff thrust is adjusted, the Captain should take control of the throttles in case of rejected takeoff and hold his hand on the throttles before V1 is reached and, if needed, adjust the takeoff thrust manually.

In fact the crew did not follow any of the SOP recommended procedures. The actual flight parameters are shown in the chart below.





The increase in thrust was done 55 degrees before lining up; the throttle position was matched at 27 degrees TLA within 2 seconds, which led to thrust increase up to 70.5 % N1 left and 84% N1 right within 17 seconds. The mentioned thrust split resulted from the right engine mistrim described above. It should be noted that such engine control method at takeoff is extremely dangerous, as if the mode is changed asymmetrically, a significant yaw moment appears due to a large split, which can lead to runway excursion if the runway friction factor is low (RWY is wet or slippery)<sup>44</sup>.

Probably at the same moment the PIC handed control over to the Co-pilot<sup>45</sup>, as the full left rudder was used first to enter the takeoff course and then full right rudder was applied to compensate the yaw moment caused by thrust asymmetry.

After the engines gained the abovementioned N1, for 20 seconds neither of the pilots controlled the engine parameters, while the aircraft continued takeoff roll up to 90 knots (~ 175 km/h). To maintain the takeoff course the Co-pilot applied full rudder. After reaching the mentioned speed the TO/GA button was pressed, which was recorded by the FDR. However, as the button was pressed after exceeding the speed of 84 knots when the autothrottle switched to

<sup>44</sup> A similar occurrence happened on April 27, 2004 at Sheremetyevo Airport with a Boeing 737-500 UR-VVB operated by AeroSwit Airline (Ukraine).

<sup>45</sup> It is not recommended to hand over control from one pilot to the other at a non-steady flight mode as it holds potential risks.

THR HOLD (the autothrottle disconnects from the throttle control linkage), the throttles did not move to the takeoff mode.

**Note:** *As the TO/GA was pressed too late, the FMC also was not able to align its position with the runway in use threshold position.*

Only after reaching the speed of approximately 120 knots (220 km/h) one of the pilots, most likely the PIC, took measures to trim the engines for the takeoff mode and match the N1. Due to the thrust split it was only possible to match both engines N1 at takeoff mode (about 88%) only after 166 knots (about 350 km/h) at 21:13:43, after the liftoff which occurred 2 seconds earlier, at 156 knots (about 290 km/h).

Right after the liftoff the FMC corrected the aircraft position with the VOR/DME of Sheremetyevo Airport, eliminating the deviation caused by the entry error made by the Co-pilot during the preflight preparation. However, the FMC correction is not connected with the IRS positioning, so the IRS was still calculating the aircraft position with the input error. Moreover, the amount of the inertial system natural drift, that can make up to 2 nm per hour, depends on the accuracy of the actual aircraft position entered during the alignment. The more accurately the position is entered during the alignment, the less will be the IRS drift during the flight.

At about 1200 ft (360 meters) over the aerodrome level, Autopilot B was engaged. When the LVL CNG was activated the autothrottle switched to N1 thrust hold.

The aircraft reached the assigned cruise flight level of 9100 m (~29900 ft) at 2130 hrs. The cruise flight was controlled by the autopilot. LNAV was used laterally, ALT HOLD and VNAV vertically. The autothrottle was engaged and for most of the flight maintained symmetric N1 by trimming the throttles at various TLA with a stagger of 13-15°.

There were no VOR/DME nav aids along the route which did not allow the FMC to correct the aircraft position. There were no complaints from the ATC about maintaining the flight route.

The CVR record starts from 22:38:32. At that time the aircraft was at 9100 m, 200 km (110 nm) away from Perm airport.

According to the SOP, 80-100 nm (about 10 minutes) before the top of descent the crew should start the DESCENT PREPARATION procedures. This preparation begins with listening to the ATIS information. The CVR record does not contain any evidence that the crew listened to the ATIS. However, the following communication showed that the crew had information about the QFE, so they could have listened to the ATIS before the start of the available CVR record.

The CVR readout showed that from the start of the available record until the top of descent (at 22:45:30) the pilots were totally engaged with programming the FMC for the descent and approach at Perm Airport. According to the SOP, programming of the FMC for approach is one of the tasks that should be done by the PF during the descent preparation.

The investigation revealed that the FMC memory did not contain the standard instrument approach patterns (STAR) for Perm Airport, so the crew had to enter the fixes of the pattern. The communications analysis showed that the crew, especially the Co-pilot, experienced obvious difficulties with programming the approach pattern manually and entering data with CDU. At this stage, when the FMC did not show the distance to Mendeleyevo NDB, the Co-pilot, who did not have much experience in operating with miles and knots, tried to calculate the top of descent using the more usual system of measurement in kilometers.

The fix which was several times mentioned by the crew and called by the Co-pilot as Sierra, S21 or C21 is most probably the glideslope entrance point for RWY 21. This fix is designated in the FMS database as CI21. The crew tried to eliminate the discontinuity in the current flight between this fix and the fix they had entered before. This discontinuity most likely was caused by the FMC inability to pass the three fixes successively with the preselected speed.

**Note:** *While pronouncing the CI21 in English the Co-pilot makes numerous mistakes which are characteristic of Russian speakers who have low level of the English language.*

Being engaged in the FMC programming, the crew did not complete the Descent Preparation and skipped the Landing Briefing and the Before Descent Checklist.

At 22:44:55 the PIC reported to the Controller: “9-600, top of descent over Mendeleyevo 5-100” and the Controller cleared descent to 4500 m, “when crossing 5-100 contact Approach 127.1. You will have SSR control”. As the PIC was maintaining the radio communication, the Co-pilot must be the PF at that stage.

It should be noted that the Controller gave all altitudes in meters, though the aircraft systems required feet. According to the analysis, the crew did not have significant difficulties converting meters to feet. One of the drawbacks in the operating procedures was that the crew failed to cross-check each other when confirming the assigned altitudes and controlling the settings, which is clear from the internal communications in the cockpit.

The descent was performed by the Autopilot in the LNAV/VNAV mode, at idle. Initial descent was conducted with vertical speed up to 5000 ft/min (~25 m/sec), and further, approaching Mendeleyevo, the rate of descent decreased 2200 ft/min (~11 m/sec).

During the initial descent and further one of the pilots changed the flight modes without informing the other, there were no callouts regarding the flight mode changes displayed on the FMA.

**Note:**

*SOP, Management and Responsibility:*

*“During automatic flight (A/P u A/T on), which is the basic flight mode, the PF shall (first informing the PM):*

- change flight director modes in the MCP or FMC;*
- engage and disengage the A/P and A/T;*
- inform the PM about the changes in flight modes and FMA indications.*

*...*

*The activation (change) of automatic flight modes shall be monitored by the FMA indication.*

*The changes in FMA indications as well as changes in the designated altitude, speed and course of the flight shall be immediately announced:*

*a) during the automatic flight mode:*

- by the PF. They are monitored, confirmed and recorded in the OFP by the PM”<sup>46</sup>.*

At 22:45:52 the PIC reminded the Co-pilot of crossing FL 300 and the necessity to check cockpit pressure. This can seem strange at first, as flight level 9100 m equals to 29900 ft, so the aircraft during its descent could not have passed FL 30000 ft. However, further the PIC not once confused flight levels, frequencies and forgot their callsign. Such small mistakes can be made when a person is not in their optimal operating condition. The PIC’s speech instrumental analysis<sup>47</sup> showed that at least for the last 30 minutes of the flight he experienced a high level of emotional stress, 40-70 % higher than the normal operational stress. The most probable cause of

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<sup>46</sup> It seems obvious that the requirements to record the values in the OFP concern only the changes in altitude, speed and course. However, when reading the given text literally, it requires recording also the changes in the FMA modes, which is impracticable, and can be actually dangerous at those flight phases when the modes change rapidly, as it will distract the crew from flying and monitoring. This ambiguity can also lead to false assumptions that the pilots should announce only those changes that refer to the altitude, speed and course.

<sup>47</sup> See Section 1.16.6 for analysis details.

this high level of stress was the presence of ethyl alcohol in his body and/or the accumulated fatigue, most likely the combination of these factors.

It should be also noted that the speech of both pilots was full of expletive words and unjustified spiteful remarks concerning the flight attendants and the Airport Control Service, as well as dispersed discourse not related directly to the current tasks, which distracted them from the urgent flight control tasks. The mentioned behavior hampered the optimum operational concentration of the crew on the whole, leading to fragmentation and distortion of the actual flight situation image, which, in case of unexpected complication and changes of flight conditions, inevitably leads to erroneous actions.

At 22:46:40 the PIC tells the Co-pilot to maintain the radio exchange. Thus, according to this formal evidence, from that moment the PIC was the PF and the Co-pilot was the PM. The analysis showed, however, that the Co-pilot was flying while the PIC interfered with the flight control from time to time.

At 8100 m the PIC turned on the cowl anti-ice, which was confirmed by the relative ANTI-ICE ON signal on the FDR. According to the SOP, this procedure is to be done by the PM.

At 22:48:40, when crossing FL 200, the crew made another correction of the altitude indicators and the pressurization system.

At approximately 22:49:30, at 5100 m, the crew passed over Mendeleyevo fix, which was reported by the Co-pilot to the Controller. The controller instructed the crew to contact Perm Approach.

After contacting the Approach Control, the Co-pilot reported continuing descent to 4500 m. The Controller confirmed passing Mendeleyevo and cleared the crew to continue descent to 2700 m, approach pattern Mendeleyevo 4 Bravo (MN 4B). The Co-pilot erroneously confirmed descending with approach pattern Mendeleyevo 4 Alpha (MN 4A). The Controller corrected the Co-pilot, and then the latter gave correct information.

In defiance of p. 5.3.2.1 of FAR “Radio Communication in Airspace of the Russian Federation”, approved by Order No. 109 by the FTOA on November 14, 2007, the crew did not report to the Controller that they had received the ATIS information, while the Approach Controller did not request if the crew had this information.

**Note:** *ATIS information for 2230 hrs: “Perm ATIS, information E, 22:30,*

*ILS approach, RWY 21, wet, friction factor 0.5, transition level 1800, TWY A, TWY M closed. If there is no danger to flight safety, flight level change must be mandatory requested from the Controller, wind 50 degrees 6, altitude 100 m – 60 degrees 7, circuit 100 degrees 15, visibility 5 km, light rain, mist, clouds overcast 240, temperature 6, dew point 6, QFE 748 mm, 997 hPa, no significant changes. Report receiving information E”.*

According to the cockpit communication, the Controller’s instruction to follow pattern 4B confused the Co-pilot, as he most likely expected to follow the Mendeleyevo 4 Alpha approach pattern, which is confirmed by his slip of the tongue when giving confirmation. The crew did not conduct additional Landing Preparation after the change of the arrival pattern (required by p. 7.6.2 of CAFOM-85).

