

*This document is an English translation of the Final Report on the accident on 10 April 2010, on Smolensk "Severny" airdrome, to the Tupolev Tu-154M tail number 101 of the Republic of Poland.*

*The translation was done ~~as accurate as~~ the translation may be to facilitate the understanding of the Final Report for non-Russian speaking people. The use of this translation for any purpose other than for the prevention of future accidents could lead to erroneous interpretations.*

*In case of any difference or misunderstanding the original text in Russian is the work of reference.*

**INTERSTATE AVIATION COMMITTEE  
AIR ACCIDENT INVESTIGATION COMMISSION**

**FINAL REPORT**

Type of occurrence	Accident
Type of aircraft	Airplane, Tu-154M
Registration	Tail number 101, Republic of Poland
Owner	Republic of Poland
Operator	Ministry of Defense, Republic of Poland
Site of occurrence	Between the middle marker and runway 26 threshold, Smolensk "Severny" Airdrome, N 54°49.450' and E 32°03.041'
Date and time	10.04.2010, 06:41 UTC, 10:41 local time, daytime

In accordance with ICAO Standards and Recommended Practices the sole objective of this Report is air accident and incident prevention.

The investigation conducted within the framework of this Report and suggested recommendations does not apportion blame or liability.

The criminal aspects of the accident are investigated within a separate criminal case.

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## Abbreviations

AAIC	– Air Accident Investigation Commission
AAISTSC	– Air Accident Investigation Scientific-Technical Support Commission
ABSU-154	– autopilot
AOA	– Angle of Attack
AP	– autopilot
APS	– Aerodrome Projector Station
APU	– Auxiliary Power Unit
ARK-15M	– Automatic Direction Finder
ARP	– Airdrome Reference Point
ATC	– Air Traffic Control
BRNAV	– Basic Area Navigation
BSKP	– ATC Near Control Place
CATC	– Chief Air Traffic Controller
CDU	– Control Display Unit
CPU	– Central Processing Unit
CVR	– Cockpit Voice Recorder
DCATC	– Deputy Chief Air Traffic Controller
DCMU	– Deputy Chief of Military Unit
DSKP	– ATC Far Control Place
E	– Eastern longitude
FAA	– Federal Aviation Administration, USA
FAR	– Federal Aviation Regulation
FCOM	– Flight Crew Operation Manual
FDR	– Flight Data Recorder
FLTA	– Forward Looking Terrain Alert
FMS	– Flight Management System
GPS	– Global Positioning System
H <sub>3</sub>	– Target altitude
IAC	– Interstate Aviation Committee
IFO	– Instruction
ILS	– Instrument Landing System



LMM	–	Locator Middle with Marker id est NDB + marker
LNAV	–	Horizontal navigation mode
LOM	–	Locator Outer with Marker id est NDB + marker
LR	–	Landing Radar
LZC	–	Landing Zone Controller
MAC	–	Mean Aerodynamic Chord
MAS	–	Moving Aim Selection (LR mode)
METAR	–	Meteorological Airdrome Report
MSN	–	Manufacturer Serial Number
N	–	northern latitude
NAV	–	navigation
NCU	–	Navigation Computer Unit
NDB	–	Non-directional Beacon
NOTAM	–	Notice to Airmen
NPSG	–	Surface Search and Rescue Group
Ny	–	vertical acceleration
NTSB	–	National Transportation Safety Board, USA
P <sub>3</sub>	–	Set pressure rack gear
PANS-OPS	–	Procedures for Air Navigation Services – Aircraft Operations. DOC 8168 – OPS/611
PF	–	Pilot Flying
PIC	–	Pilot-in-Command
PNF	–	Pilot Not Flying
RA-56	–	actuator
RPSB	–	Regional Search and Rescue Base
RTP	–	Rules for Terminal Procedures
RVSM	–	Reduced Vertical Separation Minimum
SR	–	Surveillance Radar
QAR	–	Quick Access Recorder
QFE	–	Atmospheric pressure at runway threshold level
QNH	–	Atmospheric pressure at sea level for standard atmosphere