**Note:**

*The MN 4A approach pattern follows from Mendeleyevo with the course of 84° until the turn point SINRA, then with course 80° leads the base turn for RWY 21.*

*The MN 4B pattern follows from Mendeleyevo with the course of 112° until the final turn for RWY 03, further moves with this course to the PX outer marker, makes a left turn to the course of 3° and then proceeds to the base turn for RWY 21.*<sup>48</sup>

The analysis showed that by the time the Ground Controller received information about the approaching AFL 821 (at 2236 hrs), he had already received a request from the crew of an A-319 aircraft operated by Lufthansa to takeoff with the course 32° M. The request was caused by the presence of tailwind on the takeoff course 212° M. The aerodrome shift supervisor dispatched the A-319 with the course of 32° M, on the basis of the PIC’s decision in accordance with the Russian AIP (Volume 2, AD 1.1, p.1.C): “Captains of western aircraft flying to Russia, take an independent decision about the practicability of takeoff or landing and bear absolute responsibility for the decision they take.”

At 2246 hrs the Approach Control received from the Ground Control the shift supervisor’s instruction to direct the AFL 821 to the PX outer marker with the MN 4B approach pattern, due to another aircraft taking off with the course of 32° M, to provide safe separation.

After the crew confirmed the MN 4B approach pattern, they started discussing this information. The Co-pilot said at 22:50:15: “Hey how is Bravo... Bravo different... <expl>”.

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<sup>48</sup> The charts with approach and landing patterns can be found in Section 1.10.

This discussion was interrupted by a flight attendant who entered into the cockpit and informed that the FASTEN SEATBELTS sign does not activate. The PIC said that it was too early to switch the sign on. The aircraft at that time was at about 15000 ft. According to the SOP, the minimum altitude of the sign activation is 10000 ft, while the recommended altitude was 20000 ft.

Then the PIC asked the flight attendant for tea. It was not clear from the further communication if the tea was brought or not. According to the SOP, “Pilots should eat in turns during cruise flight in favorable conditions.”

At 22:50:37 the Controller explained to the crew the reason for using the MN 4B approach pattern: “Aeroflot 8-2-1, expect approach via outer marker, for your information: aircraft lining up for departure, wind not suitable for it, heading 213... 212”.

After the crew received this information, the Co-pilot asked the PIC: “So what are we going to do? Present course”? The PIC requested the Controller about the wind and was replied that the tailwind component was 5.7 m/sec (landing course 212°). Then the PIC informed the Controller that such wind allows approach with course 212. The Controller explained again that he had informed them about the reason for Lufthansa's crew changing the takeoff course. Concluding this exchange the PIC at 22:51:29 requested the controller: "... what course", which was replied with: "...course to outer marker”.

**Note:**

*In accordance with p. 5.3.2 Radio Exchange Phraseology During Approach of the FAR “Radio Communication in Airspace of the Russian Federation”, approved by Order No. 109 issued by the FTOA on November 14, 2007, when the crew requests course and the Controller assigns it, it means transition to radar vectoring.*

*ICAO DOC 4444 defines **vectoring** as Provision of navigational guidance to aircraft in the form of specific headings, based on the use of an ATS surveillance system.*

*According to p. 2.11.3 of the FAR “Radio Communication in Airspace of the Russian Federation”: “If the crew receives clearance or instruction that they cannot follow, they shall report this to the relative ATC, using the phrase “unable to follow” and state the reason.*

Thus, according to the Controller statement, as the crew at 22:51:35 confirmed “course to outer marker, roger”, without clarifying the pattern to follow and without requesting additional



information, the Controller assumed that the crew was ready to follow the assigned track and he continued vectoring.

**Note:** *The record of controllers' internal communications revealed that one of them expressed concern: "You will confuse the crew", which referred to the deviation from the standard approach pattern.*

The Controller's instruction regarding proceeding to the outer marker caused a rather annoyed reaction inside the crew, especially by the PIC, which was confirmed by the instrumental speech analysis (Section 1.16.6, time 22:51:40).

Until that time the crew continued flying with the course of 85°, which is consistent with the MN 4A approach pattern. At 22:51:45 the crew changed the LNAV mode for HDG SEL and took a course of 104°. Before that, at 22:50:56, the VNAV mode was changed for LVL CHG.

At 22:52:25 the crew activated LNAV/VNAV again, and as probably the current flight plan had not been changed, the aircraft turned back to course 85° with a different vertical speed of descent. After this, the crew probably selected PX outer marker as an active flight plan fix, and the aircraft turned to course 108°.

At 22:53:04 the longitudinal mode of the autopilot was changed from VNAV to LVL CHG.

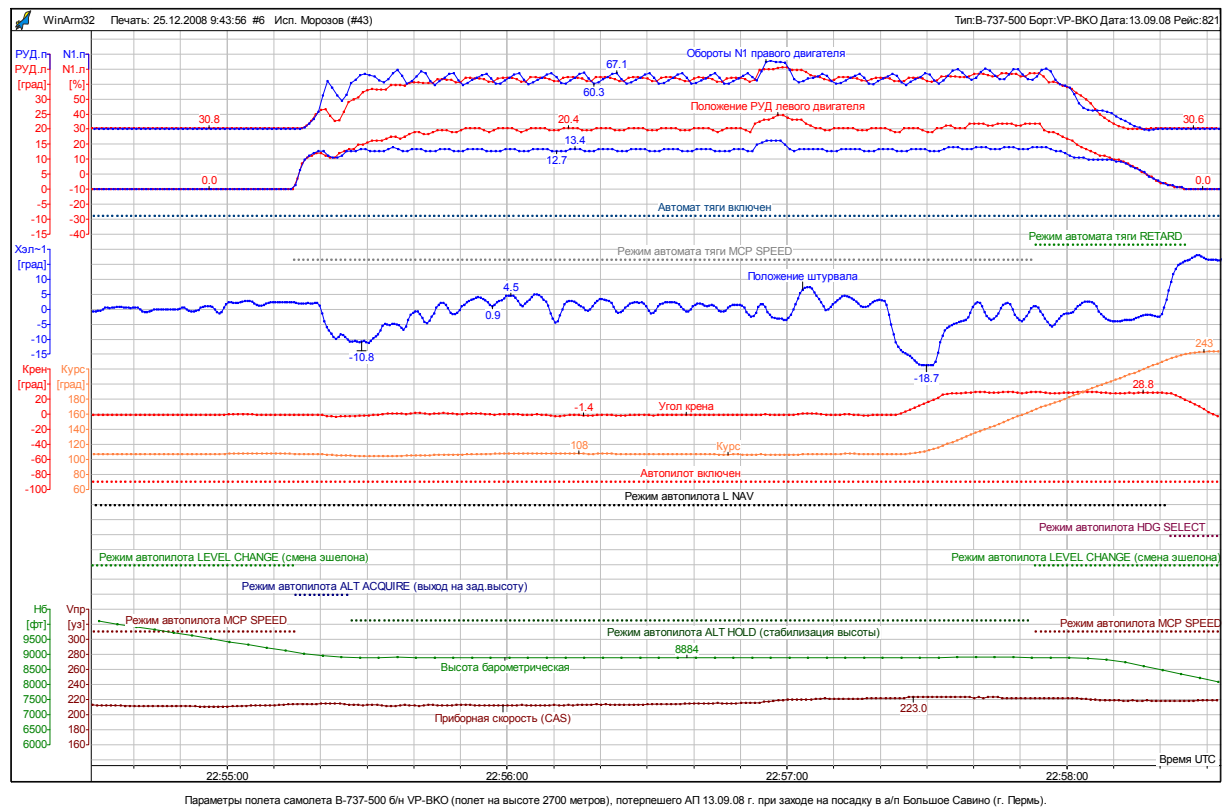
By instructing the crew to proceed to the outer marker, the Controller in fact cancelled his previous instruction to follow the MN 4B approach pattern, but did not clarify the landing course. Until 22:53:30 the crew was trying to guess their landing course. The Co-pilot even suggested several times that they should enter the marker beacon position into the CDU with the landing course of 32°. Although they were unsure of the following approach pattern, the crew did not request further instructions from the Controller. At 22:53:32 the crew, who had not yet determined the following pattern, decided to wait for the Controller's further instructions. When the Co-pilot suggested approaching with course 32° the PIC replied: "I don't know. He'll tell everything."

At 22:54:06 the PIC requested the Controller "...is the aircraft going to depart?" and was replied with "...now departing".

By that time (22:54:20) the PIC in fact had assigned the flight pattern after the outer marker by himself and addresses the Controller with: "Aeroflot 8-2-1, following your clearance we are ready for downwind leg, approach 2-1-2 ready..." The Controller's response actually

confirms the PIC's assurance of the left turn to downwind leg: "... roger now maintain 2700, course to marker".

The aircraft continued descent. At 10000 ft the crew did not check the altimeters or cabin pressure. They reached 2700 m (~8900 ft) at 22:55:25 (see chart below) and the Co-pilot reported it to the Controller at 22:55:54. The Controller instructed them to maintain 2700 m.



After reaching 2700 m, the longitudinal mode of the autopilot changed to ALT HLD. From that time until the top of descent to 2100 m at 22:58 there were sinusoidal oscillations of N1 (ranging within 6%), accompanied with control column deflection (ranging within 4°) and throttle deflection (range of 1°), which went unnoticed by the crew according to their communications. Such oscillations were caused by the operation of the autothrust that was "hunting" the N1 (provided the split was significant).

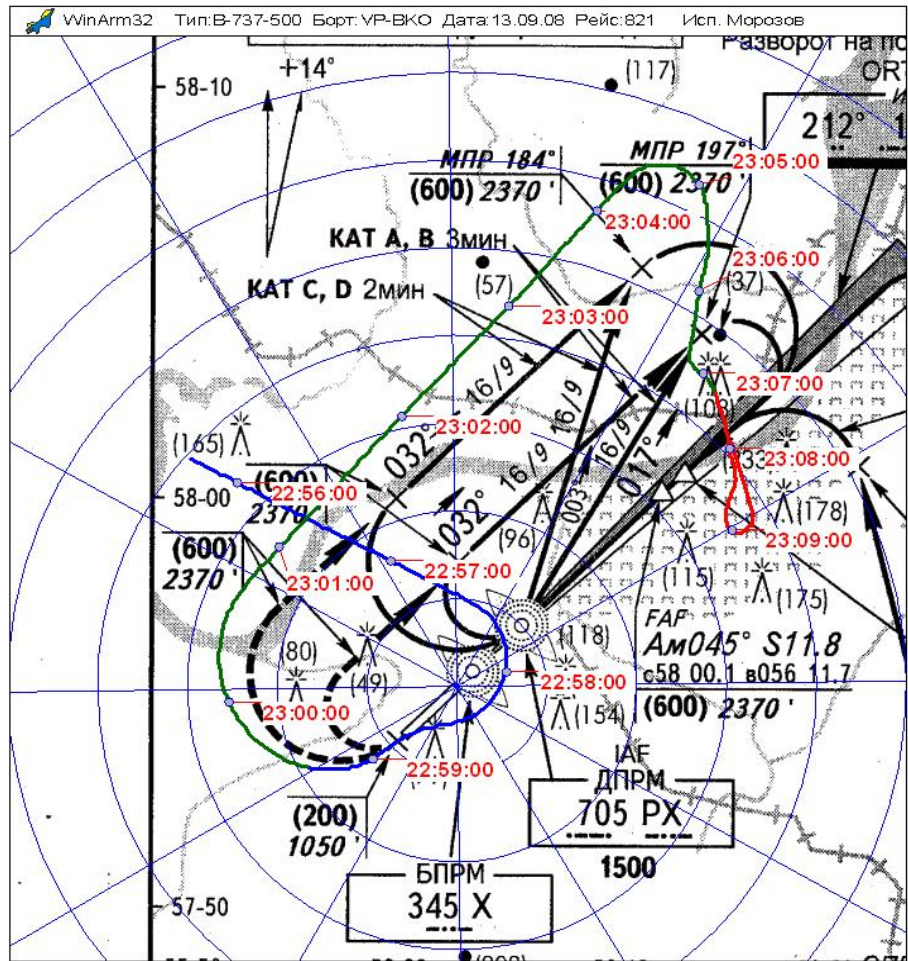
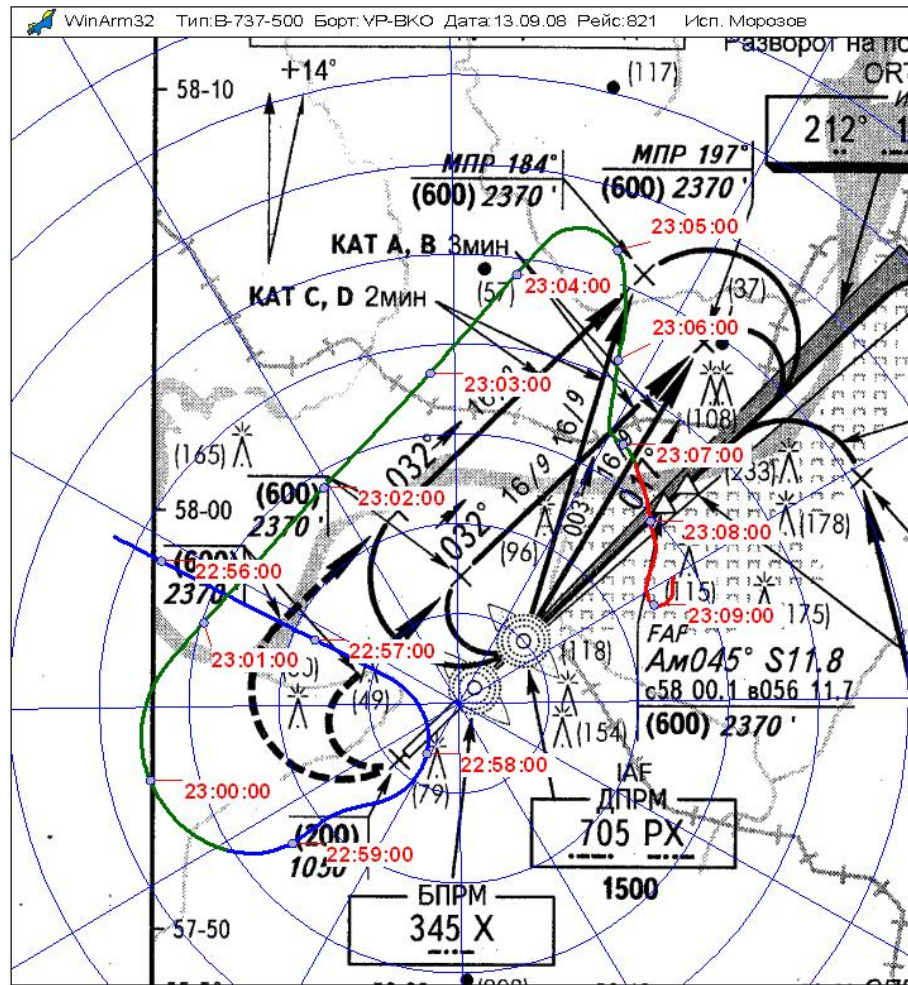
The aircraft was maintaining 2700 m. By that time the error in the FMC aircraft positioning was over 4.5 km. Such an error was caused by the natural drift of the IRS during the flight as well as the initial error made by the crew while entering the aircraft position during the alignment, and also by the inability to correct the positioning via the GPS or with the help of signals from nav aids which are not present along the flight route or at the destination airport. The crew should have observed the warning IRS NAV ONLY.

**Note:** When flying Track R487 from Sharanga NDB to Lukod CRP, the

*aircraft was about 230 km from Kazan VOR/DME. However, correction of the current position could not be made, as the aircraft was beyond the 25 nm from the beacon.*

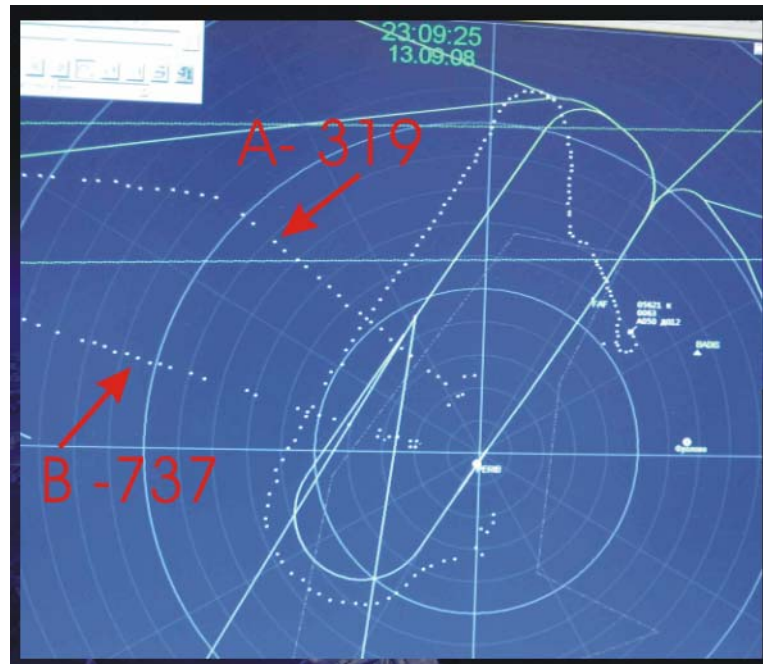
The chart below shows the actual flight path (left-hand chart), that goes approximately through the runway center and also the path that the crew saw on the navigation display (right-hand chart), that goes through the PX outer marker. The difference between the actual aircraft path and the one observed by the crew, taking into account the Controller's instruction to proceed via the marker, assumes that the crew did not use the ADF to monitor their position, nor did they tune the frequency of the outer marker.

**Note:** *One of SOP procedures during descent is monitoring the accuracy of FMC navigation with the help of other aids: VOR/DME, NDB and ATC information.*





The Controller was monitoring the flight on the radar (see picture below). According to his written explanations, he did not inform the crew that the aircraft was not moving directly to the marker beacon and did not require the crew to change the course, as their flight path provided safer separation between the taking off A-319 and the Boeing 737. At 22:56:30 the A-319 and the Boeing 737 were at a minimum distance of 6 km from each other, and their altitudes were 1100 and 2700 m respectively.



At 22:57 – 22:57:20 the crew were extensively discussing the direction of the next turn. The PIC was sure that they would have to turn left, while the Co-pilot thought it would be right. This discussion was interrupted by the Controller who instructed them to turn right, take back course and descent to 2100 m. The right turn was necessary (instead of turning left and proceeding to base turn), as the aircraft had to descend to 600 m before making the base turn.

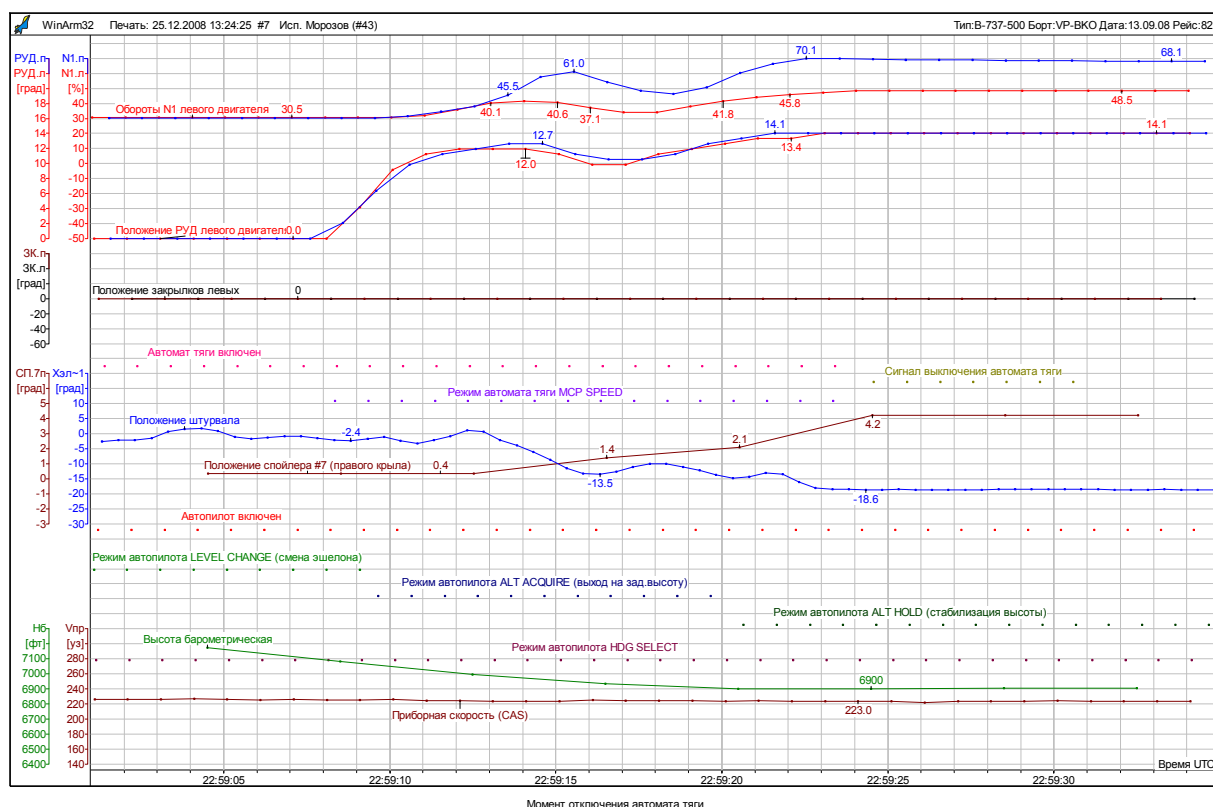
The Controller instructed the crew to turn right, back course, but did not clarify the runway landing course. The PIC was sure that it was back with reference to course 212, and was only surprised by the direction of the turn. The Co-pilot thought that the back course was estimated with reference to runway 32, which confused the PIC.

As the next active point in the flight plan after the outer marker was most probably the threshold of RWY 21, the aircraft, being in the LNAV mode, even before the Controller's instruction, at 22:57:23, started turning right with a bank of up to 30°. Thirty seconds after the turn started, the crew set a newly assigned altitude of 6900 ft (~2100 m) and switched to the LVL CHG mode, the aircraft started descending. At 22:58:20, after passing abeam of RWY 21 point, being unable to catch it at the IAS of 220 knots, the aircraft, with the LNAV selected,

started turning left, which confused the crew (22.58.17 – Co-pilot: “Where’s it going, <expl>? I don’t understand where it’s going?”)