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RSRS	– Regional Search and Rescue Service
STAR	– Standard Terminal Arrival Route
SID	– Standard Instrument Departure
TAF	– Terminal Airdrome Forecast
TAWS	– Terrain Awareness and Warning System
TCAS	– Traffic Collision Avoidance System
t/n	– Tail number
U	– Unknown speaker
UTC	– Universal Coordinated Time
UASC	– Universal Avionics Systems Corporation
UVO-15M1B	– Mechanical pressure altimeter installed on the PIC control panel
VM-15PB	– Mechanical pressure altimeter installed on the co-pilot control panel
VBE-SVS	– Main electronic pressure altimeter, there are two of them onboard on both PIC and co-pilot control panels
VNAV	– Vertical Navigation
Vy	– Vertical speed

## Synopsis

On April 10, 2010 at 10:41 local time<sup>1</sup> (hereinafter if not specified local time will be used, which is 4 hours ahead of UTC) at daytime, in the course of approach to Runway 26 of Smolensk "Severny" airdrome and descent lower than the established minimum safe altitude of 100 m, in weather conditions below the established airdrome, aircraft and PIC's minima, a Tu-154M aircraft tail number 101 of the State Aviation of the Republic of Poland (36<sup>th</sup> Special Transport Air Regiment, Polish Air Forces, further referred to as special air regiment) crashed while conducting a non-regular international flight PLF 101 carrying passengers from Warsaw (EPWA) to Smolensk "Severny" (XUBS).

The information about the accident was received by the Interstate Aviation Committee (IAC) and the Flight Safety Agency of the Russian Armed Forces around 11:00 on April 10, 2010. Immediately a working group was appointed that initiated activities at the accident site at 19:15 the same day.

On the basis of Order № 225-пн of the President of the Russian Federation dated April 10, 2010 a State investigation commission was appointed to investigate the causes of the Tu-154 aircraft accident (hereinafter referred to as the State Commission). The Investigator-in-Charge for the State Commission was the Prime-Minister of the Russian Federation.

From April 10 to April 13, 2010 the investigation at the accident site was supervised by the Head of the Flight Safety Agency of the Russian Armed Forces.

On April 13, 2010 by Order of the Head of the State Commission the general supervision of the technical investigation and coordination with the interested Russian and foreign bodies was delegated to the Chairperson of the Interstate Aviation Committee who was Deputy Head of the State Commission. The same order determined that the investigation was to be conducted in compliance with the provisions of ICAO Annex 13. This decision was supported by the Government of the Republic of Poland.

Order №8-498/p of the IAC Chairperson dated April 13, 2010 concerning the technical investigation in cooperation with the Russian Ministry of Defense appointed the following investigation team:

- |                        |   |
|------------------------|---|
| Investigator-in-Charge | – <b>A.N. Morozov</b> , Vice-Chairman of IAC – Chairman of the AAIC |
| Deputy IICs:           | – <b>V.V. Sorochenko</b> , Deputy Head of the Flight Safety         |

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<sup>1</sup> Local time is the same as Moscow time. Warsaw time is two hours behind.

- Agency, Russian Armed Forces
- Members:
- **G.A. Yachmenev**, Vice-Chairman of the AAIC, IAC
  - **A.V. Alekseyev**, Deputy of the Chief Engineer, Aviakor Ltd. Aviation Plant
  - **R.T. Yesayan**, Deputy General Director – Head of flight-research center, State Research Institute for Civil Aviation
  - **N.M. Kozhevnikova**, Consultant, AAIC, IAC
  - **M.S. Kulikov**, Chief ATC instructor, Air Navigation Institute
  - **V.G. Nekrasov**, Vice-Chairman of Airdrome and Equipment Certification Commission. IAC
  - **A.V. Roldugin**, Vice-Chairman of the AAISTSC, IAC
  - **A.A. Talalakin**, Deputy of the Chief Constructor, Tupolev Design Bureau

In compliance with ICAO Annex 13 (hereinafter referred to as Annex 13) the Republic of Poland appointed their Accredited Representative and a large group of Advisors to participate in the investigation.

The investigation was participated by experts of research institutes and aviation industry of the Russian Federation and the Republic of Poland. Aviation experts from the Azerbaijan Republic and the Republic of Uzbekistan were involved in the investigation as experts. Examination of a number of aircraft instruments was conducted on the facilities of the Federal State Enterprise “13<sup>th</sup> State Research Institute of the Russian Ministry of Defense” with participation of representatives of the equipment manufacturers and the Republic of Poland.

The USA as the State of Design for TAWS and FMS provided technical assistance via the examination and data recovery of information stored in mentioned units. The examinations of the navigation and other instruments of the aircraft were conducted at the Universal Avionics Systems Corporation (UASC) facilities (as the manufacturer) at Redmond, USA under the supervision of representatives of the Interstate Aviation Committee and the Republic of Poland. The examinations were participated by the NTSB and the FAA.

Start of investigation – April 10, 2010.

End of investigation – January 10, 2010.

The preliminary judicial inquest is conducted by the Main Investigation Office of the Investigation Committee, Main Prosecutor's Office of the Russian Federation.

## **1. Factual Information**

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

On March 2010 the Third European Department of the Ministry of Foreign Affairs, Russian Federation was sent Letter PdS 10-14-2010 from the Embassy of the Republic of Poland with two requests attached to conduct non-scheduled (single) flights in the Russian airspace on April 10, 2010.

According to the requests two flights were planned for April 10, 2010 from Warsaw (EPWA) to Smolensk "Severnoy" airdrome (XUBS) and back to Warsaw (EPWA) on Tu-154M (tail number 101, flight PLF 101) and Yak-40 (tail number 044, flight PLF 031). The flight objective was specified as "the visit of Polish delegation headed by the President of the Republic to Katyn and participation in the celebrations in the Memorial Complex".

The letter of the Embassy of the Republic of Poland in the Russian Federation contained a request to provide handling at Smolensk airdrome as well as "up-to-date airport charts and procedures". The Polish side requested to provide a navigator on board the aircraft.

The request in question was agreed upon by the Department of Management and Control of the VIP flights of the Russian CAA on March 31, 2010. The PLF 101 flight was assigned Category A and the PLF 031 was assigned Category K.

In accordance with Para 3.13 GEN 1.2-9 of the Aeronautical Information Publication of the Russian Federation and countries of the Commonwealth of Independent States (Russian AIP) on April 9 the Ministry of Foreign Affairs, Russian Federation sent Letter 176CD/10 to the Polish Embassy in the Russian Federation with a flight permission for Flight PLF 101 and Letter 177CD/10 with a flight permission for Flight PLF 031 .

On March 30, 2010 the Third European Department of the Ministry of Foreign Affairs, Russian Federation was sent one more letter PdS 10-19-2010 from the Embassy of the Republic of Poland with three requests to conduct non-scheduled (single) flights in the Russian airspace on April 7, 2010.

According to the requests for April 7, 2010 three flights were planned with route Warsaw (EPWA)-Smolensk "Severnoy" (XUBS)-Warsaw (EPWA) on Tu-154M (tail number 101, flight PLF 102) and two Yak-40 (tail number 044<sup>2</sup>, flight PLF 034 and tail number 044, flight 035) with a Polish delegation headed by the Chairman of the Minister Council of the Republic of Poland.

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<sup>2</sup> Two identical tail numbers were mentioned in the requests.

The request in question was agreed upon by the Department of Management and Control of the VIP flights of the Russian CAA on March 31, 2010 with Category K assignment.

On March 30, 2010 the Third European Department of the Ministry of Foreign Affairs, Russian Federation was sent an additional letter PdS 10-20-2010 from the Embassy of the Republic of Poland with one more request to conduct a non-scheduled (single) flight in the Russian airspace on April 7, 2010.

In accordance with the request for April 7, 2010 one more flight was planned with route Warsaw (EPWA)-Smolensk "Severny" (XUBS)-Warsaw (EPWA) on a Yak-40 (tail number 047, flight PLF 037). The request was also agreed upon by the Department of Management and Control of the VIP flights of the Russian CAA on April 1, 2010. The flight was assigned Category K.

Additionally on the basis of Letter PdS 10-21-2010 of the Embassy of the Republic of Poland in the Russian Federation of April 1, 2010 the arrival of three CASA-295M aircraft was arranged for April 7.

Actually on April 7 three flights arrived at Smolensk "Severny" Airdrome: one on Tu-154M (PLF 102), one on Yak-40 (PLF 035) and two on CASA-295M.