The PIC commanded to select the HDG SEL mode and enter the back course, which was done and the aircraft continued the turn to course 30°, with an average right bank of 20°.

During the turn, while reaching 2100 m, the autothrottle was automatically disengaged. The analysis showed that the autothrottle disengagement was as per design<sup>49</sup>, as the following conditions were met simultaneously at 22:59:23 (see the chart below): flaps less than 12.5°, thrust split more than 700 lb, and spoiler on any wing deflected more than 2.5°.



These conditions were caused by the following chain of events. The aircraft, being in the LVL CHG mode, was reaching the assigned flight level of 6900 ft (~2100 m). Laterally, HDG SEL mode was active, and the aircraft was turning with a bank of 20°. Both engines were operating at idle. This was set by the autothrottle before starting descent from 2700 m. According to the logics of the joint operation of the autopilot and the autothrottle, idle mode is maintained until LVL CHG is changed to ALT ACQ<sup>50</sup>. After the autopilot mode was changed, the autothrottle switched to SPEED mode. To maintain the speed when reaching the assigned flight level, the autothrottle starts moving the throttles synchronically to increase thrust. When

<sup>49</sup> See also Section 1.16.1.

<sup>50</sup> This switch of modes is automatic and does not require the pilots' input.

both engines' N1 reach 40%, the autothrottle starts automatically matching them, by staggering the throttles. If during this matching for some reason the N1 of one engine drops lower than 40%, the matching stops.

With regard to this portion of the accident flight, the ALT ACQ mode was activated at 22:59:09. Simultaneously, the autothrottle SPEED mode was activated and both throttles started advancing. At 22:59:13 the N1 of both engines reached 40% and the autothrottle started matching them, independently moving the throttles. However, after 3 seconds left engine N1 dropped lower than 40%, so the matching stopped. By that time the N1 split was about 20%, which led to a significant left banking moment (created because of right sideslip) and forced the autopilot to apply right wheel to maintain the roll angle established during the turn. The right wheel caused the deflection of ailerons and spoilers on the right wing. Finally, at 22:59:23, after the spoiler deflected more than 2.5°, the autothrottle was automatically disengaged, which is confirmed by recording of the On/Off signal on the FDR. It should be noted that in previous flights the autothrottle was also disengaged several times in similar conditions.

The autothrottle disengagement is accompanied with a moving of the A/T switch to OFF and the A/T WARN activation. According to the communications, the crew noticed the autothrottle disengagement. At 22:59:30 the crew switched off the warning, as the corresponding On/Off signal disappeared. The PIC also told the Co-pilot to control the engines manually. It can be assumed that from that time the Co-pilot was again PF, though actually there was no transfer of duties.

During the rest of the flight the crew manually moved the throttles synchronically, and neither of the pilots monitored N1 (according to the SOP, it is the PM's duty to monitor the engines). The crew did not attempt to match the N1. At some portions of flight it led to a significant split in engine thrust (up to 4700 lb or 2130 kg) and created a significant yaw moment and rolling moment to the left. The crew did not apply the rudder to compensate the sideslip, so they had to use the wheel (first the autopilot did this, but after its disengagement the PF continued the same) to balance the aircraft. ***After analyzing the pilots' actions during a flight with thrust asymmetry, the investigation team concluded that both pilots lacked basic skills for flying multiengine planes with spaced-apart engines.***

**Note:**

*A selective analysis of control inputs of the other pilots who had flown the same aircraft revealed that most of them acted in the same way.*



The aircraft entered the back course at 23:00:45. At 23:01:14 the Controller instructed the crew to descend to 600 m, QFE 997 hPa (748 mm mercury). The PIC confirmed descending and, as he was still unsure of the landing course, he clarified: "... and... ILS approach", which was confirmed by the Controller: "...expect ILS approach". So only at 23:01:30, 12 minutes after receiving the first instruction to follow MN 4B pattern, the crew finally understood that they will approach runway 21, as the ILS system is not installed for the other runway. The fact that the crew was unsure of the landing course distracted them from completing other tasks and probably increased their level of emotional stress.

At 23:01:30, without any command, the flaps were extended to 1°. Simultaneously the autopilot LVL CHG mode was activated, but the throttles were not moved to idle.

By that time the aircraft airspeed increased up to 232 knots (430 km/h), as after the autothrottle disengagement the engine thrust was higher than required for level flight. The PIC responded this at 23:01:45 by commanding to extend spoilers and set a selected speed of 190 knots, which is recommended for Flaps 1 if the weight is less than 53070 kg.

**Note:** *According to the calculations, the aircraft landing weight was about 49700 kg.*

The spoilers were extended at 23:01:47 for 30 seconds, and the throttles moved to idle, which reduced the speed to the assigned 190 knots by 23:02:30.

**Note:** *After the throttles were move to the TLA of less than 10°, with landing gear retracted and Flaps 1, an aural alert activated. The alert sounded for over 12 seconds, before the crew deactivated it. The PIC expressed obvious irritation, trying to find the relative pushbutton for quite a long time: "... where's that pushbutton?"*

During all this time, despite the activated LVL CNG mode, the aircraft did not descend. It is explained by the autopilot's logics: if the new MCP SPEED and LVL CNG are selected simultaneously, first the aircraft tends to reach the selected speed and then it will start descending.

At 23:02:30 the crew set the ILS frequency (109.9 MHz) and selected manual mode on both NAV selectors.

At 23:02:38, after the Co-pilot's callout, the flaps were extended 5°. Most likely a lower speed was also selected, which reduced the rate of descent.

At 23:03:00 the Controller gave the crew the latest wind information: 50 degrees, 5 m/sec, tailwind component 4.8 m/sec. The crew confirmed that this tailwind component allows them to land and requested base leg.

**Note:** *According to the aircraft actual position at that moment, it was too early to make the base turn so far, but the navigation display had a map shift of over 4.5 km to the north which most probably caused the crew to request turn to base leg.*

The Controller informed the crew that their radial distance was 16 km and the lateral deviation was 10 km, and noted that the current altitude was about 1800 m by asking: “Are you descending? My radar shows 1800”.

This question led to an intense reaction of the PIC, who asked twice emotionally: “”How low must we descent? How low must we descent?”. This response as well as the previously mentioned small mistakes made by the PIC (callsign, frequencies, flight levels), assume that his level of emotional tension and situational awareness were far from optimum.

The Co-pilot replied that they must descent to 600 m, and the PIC immediately reported to the Controller that they are descending 600 m. Then followed the Co-pilot’s phrase: “<expl>, why doesn’t it descend, <expl>? I’ve pressed heading select, <expl>.” This phrase, as well as some other phrases, said by the Co-pilot earlier, show that the Co-pilot had insufficient knowledge of the AUTOFLIGHT modes and their combinations<sup>51</sup>. The PIC in an annoyed manner explained to the Co-pilot that he should select LVL CHG. In fact, as was mentioned before, the LVL CHG mode had been activated earlier, but the aircraft descended slowly, as it reduced speed first.

Further, the vertical speed of descent increased to 1500 ft/min (~7.5 m/sec).

At 23:03:53 the PIC again requested right turn to landing course. As the aircraft was at 1700 m at that moment, with the transition level of 1800, the Controller requested confirmation that the crew had set the QFE. The PIC confirmed that they did and again, for the third time now, requested right turn to the landing course.

**Note:** *1. The FDR data showed that the QFE was set only at the Co-pilot’s altimeter. The PIC did not set the QFE on his altimeter. According to the SOP, the PIC who was the PM, was to cross-check the pressure settings and altimeter*

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<sup>51</sup> Similar problems for pilots when using AUTOFLIGHT modes were noted by investigators of previous accidents to modern highly automated aircraft (See final report on A-320 accident near Sochi on May 03, 2006).

*readings.*

2. *At that stage the crew was to read the APPROACH CHECKLIST. The CVR does not contain this checklist.*

The Controller informed the crew that their radial distance was 20 km and lateral deviation 10 km, and cleared them for the base turn when ready. The PIC replied that they were descending 600 and making the base turn. The Controller cleared the crew for the base turn.

In that case the Controller was in fact vectoring the aircraft, as was mentioned before. It should be noted that Russian regulatory documents of civil aviation do not completely consider all the requirements set forth for vectoring in ICAO Doc. 4444<sup>52</sup>. Probably it accounted for the fact that the Controller cleared the crew for the base turn when ready, but did not assign the start of turn and the next heading.

In accordance with the approach pattern, before making the base turn the aircraft should be at 600 m QFE. In fact, the aircraft was 750 m higher than that, which created extra complications for the crew and was not considered duly by the Controller when he was issuing the clearance.

The crew started executing the base turn at 23:04:15 with the HDG SEL mode. Knowing that the aircraft is much higher than the required altitude of 600 m, the PIC during the turn decides to extend the landing gear and set Flaps 15, probably in order to increase the rate of descent and reduce the airspeed. After Flaps 15 the selected speed was reduced to 150 knots (according to the CVR record), which again resulted in a certain decrease in the rate of descent.

**Note:** *According to the standard ILS approach pattern, it is recommended to extend the landing gears and set Flaps 15 only after glide slope being alive.*

Due to the low ground speed, the roll of 25 degrees during the turn and taking into account the north-easterly wind at the altitude, the turn radius was not large. Because of the accumulated FMC positioning error, absence of VOR/DME or ILS/DME at Perm Airport, the crew having only the navigation display indications could have erroneously assumed that the aircraft was at the estimated distance from the runway threshold, which allowed them to continue approach. In fact, the aircraft position was almost 5 km closer.

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<sup>52</sup> The differences are specified in the ATC Group Report, which is in the investigation file.

At 23:05:15 the aircraft entered course 160° after the turn. According the information on the navigation display, following this course the aircraft would have intercepted the landing course at a distance of 14-15 km from the runway threshold (distance of the glideslope entrance point 12.6 km). In fact the aircraft was intercepting the landing course at 9-10 km from the runway threshold, which was closer than the glideslope entrance point, so the glideslope would not have been intercepted at 600 m.

Therefore, it is impossible to use the FMS as a primary source of navigation during the approach maneuver if it is not accurate enough. In such cases, the landing course should be intercepted with the help of vectoring or using the standard ILS approach pattern, via some navigation aid, like NDB, as was provided by the MN 4B approach pattern at Perm.

The Controller estimated on the basis of the radar data that the aircraft would join the landing course at a distance of 9-10 km, and informed the crew about it, but did not give any instructions to change the course. The crew received the information and reported: "...high-lift devices deployed, ready for landing".