On April 10, 2010 the crew of the special air regiment of the Polish Air Forces including the PIC<sup>3</sup>, the co-pilot, the navigator and the flight engineer conducted a non-scheduled international flight PLF 101 Category "A" on Tu-154M tail number 101 carrying passengers from Warsaw (EPWA) to Smolensk "Severny" (XUBS). There was no leaderman-navigator on board the aircraft.

Besides the 4 flight crew members there were 3 cabin crew members, 88 passengers and 1 security officer on board making a total of 96 persons, all citizens of the Republic of Poland.

According to the first request for flight the departure from Warsaw was planned for 8:30. However later the flight plan was modified and the departure time was shifted to 9:00. The takeoff from Warsaw was actually conducted at 09:27 with a delay of 27 minutes as per the modified flight plan.

The cruise flight was conducted on FL330 (~10000 m).

At 10:09:30 being controlled by the Minsk Control the crew requested estimated descent to 3900 m which was cleared.

At 10:14:30 during the descent the Minsk Control informed the crew that the visibility at Smolensk "Severny" Airdrome was 400 m, fog.

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<sup>3</sup> In the mentioned requests for flights on April 7 and 10 for the Tu-154M aircraft the same PIC was specified who was the chief of squadron. Actually, the flight of April 7 was performed by him, but on April 10 (during the accident flight) the PIC's duties were performed by another pilot who was co-pilot in the flight of April 7.

Before that, at 9:15 a Yak-40 aircraft flight PLF 031 landed at Runway 26 at Smolensk "Severny" Airdrome.

During the approach of the Yak-40 the weather started getting worse (at 9:00 the visibility was 4 km, while at 9:06 it decreased to 2 km) as the fog that had started to form in parts of Tula, Kaluga and Smolensk Regions after 04:00 was drifting from the south-east to the north-west.

During the two approaches of the Russian IL-76 aircraft tail number 78817 (from 09:20 to 09:39) the weather conditions at Smolensk "Severny" Airdrome were getting still worse. Making two approach attempts the IL-76 proceeded to an alternate airdrome in Moscow. The weather measurements taken at 09:40 showed that the weather conditions (visibility 800 m, cloudbase 80 m) got below the airdrome minima (100x1000) for landing at RWY 26 using the radar + 2NDB landing system.

At 10:22:30 over the ASKIL navigation point the Tu-154M aircraft was handed off to the Moscow Control. The ATC cleared it for further descent to 3600 m and then the aircraft was handed off to the ATC group of Smolensk "Severny" Airdrome, callsign "Korsazh".

The crew established radio communication with the Control of Smolensk "Severny" airdrome at 10:23:30.

The ATC CATC of Smolensk "Severny" Airdrome clarified the remaining fuel (11 tons) and alternate airdromes (Minsk, Vitebsk) and informed the crew that at Korsazh it was foggy, visibility 400 m, no conditions for arrival. In addition he informed that the temperature was +2° C and the QNH was 745 mm mercury.

Despite the actual weather that was below the airdrome, PIC's and aircraft minima, at 10:25 the crew requested a "trial" approach. Considering the provisions of the Russian AIP, the Controller cleared the crew to approach but later warned the crew not to descent below 100 m and required them to be ready for missed approach from that altitude.

In the course of further descent and flight at circuit altitude (500 m QFE) the crew of the PLF 101 flight contacted the crew of the Yak-40 (PLF 031 flight) that had landed earlier. The Yak-40 crew several times informed the crew of the Tu-154M on the unfavorable weather conditions, last warning given before the latter approached the final turn. The Yak-40 crew transmitted that the visibility at the airdrome was 200m.

The Tu-154M crew continued approach and final descent. At a distance of 1100 m from RWY 26 threshold and about 35 m left from the extended runway centerline the aircraft first hit the top of a tree at a height of about 11 m above ground level. The impact occurred before the middle marker (1050 m distance from RWY 26 threshold). The terrain elevation in the middle marker area



is 233 m, the RWY 26 threshold elevation is 258 m. Thus, at the time of the impact the aircraft was about 15 m below the RWY 26 threshold.

Further, 245m from the point of the first impact with a lateral deviation of about 60m left from the extended runway centerline the aircraft hit a birch with the trunk 30-40m cm wide which led to the damaged left wing and significant left bank. Further the aircraft crashed inverted and was totally destroyed. The emerging insignificant ground fire at the accident site was extinguished by the arriving fire fighters 18 minutes after the accident.

As a result of the crash all the passengers and crew members on board died.

The accident occurred at 10:41:06.

## 1.2. Injuries to Persons

Injuries	Crew	Passengers	Other <sup>4</sup>
Fatal	7	88	1
Serious	-	-	-
Minor/None	-/-	-/-	-/-

## 1.3. Damage to Aircraft

The aircraft was totally destroyed on impact with the trees and ground. The emerging insignificant ground fire at the accident site was extinguished by the arriving fire fighters 18 minutes after the accident.

## 1.4. Other Damage

A power line VL-6kV PS Northern was damaged.

## 1.5. Personnel Information

### 1.5.1. Flight Crew

#### Pilot-in-Command

Position	PIC, I Class pilot
Sex	Male
Year of birth	1974
Pilot's license <sup>5</sup>	Not issued

<sup>4</sup> Security officer who was on board.

Education	Secondary, Higher Officer Flight School for Air Forces, Demblin, 1997. During the training operated TS-11, and further Yak-40.
Transition training for Tu-154M	<p>Underwent transition training directly at the Military Unit. The transition training program for Tu-154M as navigator and pilot was not submitted.</p> <p>Flight log extracts:</p> <ul style="list-style-type: none"> <li>– Authorized for flights on Tu-154M as a navigator on 25.01.2002, Order №20/2002 of 25.01.2002;</li> <li>– Authorized to fly as a co-pilot on Tu-154M on 16.07.2002, Order №138/2002 of 16.07.2002;</li> <li>– Authorized as a PIC on Tu-154M (Order №Z-137/2008 of 15.07.2008) with the weather minimum of 60x800 m on 11.07.2008 (daytime), 03.09.2008 (nighttime);</li> </ul> <p>Authorized for radar+2NDB approaches with the following minima: cloud base 100m, visibility 1200m, Order № Z-137/2008 of 15.07.2008.</p> <p>Authorized for VIP flights on 08.09.2008.</p>
Total flying experience including:	<p>3400+ hours (TS-11, Yak-40, Tu-154M)</p> <ul style="list-style-type: none"> <li>– Yak-40 as a PIC 72 hours</li> <li>– Tu-154M as a navigator 656 hours</li> <li>– Tu-154M as a co-pilot 1663 hours</li> <li>– Tu-154M as a PIC 530 hours (until 01.01.2010)</li> </ul>

<sup>5</sup> According to the information provided by the Polish side, issuance of pilot's licenses to crew members is not stipulated.

Authorization for instructor job on Tu-154M	Not authorized, but according to the flight log had flights both in the left pilot seat and in the right seat
Checkride in the assigned weather minima 60x800	11.07.2008 (daytime), mark "5" (Excellent)
Confirmation of minima 60x800 (solo)	10.11.2009 (Warsaw), 11.02.2010 (Brussels). The investigation revealed that the actual weather at Brussels airdrome was as follows: cloudbase 900 m, visibility over 10 km (METAR 111620Z), which does not comply with the record confirming the minima. According to the explanations of the Polish representatives the minima confirmation is mandatory once in 4 months. Thus, the effect of the weather minima expired <sup>6</sup> .
Authorization for RVSM flights	no information
Authorization for BRNAV flights	no information
Checkride	11.07.2008 (daytime), "Excellent" 03.09.2008 (nighttime)
Navigation check	no information
Simulator training on Tu-154 Full Flight Simulator	Not conducted
Recurrent training	23.03.-24.04.2009
Flying time within the last month	According to the data provided by the Polish representatives 17hours 07minutes. No record in the flight log
Flying time within the last 3 days	2 hours 56 minutes
Flying time on the day of the accident	1 hour 14 minutes
Time on duty on the day of the accident	about 3 hours
Annual medical examination	11.01.2010, Conclusion: Fit for flight operations

<sup>6</sup> According to the flight log from June 2008 the PIC had conducted 16 approaches (as a PIC) in the weather conditions complying with the confirmation of the 60x800 weather minima. All these flights were to large airports equipped with precision landing systems.