**Note:** *According to p. 8.9.4.1 of ICAO Doc. 4444 «Vectoring will normally terminate at the time the aircraft leaves the last assigned heading to intercept the final approach track». The Radio Exchange Phraseology During Approach of the FAR "Radio Communication in Airspace of the Russian Federation" does not provide for the standard phrase to terminate vectoring procedure.*

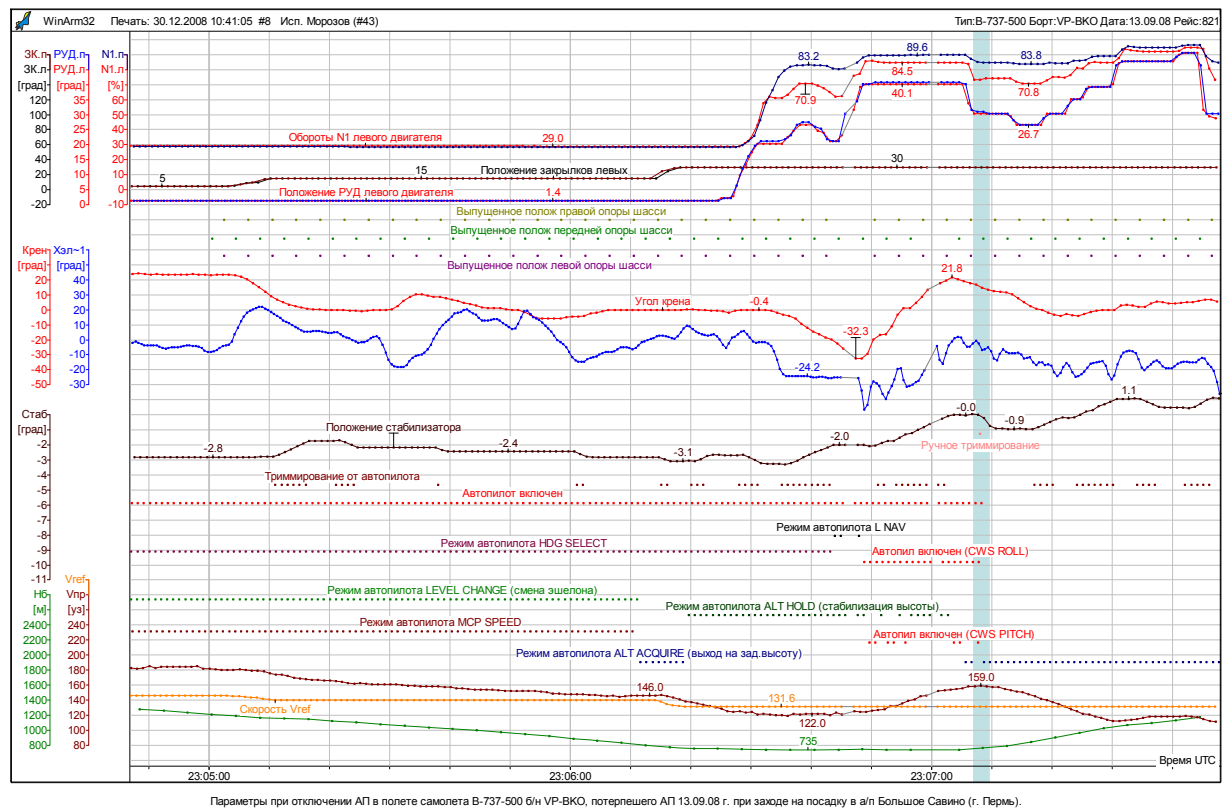
At 23:06:04 the Co-pilot called out to set Flaps 30. According to the standard procedure, the flaps landing configuration should be set after intercepting the glideslope. The PIC did not respond to this callout, as he was engaged in maintaining exchange with the Approach Control, who transferred the aircraft to the Ground Control. The Co-pilot repeated the callout twice before it was followed. After the third time, the PIC, being highly stressed, asked the Co-pilot to do everything by himself: flaps settings, MCP speed settings, thrust control. In fact the crew started to lag behind the aircraft, and due to lack of experience could not catch up with the tempo of the required procedures.

At 23:06:11, while the flaps were moving to 30°, the autopilot started maneuvering the aircraft to the assigned altitude of 600 m (see picture below) <sup>53</sup>. At the beginning of that maneuver the airspeed was about 150 knots (consistent with the required speed for Flaps 15), the throttles were positioned at idle, the landing gears extended. As the drag was increasing due to

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<sup>53</sup> Pressure altitude on the picture is based on the standard pressure of 760 mm mercury. The actual QFE at the time of the accident was 748 mm mercury.

the increasing vertical acceleration created by the autopilot to enter level flight, and as the flaps were extended to 30, the airspeed started decreasing briefly. At 23:06:20 the autopilot pitch mode changed to ALT HOLD to maintain the altitude of 600 m.



At 23:06:22 the airspeed reached the Vref, which equaled 130 knots for the actual landing weight, and continued decreasing.

**Note:**

*The analysis conducted by the investigation team with the help of line pilots flying Boeing 737 revealed that the Co-pilot did not have steady skills of manual thrust control. In particular, he could not foresee the required thrust change after the extension of high-lift devices, but only reacted to the actual changes in speed and often moved the throttles disproportionately, which led to a need to adjust the thrust constantly and distracted the Co-pilot from monitoring the other flight parameters. The lack of skills that the Co-pilot demonstrated in controlling speed and other flight parameters during the approach was several times noted by the instructor who trained him during his transition training.*

The crew, most probably the Co-pilot, started to increase N1. The throttles were shifted synchronically, first to 27° and then to 40°. After TLA 27° the thrust split made up 13% N1, which, without being compensated by the rudder, resulted in a significant left banking moment. To compensate the bank, the autopilot applied right wheel up to the autopilot limit (~25° with flaps extended).

**Note:** *The maximum control surfaces deflections occur at 87.5 degrees of wheel deflection while the maximum wheel deflection (mechanical stop) is 107° due to cable stretch.*

The actual autopilot wheel was not enough to compensate the disturbing moment from the engines, so from 23:06:35 the aircraft started banking left with a rate of 2 °/sec. Being engaged in the speed control, the Co-pilot did not notice the start of banking.

The PIC at that time was maintaining the radio exchange with the Ground Control, clarifying the latest weather conditions. The cloud base was at 240 m, so no ground reference points were visible.

At 23:06:44 one of the pilots selects the LNAV mode. Most probably it was done by mistake, when trying to select the VOR/LOC mode (the mode pushbuttons are next to each other), which was actually selected a bit later.

Only at 23:06:48, when the left bank reached 32°, the Co-pilot applied more right wheel, switching the autopilot to the CWS ROLL mode.

**Note:** *The force required to switch the autopilot to the CWS ROLL mode is 10 lb (~ 4.5 kg).*

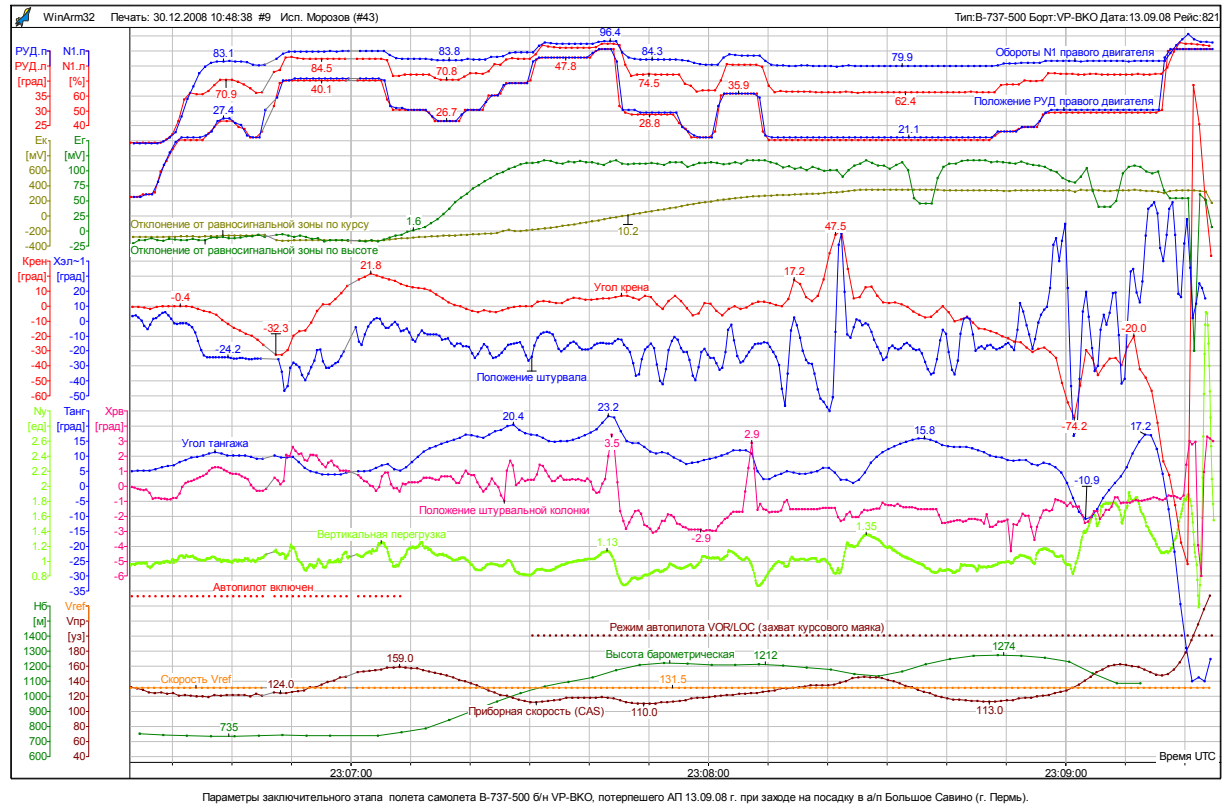
Probably the Co-pilot was not completely familiar with the CWS mode, as he also inadvertently applied force in pitch channel, switching the autopilot also to the CWS PITCH mode.

**Note:** *The force required to switch the autopilot to CWS PITCH mode is 21 lb (~ 9.5 kg).*

As the Co-pilot was controlling the flight in the CWS ROLL and PITCH modes, concentrating on the roll control (by 23:07:21 he had managed to recover from the bank) and the increasing speed (up to 160 knots by 23:07:08), the aircraft started climbing (which was assisted by a significant noseup moment from the engines operating at 85-90% N1) and 20 seconds after switching to the CWS mode (at 23:07:08), the Co-pilot applying manual stabilizer trim (most

likely inadvertently) disengages the autopilot. Neither of the pilots made a relevant callout though one of them switched off the alert that was activated.

The chart below shows the aircraft flight parameters during the final portion of the flight, after the autopilot was disengaged. The FD's on both EADI's were active.



The Co-pilot noticed only the increase in speed, and he reduced the engine thrust (at 23:07:07) without monitoring the pitch.

As the Co-pilot did not try to compensate the noseup pitching moment and did not notice the increase in pitch (up to 20° by 23:07:27), the Co-pilot again allows the speed to drop to 110 knots (~200 km/h), which is 20 knots (~35 km/h) lower than the Vref.

**Note:**

*Further decrease in speed, which could have resulted in stick shaker activation, was prevented by the Speed Trim System that applied the nose down stabilizer<sup>54</sup>.*

At 23:07:24 the PIC selects the VOR/LOC mode. As the aircraft was almost on LLZ centerline, the localizer was captured. Only then the PIC, who had not monitored the aircraft attitude, noticed the decrease in speed and told the Co-pilot to “increase”.