Previous accidents	None
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**Co-pilot (First officer)**

Position	Co-pilot, I Class pilot
Sex	male
Year of birth	1974
Pilot's license	Not issued
Education	Secondary, Higher Officer Flight School for Air Forces, Demblin, 1997., during the training operated PZL-130, TS-11, further Yak-40
Transition training for Tu-154M:	
<ul style="list-style-type: none"> <li>- As a navigator</li> </ul>	<p>Individual program of theoretical training of 01.02.2008 approved by the head of Military Unit 2139. The transition training was conducted directly at the Military Unit. According to the log of ground training was authorized for flights as a navigator of Tu-154M. Checkride for authorization as a navigator was not recorded in the flight log. The order for commissioning as a navigator was not mentioned.</p>
<ul style="list-style-type: none"> <li>- As a pilot</li> </ul>	<p>Trained according to individual theoretical and practical programs approved by the head of Military Unit 2139 of 06.10.2008.</p> <p>Order for authorization for ground training before the training flights as a co-pilot issued 03.10.2008.</p> <p>Commissioned from 11.12.2008 to 21.05.2009.</p> <p>Order №Z-246/2008 of 18.12.2008 authorizing for VFR flights as a co-pilot at daytime.</p> <p>Order №Z-250/2008 of 24.12.2008 authorizing for IFR flights at daytime.</p> <p>Order №Z-98/2009 of 21.05.2009 authorizing</p>

	for VFR flights at night time. Order №Z-99/2009 of 22.05.2009 authorizing for IFR flights at night time. Order №Z-99/2009 of 22.05.2009 authorizing for VIP flights.
Total flying experience including: – Tu-154M as a navigator – Tu-154M as a co-pilot  – Yak-40	1700+ hours (PZL-130, TS-11, Yak-40, Tu-154M) 277 hours 198 hours. Solo flying experience after the commissioning (after 22.05.2009) was 160 hours.  1192 hours
Checkride	23.12.2008 (daytime) mark "5"; 21.05.2009 (night) mark "5".
Navigation check	no information
Simulator training on Tu-154 Full Flight Simulator	Not conducted
Recurrent training	23.03- 24.04.2009
Flying time within the last month	35 hours 27 min
Flying time within the last 3 days	1 hour 14 min
Flying time on the day of the accident	1 hour 14 min
Time on duty on the day of the accident	about 3 hours
Annual medical examination	17.12.2009, Conclusion: Fit for flight operations.
Previous accidents	None

### Navigator

Position	Navigator
Sex	male
Year of birth	1978
Pilot's license	Not issued
Education	Secondary, Higher Officer Flight School for Air

	Forces, Demblin, 2001
Transition training for Tu-154M	<p>Individual program of theoretical training of 04.02.2009 approved by the head of Military Unit 2139. The transition training was conducted directly at the Military Unit.</p> <p>Order №Z -116/2009 of the head of Military Unit 2139 of 17.06.2009 authorizing for in-flight training as a navigator of Tu-154M. The checkride for authorization as a navigator and authorization for solo work as a navigator are not recorded in the flight log. No documents provided concerning the flight training with an instructor.</p> <p>Order №Z-9 of the head of Military Unit 2139 of 14.01.2010 provided concerning authorization for flights as a navigator of Tu-154M and authorization for VIP flights.</p>
Total flying experience  including: <ul style="list-style-type: none"> <li>- Tu-154M as a navigator</li> <li>- Yak-40 as a co-pilot</li> </ul>	<p>1060+ hours (PZL-130, TS-11, Yak-40, Tu-154M)</p> <p>59 hours 19 min. Solo flights as a navigator – 26 hours.</p> <p>389 hours</p> <p>Break in flights as a navigator of Tu-154M from 24.01.2010 to 10.04.2010 (2,5 months). At that period he was flying as a co-pilot of Yak-40, flying experience 40 hours 44 min.</p>
Navigation check	No information
Simulator training on Tu-154 Full Flight Simulator	Not conducted
Recurrent training	23.03.-24.04.2009 as a co-pilot of Yak-40
Flying time within the last month	7 hours 40 min
Flying time within the last 3 days	1 hour 14 min

Flying time on the day of the accident	1 hour 14 min
Time on duty on the day of the accident	about 3 hours
Annual medical examination	23.11.2009, Conclusion: Fit for flight operations
Previous accidents	None