<sup>54</sup> For details about the Speed Trim System see Section 1.16.3.



Responding to the speed decrease and the Captain's command, the Co-pilot advances the throttles synchronically in steps almost reaching the takeoff mode by 23:07:42.

The Controller, seeing that the aircraft altitude reached 900 m and was still increasing, noted this to the PIC 23:07:40: "According to my information you are climbing, now altitude 900, confirm". The Co-pilot was still the PF, so the PIC seeing high vertical speed drew the Co-pilot's attention to the vertical speed control ("look at the vertical speed indicator").

After a pause, the PIC confirmed to the Controller that they were climbing. The Controller realized that the aircraft was not in a position suitable for landing, so at 22:07:55<sup>55</sup> he instructed the crew to turn right, heading 360° and descend to 600 m, actually canceling the approach. The PIC confirmed the instruction, but then started to discuss with the Controller the possibility of landing without making second approach. This discussion lasted until 23:08:53, meanwhile the Controller instructed the crew three times to descend to 600 m and turn right heading 360. All the three times the PIC confirmed the instruction, but the crew did not follow it.

The Controller felt that the crew's behavior was inadequate, so at 23:08:36 he requested: "... is everything all right with the crew?", which was responded by the PIC with "... affirm".

While communicating with the Controller, the PIC most likely interfered with the flight control from time to time (abrupt wheel and control column deflections). For example, at 22:08:13 and 22:08:20 he abruptly applied disproportionate right wheel, which resulted in right bank first of 17° and then 50° which activated the BANK ANGLE artificial voice alert. These inputs were made while the PIC was requesting to land without a go-around, and probably were connected with the PIC's wish to turn right to join the landing course.

After the alert, the Co-pilot cried out: "Ah! Where are you?... What are you doing?" and the crew, probably using joint efforts, recovered the aircraft to wings level. However, at the same time the aircraft also started climbing (15°-16° pitch), which went unnoticed by both pilots. As a result, the speed dropped again to 113 knots.

From 23:08:25 to 23:08:52, due to the thrust asymmetry with the matched throttles and insufficient right wheel, the aircraft started banking left with a rate of approximately 1 degree per second.

For about 25 seconds the position of the throttles did not change, there were almost no roll or pitch control inputs, so the aircraft was actually not controlled by anyone. As mentioned before, the PIC was engaged in the radio communication, while the Co-pilot obviously lost control of the situation.

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<sup>55</sup> By that time the aircraft had crossed the landing course and was significantly higher than the glideslope.

At 23:08:55, after the left bank reached 30°, and the speed was again lower than Vref, the Co-pilot asked the PIC to take control (“Take it, er take it, take..!”), probably realizing that he was not able to control the aircraft. However, the PIC by that time was not aware of the situation either and was not ready to take control: “Take what, <expl>? I can’t do it either!”.

However, a second later, the PIC applies abrupt left wheel and this increases the bank from 30° to 76°. The PIC not only made an error in the recovery direction, but also applied the wheel too abruptly, which is unusual for normal piloting. This is evidence that the PIC experienced psychological breakdown and lost composure. The Co-pilot reacted immediately to the erroneous actions of the PIC: “On the contrary! In the opposite direction!” and most likely helped the PIC again to recover the aircraft from a deep bank. It confirms that the Co-pilot at least was aware of the bank direction.

From 23:09:03 until the end of the flight the PIC was the PF. The abrupt disproportionate wheel roll inputs directed both ways, without any pitch control assume that the PIC lost spatial orientation, misinterpreting the western type EADI indications. The Co-pilot, seeing the PIC’s actions, tried to stop him: “<expl>, what are we doing?!..” However, the PIC was not able to assess the situation adequately. At 23:09:14 he made a critical error abruptly applying left wheel, almost full.

**Note:**

*The investigation revealed that the crew **did not get Upset Recovery Training and did not have steady automated skills of handling such situations.** Psychological experts have concluded that in a stressful situation the PIC could only make use of highly automated skills which, as was mentioned above, he did not have.*

The aircraft made an almost full barrel-roll with the nose down pitch increasing to 65°. It was impossible to recover from such a position without enough altitude even at a high speed (about 250 knots at the time of the impact) and having a vertical acceleration of 4.3g.

The aircraft collided with the trees and then with the ground at 23:09:25. At that time the aircraft was banking to the left intensively with a rate of 35-40 °/sec. The last recorded right bank 2-3 seconds before the crash (after the barrel-roll) was about 30°<sup>56</sup>.

The investigation team revealed a number of causes and factors<sup>57</sup> during the flight that led to the pilots’ spatial disorientation. The low level of professional training received by the

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<sup>56</sup> See also Section.1.11.

<sup>57</sup> See Section 1.18.4.

pilots, as well as unsatisfactory CRM during the descent and approach, improper distribution of the PF/PM duties, and incompliance with the SOP resulted in excessive workload on the Co-pilot, who did not have steady skills in manual piloting and failed to control aircraft properly. The workload on the Co-pilot was also increased by the thrust split and his lack of basic skills of piloting an aircraft with spaced-apart engines, especially in flights with thrust asymmetry.

The PIC did not monitor the Co-pilot's actions properly and did not assist him. Before the abnormal situation developed, when the PIC had to take control, he had been maintaining radio communication with the Controller all the time, the content of which was not consistent with the developing situation, distracted him from his duties as a PM and affected his situational awareness on the whole. This behavior of the PIC, apart from his insufficient level of training, was contributed to by his high level of emotional stress during the whole approach, which was most likely caused by presence of alcohol in his body and fatigue accumulated due to the work and rest imbalance during the previous days.

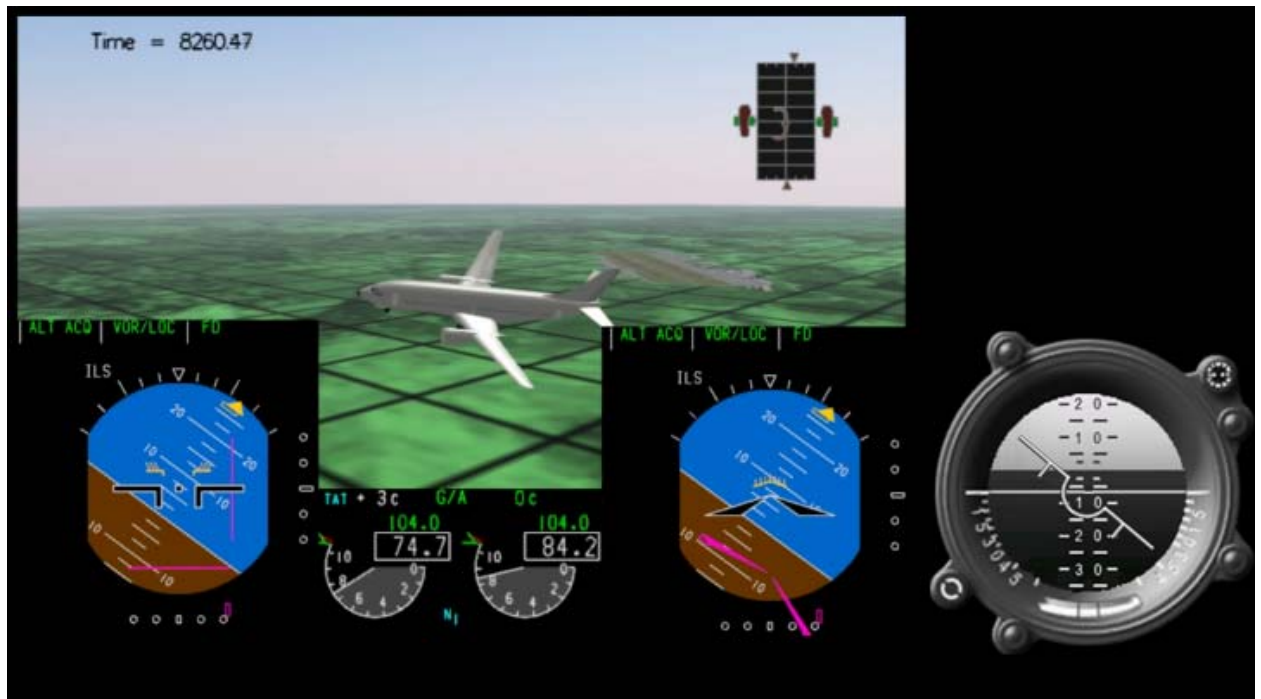
The PIC was unable to determine the bank direction properly and recover spatial orientation, as he did not have steady upset recovery skills for aircraft with western type of attitude indicators installed on modern Russian and western aircraft. This type of indication is different from the one used on the aircraft operated by both pilots before the Boeing 737. The complicated situation accompanied with increasing emotional stress caused a negative transfer of piloting and flight control skills from the earlier aircraft type (Tu-134).

One more possible factor (apart from the type of indication on EADI) that could have contributed to a negative transfer of skills from Tu-134 aircraft was that the VP-BKO aircraft was fitted with an integrated cue EADI. Ten out of the 12 Boeing 737 aircraft operated by Aeroflot-Nord by the time of the accident were fitted with the usual split command bars while two of them - with the integrated cue type<sup>58</sup>. The picture below shows EADI readings (left one with "normal" command bars and middle one with integrated cue) at the moment when the PIC took control of the aircraft and deflected the control wheel abruptly to the left. For comparison the EADI installed on Tu-134 aircraft is shown on the right side of the picture. This EADI shows 40° of bank to the right (not to the left as it was during accident flight) and 7° pitch down (to make a more obvious comparison with the actual position of the command bars on VP-BKO). It is clear from the picture that, being in complicated situation and not having enough recovery skills, one could mistakenly interpret the integrated cue command bars indication in the same way as bank indication on the EADI installed on Tu-134 aircraft. Consequently, erroneous recovery actions would be taken. The assessment made by an independent expert pilot group

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<sup>58</sup> See Section 1.6.

stated, that “it is impracticable to use EADI’s with different types of indications on aircraft of one type within one airline.”



### 3. Findings and Conclusion

- 3.1. Meteorological service was in compliance with the current regulations. The weather conditions at the time of the accident did not threaten the safety of ILS approach and landing on RWY 21 of Perm aerodrome (Bolshoye Savino).
- 3.2. The aeronautical support of the flight on the whole was in compliance with the current regulations.

After passing over Mendeleyevo fix, the Approach Controller vectored the Boeing 737 with radar control, in order to provide its safe separation from the A-319 that was taking off. The actual flight path of the aircraft differed from the standard arrival and approach patterns, particularly from the MN 4A pattern that the crew was going to follow.

While vectoring the aircraft, the Controller gave a number of inaccurate instructions which confused the crew about the further approach pattern.

Before the base turn the aircraft was 750 m higher than the assigned approach pattern. Despite this, the Controller did not continue vectoring the aircraft, but cleared them for the base turn when ready, which could increase the workload on the crew.

The inaccuracies made by the Controller were on the whole connected with the imperfect character of Russian regulatory documents in terms of considering all provisions of ICAO Doc. 4444, which determine the order and rules of vectoring and are not directly related to the accident cause.

- 3.3. The aircraft was dispatched for the last flight on September 13, 2008 with 2 MEL items, including the TCAS and the autothrottle.

The autothrottle was deferred as per MEL on September 12, after a crew reported that it was inoperative. This report was caused by the fact that the autothrottle disengaged several times during the flight.

The analysis showed that the autothrottle was operative. Its numerous disengagements during the flight were connected with the engine mistrim which at part power led to a N1 split up to 20% with matching TLA, or a throttle stagger up to 15 degrees with matching N1. The left engine thrust was within the limitations at all modes, while the right engine thrust was higher than nominal. The engine trim was equal at idle and almost equal at takeoff mode.

This defect first appeared on August 6, 2008 and, despite numerous records made by the flight crews in the flight log, it was not rectified by the maintenance personnel. The

investigation team revealed that the relative AMM troubleshooting procedures were not followed, and the flight records were not used.

The fact that the maintenance staff did not rectify the defect nor followed the relative troubleshooting procedures as well as a significant numbers of extended MEL items in the airline's Boeing 737 fleet is an evidence of unsatisfactory quality of Boeing 737 type maintenance in the airline and a low level of training of VARZ-400 staff who performed that maintenance.

- 3.4. According to the maintenance personnel, the autothrottle was deactivated in accordance with the MEL: DC and AC autothrottle CB's were opened and collared, the autothrottle switch was tagged with INOP.

This defect was included into the list of deferred MEL items which are mandatory for the crew to get aware of before the flight.

Despite that, the investigation team revealed that in all the 7 flights, including the accident flight, 4 different crews used the autothrottle in flight.

According to three Captains who used the autothrottle, the autothrottle was not deactivated according to the abovementioned procedures.

In any case, the usage of deferred and officially listed MEL items in flight is an evidence of lacking safety culture within the flight personnel of the airline.

- 3.5. All the aircraft and engines systems, including the autothrottle but excluding the TCAS, were operative when the aircraft departed Moscow. The examinations conducted by the investigation team did not reveal any evidences of systems or engine failures during the accident flight before the ground impact.

During the whole approach the abovementioned mistrim in the engines was present, which increased the workload on the crew during the approach with a disengaged autothrottle.

- 3.6. By the time of approach, the accumulate error in FMC positioning reached over 4.5 km. Such an error was caused by a natural drift of the IRS during the flight, an error made by the pilots when entering the current aircraft position during the IRS alignment and also by the impossibility to correct the current position due to the absence of a GPS system on board or ground nav aids along the flight route or at the destination airport.
- 3.7. The crew had valid pilot's certificates. The PIC's total experience on Boeing 737 was 1190 flight hours, including 477 hours as a captain. He was permitted to fly as a captain

on February 08, 2008. Previous aircraft types: Tu-134 and An-2 (flight college). The PIC did not have any experience as captain before transitioning to Boeing 737.

The Co-pilot's total experience on Boeing 737 was 236 flight hours. He was permitted to fly as a co-pilot on May 08, 2008. Previous experience on Tu-134 and An-2.

Neither of the pilots had previous experience on aircraft with western type of EADI installed on modern Russian (Tu-154, Yak-42, Il-86, Il-96, Tu-204) and western aircraft, nor did they have any experience of operations in a two-member crew on aircraft with modern avionics or on aircraft with spaced-apart engines on which a thrust split creates significant yawing moment.

In the Russian Federation there is no flight training program that would address the CRM problems encountered by pilots when transitioning from multicrew Russian aircraft to aircraft with two crew members.

Neither of the pilots was trained for special Upset recovery techniques.

- 3.8. The permission to operate Boeing 737 was issued to the airline without considering the actual level of the flight and maintenance personnel training and their number, which was later reflected on the quality of flight operations and maintenance.

The pilots were trained on the basis of the FCTM developed by Aeroflot-Nord and approved by the Russian Aviation Authorities.

The investigation team revealed a number of significant deviations of this FCTM from the requirements of the main regulatory documents for civil aviation (CAFOM-85, FCTM-92, ROLRGA-87) with regard to crew formation, permits to fly and documentation principles.

A number of shortcomings were revealed in the PIC's transition training:

- the training was conducted at the FTI Center that at the time of the training was not approved by Russian Aviation Authorities;
- after the training and before commissioning the PIC for 4 months continued flying the previous type, Tu-134, which is significantly different from Boeing 737 with regard to flight instruments, number of crew members and CRM procedures, which could have affected the formation of steady skills of flying an absolutely different type of aircraft;
- after a break of over 90 days after transitioning there was no refresher training on the simulator, though required by the FCTM;



- the order of tasks during the commissioning was distorted.

The Co-pilot was trained for Boeing 737 at the Flight Training Center of St. Petersburg State University of Civil Aviation. On November 19-21, 2008 a FTOA commission inspected the training center. The general conclusion of the inspection was that the initial, transition and refresher training for pilots does not comply with the requirements of FAR “Certification of Aviation Training Centers”.

The following main shortcomings of the Co-pilot’s transition training were revealed:

- the break in flights after the training and before the commissioning was 3 months, which could have affected the formation of steady skills of flying an absolutely different type of aircraft;
- the same pilot-instructor conducted the simulator training and the checkride, issued the certificate of transition training, and afterwards he also did the training, assessed the checkrides and permitted the Co-pilot to fly during his commissioning.

When issuing permits to fly Boeing 737, the qualification boards had a formal attitude to their duties and did not check the evidence documentation completely.

The abovementioned shortcomings in the pilot training reveal a low level of flight operations management in the airline and lack of control over the flight operations from Russian Aviation Authorities.

- 3.9. Both pilots learnt Technical English at a non-certified training center. The teachers who conducted the training did not have any aviation, linguistic or pedagogical education.

The Co-pilot’s level of English proficiency did not allow him to make proper use of the technical documentation, which is only published in English for this type of aircraft.

The Russian regulations only set requirements with regard to English proficiency only to the pilots who fly international flights.

- 3.10. The crew was formed without taking into account the level of the pilots’ professional skills. The two-member crew was formed of the PIC who had little experience as a captain and the Co-pilot who had little experience on type, provided both used to operate multicrew aircraft.

According to independent expert psychologists the formation of the crew was also done without considering the psychological traits of the pilots.

- 3.11. The duration of the preflight rest of the crew complied with the requirements.

However, within the last three days it was the PIC's 7<sup>th</sup> flight, 3 of which including the accident flight were at nighttime. On September 11-12 the PIC made four flights with significant violations of the work and rest balance requirements.

Thus, the accumulated fatigue could have negative effect on the psychological condition of the PIC and his actions.

- 3.12. According to the forensic medical expertise carried out at the State Health Institution "Perm Forensic Medical Expertise Bureau", the PIC had ethyl alcohol in his body before death.
- 3.13. For the last 30 minutes of flight the PIC's stress was 40-70% higher than the operational level. The most possible causes of the increased stress were the presence of alcohol in the PIC's body and/or accumulated fatigue, most likely the combination of these factors.
- 3.14. During the whole flight, with rare exceptions, the crew significantly deviated from the SOPs:
- mandatory cross-checks were not carried out;
  - flights modes were changed without informing the other pilot;
  - no callouts about the FMA indications or flight mode changes were made;
  - the checklists were not read;
  - the before landing preparation as well as the recurrent one after changing the approach pattern was not carried out;
  - the PF/PM duties distribution was not complied with, the CRM was unsatisfactory;
  - the control was passed from one pilot to another without the mandatory callout, which resulted in situations when during some portions of the flight virtually nobody controlled the aircraft;
  - the order and sequence of actions, particularly at takeoff and approach, was not followed.

- 3.15. The abnormal situation on board started developing when the aircraft was at base leg, with landing gears extended and flaps 30 at 600 m. The aircraft was flying with the autopilot engaged and the autothrottle disengaged.

The autothrottle was disengaged (with the relative alert activated) earlier, at establishing 2100 m by the cruise split monitor due to the significant thrust split. The crew did not attempt re-engaging the autothrottle.

The Co-pilot was the PF during most of the approach. As he did not have basic skills of flying multiengine aircraft with spaced-apart engines, he synchronically shifted the throttles for manual speed control and thus created a significant yawing moment to the left due to the thrust split. The PIC (as the PM) was engaged in the radio communication and did not monitor the engine parameters. The crew did not attempt to match the N1.

The pilots did not apply rudder to compensate the yaw moment, which led to a constant left banking. The autopilot's ability to counteract it by right wheel inputs was decreasing as the airspeed was dropping and the aerodynamic efficiency of the ailerons was decreasing.

After the autopilot was saturated followed by 30° left bank, the Co-pilot, while compensating the roll, overrode the autopilot to the CWS ROLL and CWS PITCH mode.

Then, in the CWS mode, the Co-pilot inadvertently pressed the manual stabilizer pushbutton, which disengaged the autopilot, accompanied with the relative alert. The crew switched off the alert and did not attempt to re-engage the autopilot.

As the pilot lacked steady piloting skills, he could not monitor all the flight parameters (altitude, speed, roll and pitch) when flying manually. The flight was unstabilized with significant changes of altitude, speed, pitch and roll, and fluctuations of thrust. An increase in thrust led to a significant noseup pitching moment, high pitch attitude (up to 23°) and consequently to significant reduction of airspeed (three times – down to 112, 110 and 113 knots).

The PIC was leading lengthy discussions with the Controller and did not monitor the flight properly, only interfering with the flight control from time to time.

The crew did not follow the Controller's instruction to terminate the approach and prepare for the second one.

At altitude about 1200 m with airspeed of 120 knots (10 knots lower than Vref) and left bank of about 30° the PIC, following the Co-pilot's request, took control.

Not having proper situation awareness the PIC abruptly applied left wheel, increasing the left bank up to over 70°. Despite the correct remark from the Co-pilot after which he initially used right wheel (decreasing the left bank to 30°), the PIC then abruptly and disproportionately made several wheel inputs causing rapid left banking, followed by left overturn and deep descent with 65° nosedown pitch. It was impossible to recover from such upset at a low altitude.

- 3.16. The investigation team revealed a number of causes and factors during the flight that led to the pilots' spatial disorientation. The low level of professional training as well as unsatisfactory CRM during the descent and approach, improper distribution of the PF/PM duties, and in compliance with the SOP resulted in excessive workload on the Co-pilot, who did not have steady skills flying aircraft manually and failed to control aircraft properly. The workload on the Co-pilot was also increased by the thrust split and his lack of piloting an aircraft with spaced-apart engines, especially in flights with thrust asymmetry.

The PIC did not monitor the Co-pilot's actions properly and did not assist him. Before the abnormal situation developed, when the PIC had to take control, he had been maintaining radio communication with the Controller all the time, the content of which was not consistent with the developing situation, distracted him from his duties as a PM and affected his situational awareness on the whole. This behavior of the PIC, apart from his insufficient level of training, was contributed to by his high level of emotional stress during the whole approach, which was most likely caused by presence of alcohol in his body and fatigue accumulated due to the work and rest periods violations during the previous days.