### Flight Engineer

Position	Flight Engineer
Sex	male
Year of birth	1973
Pilot's license	Not issued
Education	Higher civil education, 2003. Specialization courses at the Central School for Aviation Specialists (CSIL) in 1996. Specialization: aviation mechanic for airframe and engine.
Transition training for Tu-154M	No data provided as to the training program. Order of the head of Military Unit 2139 №Z-131/2008 of 07.07.2008 authorizing for start of practical in-flight training on Tu-154M as a flight engineer. Order of the head of Military Unit 2139 №Z-244/2008 of 16.12.2008 on the basis of the check authorizing to fly as a flight mechanic <sup>7</sup> on Tu-154M. Order №Z-253/2008 of 31.12.2008 authorizing for flights as a flight mechanic on Tu-154M at night time. The flight log contains records on the conducted checkrides for flight authorization. Order №Z-88/2009 of 07.05.2009 authorizing for VIP flights.
Total flying experience	320+ hours (only Tu-154M), solo flights – 240 hours.
Check in flight	08.12.2009, mark "5". Done by a pilot, not a

<sup>7</sup> The order for transition training contained the words "flight mechanic" but not "flight engineer".

	flight engineer.
Simulator training on Tu-154 Full Flight Simulator	Not conducted
Recurrent training	23.03-24.04.2009
Flying time within the last month	9 hours
Flying time within the last 3 days	1 hour 14min
Flying time on the day of the accident	1 hour 14min
Time on duty on the day of the accident	about 3 hours
Annual medical examination	16.11.2009, Conclusion: Fit for flight operations
Previous accidents	None

### **1.5.2. Assessment of the Professional Training of the Flight Crew and Flight Operations Management in the Military Unit**

It is impossible to assess the professional level of the PIC and the other crew members completely as the Polish representatives did not provide relative documentation to confirm their qualification (training programs completion, ground and flight training, checkride data including flight data monitoring) as well as results of the simulator training.

According to the provided documents the PIC and the co-pilot were qualified as Class I pilots, the navigator and flight engineer were not rated for any class (not applicable). The navigator was qualified as a Class II pilot on Yak-40. Neither the PIC nor the other crew members have pilot's licenses. According to the medical examination all the crew members were fit for flight operations.

The flight crew members underwent theoretical and flight training in their Military Unit.

The flight logs contain data on the recurrent training.

Upon the investigation team request on the preflight briefing before the flight to Smolensk "Severny" Airdrome the Polish side provided information that the crew conducted a self preparation for the flight in question on 09.04.2010. The crew submitted the results of the preflight briefing to the chief of Military Unit and chief of squadron. There were no records concerning the preflight preparation, questions under study, used materials and monitoring of the flight preparation by the chiefs. Being interviewed the chief of squadron said that monitoring the readiness of subordinate crews was beyond his responsibility. The Military Unit has a flight task log (results of the preflight briefings and crew preparation) filled in by the PIC. The only record contained the crew data, number of flight task (№69/10/101) and type of flight. Following this is the PIC's signature confirming that the crew is ready for the flight.



According to the analysis of the provided materials a number of serious shortcomings have to be noted as to the arrangement of a VIP flight, formation of the crew and professional training of the crew.

The crew for the VIP flight was formed on April 2. The PIC had a comparatively insignificant experience of unsupervised flights in his position (a little over 500 hours) and he was appointed along with the crew who had even less experience of unsupervised flights on type (Tu-154M): co-pilot had 160 hours, navigator 26 hours and flight engineer 240 hours.

The PIC, co-pilot and navigator had initial flight training, had undergone transition training in their Military Unit for Tu-154M by individual training programs. The flight engineer, according to the Polish representatives, after receiving a qualification of the aviation mechanic (airframe and engine) performed ground maintenance of Tu-154M. Then he was directed for transition training to become a flight engineer (flight mechanic as mentioned in the order) of Tu-154M. The transition training program was not provided for the investigation team.

During the transition training the navigator and co-pilot conducted regular flights on the previous aircraft types, which could have affected the quality of the training. There are no simulators in the Military Unit which makes training and maintaining a needed professional level in IFR flights and handling emergency situations virtually impossible. No other simulator training centers for Tu-154 were used to provide this type of training.

After commissioning the PIC instead of strengthening his skills of piloting and crew management during the flight preparation and completion, without having an instructor authorization and proper training regularly changed his piloting seat from left as a PIC to right as a co-pilot. Thus, on April 7, 2010 the PIC flew to Smolensk "Severny" Airdrome as a co-pilot.