The PIC did not determine the bank direction properly and recover spatial orientation, as he did not have steady upset recovery skills for aircraft with western type of attitude indicators installed on modern Russian and western aircraft. This type of indication is different from the one used on the aircraft operated by both pilots before the Boeing 737. The complicated situation accompanied with increasing emotional stress caused a negative transfer of piloting and flight control skills from the earlier aircraft type (Tu-134).

## Conclusion

The immediate cause of the accident was spatial disorientation of the crew, especially the Captain who was the pilot flying at the final stage of the flight, which led to the left flip-over, a steep descent and the crash of the aircraft. The spatial disorientation was experienced during the night time operation in clouds, with both autopilot and autothrottle disengaged. Contributing to the development of the spatial disorientation and failure to recover from it was a lack of proficiency in aircraft handling, crew resource management and of skills associated with upset recovery using "western"-type attitude indications that are found on foreign and modern Russian-made aircraft. This type of indication differs from the one used on aircraft types previously flown by the crew (Tupolev 134, Antonov 2).

The cause above was determined on the basis of flight recorders and ATC recorder data analysis, examination of the airframe and engine wreckage, results of the accident flight simulation, findings of the independent expertise conducted by test pilots from State Research Institute of Civil Aviation and Gromov Flight Research Institute as well as line pilots, and also on the basis of all the works conducted with participation of experts from Bermuda, France, Russia, UK and USA in the course of the investigation.

The systemic cause of the accident was insufficient management by the airline of flight and maintenance operations of the Boeing 737 type of aircraft. These deficiencies in the aircraft maintenance also revealed through safety inspections conducted by the Russian Transport Oversight Authority and the Russian CAA after the accident.

Deficiencies in the aircraft maintenance led to a situation when flights were performed for a long time with a throttle stagger<sup>59</sup> that exceeded the limitations in the AMM and when the maintenance staff did not follow the AMM recommended troubleshooting procedures. The need to manage the throttle stagger during the approach increased crew workload.

The forensic medical examination performed in the State Healthcare Center of Special Status "Perm Regional Forensic Expertise Bureau" confirmed the presence of ethyl alcohol in the Captain's body before his death. The captain's recent work schedule during the time period before the accident was conducive to fatigue and did not comply with national regulations.

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<sup>59</sup> The throttle stagger is understood as a difference in trim of right and left engines, when matching throttle position leads to a split in engine thrust while matching thrust leads to different throttle position.

#### **4. Shortcomings**

- 4.1. The pilots' personal files did not contain complete sets of documents required to assess the level of their professional training.
- 4.2. The FAP point for RWY 21 approach at Perm Airport was entered into the FMS of the VP-BKO with an error.
- 4.3. During the accident flight and some previous flights the FDR channel for the control wheel input was faulty while the channel for control column inputs recorded the values with a shift.
- 4.4. The approved implementation plans developed on the basis of accident or incident investigation teams' recommendations are not complied with.
- 4.5. The approach patterns at Perm Aerodrome contain an error with respect to the magnetic azimuth of FAF fix.
- 4.6. The reference letter by the Boeing Company stating that it "heavily relies on the English language courses..." conducted by METEK LTD was provided without a sufficient analysis of the status and possibilities of the mentioned organization.

## 5. Safety Recommendations

### **The Russian Aviation Authorities<sup>60</sup> is recommended to:**

- 5.1. Check the implementation of measures developed and approved in order to implement the recommendations given by investigation teams for accidents with heavy transport category aircraft in 2006-2008.
- 5.2. Consider the practicability of increasing requirements to flight training programs and transition training programs and elaborate a mandatory syllabus minimum for every aircraft type in order to improve the level of training and avoid simplifications during the training.
- 5.3. Develop a CRM training program for flight crews that fly two-member crew aircraft and ensure this program is mandatory for flight personnel who transition from multicrew aircraft.
- 5.4. Ensure that the aviation psychologists when selecting personnel for transition training should pay attention to the personality traits of the candidates with regard to their emotional reactions and behavior in abnormal situations (high workload, stress, etc.), and if they find negative traits, should give recommendations on their suitability for transition training and/or the necessity of individual approach during the training<sup>61</sup>.
- 5.5. Arrange and conduct research of spatial disorientation and upset conditions and develop practical safety measures. Based on the research results, develop and implement a special flight crew training course (similar to Upset Recovery Training) that would contain theory and practice<sup>62</sup>.
- 5.6. Pay attention, when approving airlines' FCTM, to the compliance of their provisions with the main civil aviation regulations (FAR, CAFOM-85, FCTM-92, ROLRGA-87). Consider the practicability of improving the main regulations, taking into account two-member crew aircraft operations. Expedite the implementation of the Flight Operations FAR.
- 5.7. Amend transition training and commissioning requirements onto the new aircraft type to establish the minimum value of flight hours on the new aircraft type that are required before returning to previous aircraft type.

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<sup>60</sup> The aviation administrations of other Contracting States should consider the applicability of these recommendations taking into account the actual conditions at these States.

<sup>61</sup> Recommendations 5.2, 5.3 and 5.4 are given for the second time. Initially these recommendations were given after the investigation of the A-310 F-OGYP accident on July 09, 2006 at Irkutsk Airport.

<sup>62</sup> The recommendation is given for the second time. Initially it was issued after the investigation of the A-320 EK-32009 accident on May 03, 2006 at Sochi Airport.

- 5.8. Draw the attention of qualification boards of all levels to the necessity of checking the flight personnel documents compliance to the regulations when commissioning them to a new position. Establish a personal responsibility of the heads of qualification boards for the unjustified issue of permits.
- 5.9. Develop and implement English language proficiency requirements for flight personnel who fly aircraft with documentation in English, as well as for maintenance personnel who maintain the abovementioned aircraft.
- 5.10. Consider the practicability of using aircraft with western type attitude indicators at colleges of initial flight training. While Russian training aircraft of such type would be designed, consider the practicability of acquiring western aircraft suitable for initial training. As an alternative measure, consider installing western type attitude indicators on the already used Russian training aircraft.
- 5.11. Consider the necessity of inspecting the level of training of pilots who were trained for Boeing 737 at the FTI Center and the Flight Training Center of St. Petersburg State University of Civil Aviation. On the basis of the inspection consider the necessity of additional training.
- 5.12. Within the framework of Agreements on the basis of Article 83bis, ICAO Convention, consider the practicability of taking part, along with the State of Registry, in approving maintenance organizations.
- 5.13. According to the recommendations given in Section 1.16.4 of the report, consider introducing flight experience limitations for every aircraft type for co-pilots who apply to upgrade to captains.
- 5.14. Apply the practicability of resuming practical conferences with regard to share operational experience of different aircraft types and inviting representatives of aircraft Designer and Manufacturer as well as test pilots to such conferences.
- 5.15. Introduce all necessary amendments and additions into the civil aviation regulatory documents to comply with all provisions of ICAO Doc. 4444 with regard to vectoring aircraft at approach. Ensure that Approach Control personnel get relative training.
- 5.16. Expedite equipping international aerodromes with VOR/DME and/or ILS/DME systems to provide accurate navigation environment in the takeoff/landing areas.
- 5.17. Consider the practicability of mandatory fitting international aerodromes with ILS equipment for all runways where technically possible.
- 5.18. Consider the issue of operating aircraft equipped with the single FMC without a possibility of position correction only along the routes with ATC radar control. Consider



the practicability of installing GPS to ensure accurate navigation when flying along routes without nav aids.

- 5.19. Require that certified staff approved for maintaining a certain aircraft type should be present during pre-flight inspections, especially if the aircraft is dispatched with MEL items.
- 5.20. Carry out one time inspections of FDR and CVR recording quality in cooperation with operators of western aircraft and store the readout records.
- 5.21. Eliminate other shortcomings revealed in the course of the investigation.

**Aeroflot-Nord airline and other airlines<sup>63</sup> of the Contracting States are recommended to:**

- 5.22. Inspect the professional level of pilots who were trained for Boeing 737 at the FTI Center, Denver, and at the Flight Training Center of St. Petersburg State University of Civil Aviation. Based on the inspection findings, consider the necessity of additional training.
- 5.23. Ensure that the flight personnel strictly follow the SOP. Ensure continuous monitoring of flights using, among other means, CVR records read out.
- 5.24. Ensure continuous MEL usage monitoring. Avoid flights with extended MEL items without a detailed analysis of any particular case.
- 5.25. Develop and implement a procedure of using flight recorders' data when doing the troubleshooting.
- 5.26. Ensure that the airline psychologists, when selecting applicants for transition training, pay more attention to their personal traits with regard to their emotional reaction and behavior in abnormal situations (increased workload, stress), and if they find negative traits, give particular recommendations as to whether these pilots are suitable for transition training and/or if they require individual approach.
- 5.27. Develop and implement prevention measures to maintain high level of safety when transitioning to new aircraft types.
- 5.28. Assess the English language proficiency level of pilots who fly western-made aircraft and who were trained at METEK LTD. On the basis of this assessment consider the necessity of additional training at a certified training center. This recommendation is also applicable to maintenance personnel who maintain western aircraft.
- 5.29. Arrange and conduct special training for pilots who fly Boeing 737 aircraft without previous experience on aircraft with spaced-apart engines, with regard to handling such aircraft in case of thrust asymmetry. Consider the practicability of engaging test-pilots in

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<sup>63</sup> Other airlines should consider the applicability of these recommendations in accordance with the actual conditions.

arranging such training. Consider the applicability of this recommendation to other aircraft types.

- 5.30. Introduce extra sections into airlines' FOM and SOP with recommendations as to how to perform flights along routes and at aerodromes without an accurate radio navigation environment for FMC position correction.
- 5.31. Introduce additional sessions into flight simulator training with regard to approaching with FMC position deviation, estimating the value of the error and conducting the flight with the help of raw data.
- 5.32. Determine "problem" aerodromes for every airline and develop recommendations on flight operations at these aerodromes. Practice raw data approaches during flight simulator training.

**Aeroflot-Nord airline is recommended to:**

- 5.33. Redevelop the FCTM to comply with the main regulatory documents.
- 5.34. Develop and implement a system of monitoring the work of invited instructors.
- 5.35. Eliminate other shortcomings found in the course of the investigation and during the inspections conducted by the FTOA and the CAA of Russia.

**PLC VARZ-400 is recommended to:**

- 5.36. Brief their personnel on the basis of the investigation findings. Consider the necessity of additional training or refresher training of the personnel who did the maintenance of the VP-BKO aircraft.
- 5.37. Eliminate all the shortcomings found in the course of this investigation and during the EASA audit.

**The Boeing Company is recommended to:**

- 5.38. Consider including into the AFM and/or FCOM of Boeing 737 aircraft the information on the limits of throttle stagger and the recommendation for the flight crews on handling the aircraft in case of throttle stagger.
- 5.39. Together with the equipment manufacturer consider the practicability of replacing the artificial voice warning "Bank angle" by a similar phrase which would indicate the direction of bank (left/right).

**METEK LTD is recommended to:**

- 5.40. Have their teachers and training programs approved and licensed for teaching General and Technical English for flight and maintenance personnel who fly or maintain western-made aircraft.

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