The Military Unit has a practice of transition training of pilots of one aircraft type to navigators of another aircraft type and a combination of regular flights as pilot on one type and as navigator on another. Thus, the navigator was also authorized for flights as a co-pilot of Yak-40. This practice can lead to the negative transfer of SOP skills from one aircraft type to another.

An interview with the Captain of a Yak-40 aircraft that conducted flights to Smolensk "Severny" Airdrome revealed that the existing SOP of the Polish crews on Yak-40 prescribes informing the PIC about the actual flight height using radio altimeter indications from the height of 250m (during approach).

The Military Unit has no Instruction on the SOP for the four-member Tu-154M crew. According to the explanations of the Polish representatives the flights are conducted by using directly the FCOM. It should be noticed that the Tu-154M FCOM was developed for the minimum

crew of 3 members, while the navigator's responsibilities and his interaction with the other crew members are not specified there.

Another shortcoming is that the validity of the PIC's weather minima (60x800) expired in February 2010. There is an unjustified note in the flight log concerning the weather minimum confirmation during an approach in Brussels on February 11, 2010. The check of actual weather conditions at Brussels on February 11, 2010 revealed that cloudbase was at 900m, visibility over 10 km.

The flight log contains 6 records on using the NDB approach during all flying experience as the PIC of Tu-154, the last conducted in December 2009. All the approaches were performed in the simple meteorological conditions.

The flight logs of some of the crew members (navigator) miss records concerning the authorization for unsupervised flights. There are no data as to navigation checks of the PIC, co-pilot and navigator. The provided data that the PIC underwent international flights training from 14.01.2005 to 24.04.2005 at LOT Airline are dubious as at that period the PIC was extensively engaged in flights (January – 13 flights, February – 24 flights, March – 6 flights, April – 17 flights, total time spent in flight – 32 days).

None of the crew members had insurance policies.

### 1.5.3. Ground Personnel

#### Chief Air Traffic Controller

Position	Chief Air Traffic Controller for Military Unit 06755
Sex	male
Year of birth	1961
Education	Riga Flight School for Civil Aviation in 1982
Qualification	First Class Specialist
Authorization for work as an airdrome control CATC	from 21.08.2000, Order № 161 of Chief of Military Unit 15401 of 25.08.2000
Experience	from 23.08.1984
Theoretical training	16.11.2009
On-the-job training	27.06.2009, complete check (flight shift duration 7 hours, 8 flights, 4 aircraft airborne at the same time). Total mark – "Excellent".

Annual medical examination conclusion validity	till 13.04.2010
Medical examination before the shift	at 05:15, authorized for air traffic control by the doctor on duty of Military Unit 06755.
Breaks in shift supervision over 3 months	None
Experience in the last 12 months	52 working shifts as an airdrome control CATC
Previous accidents	None
General conclusion	The professional level complies with the requirements to the CATC.

### Landing zone controller

Position	Main Assistant of the CATC Military Unit 6955 aviation base
Sex	male
Year of birth	1978
Education	Higher, secondary military, graduated from Balashov Higher Military Flight School in 2000
Qualification	First Class Specialist
Authorization for work as a landing zone controller	from 14.03.2005, Order № 42 of Chief of Military Unit 21322
Authorization for work at Smolensk "Severny" airdrome	On April 6, 2010 by order №83 of Chief of Military Unit 06755
Experience	from 30.09.2003
Theoretical training	16.11.2009
On-the-job training	09.02.2010, on-the-job check, day and night in simple meteorological conditions. Complete check (flight shift duration – 9 hours, 34 flights, 5/3 aircraft/air groups controlled at a time). Total mark – "good".
Annual medical examination conclusion validity	till 02.09.2010
Medical examination before the shift	at 06:50, authorized for air traffic control by the doctor on duty of Military Unit 06755.

Breaks in shift supervision over 3 months	None
Experience in the last 12 months	As near area controller – 37 shifts; As landing zone controller – 9 shifts
Previous accidents	None
General conclusion	The professional level complies with the requirements to the landing zone controller.

### Deputy Chief Air Traffic Controller<sup>8</sup>

Position	Second class pilot
Sex	Male
Year of birth	1977
Education	Higher, secondary military, graduated from Balashov Higher Military Flight School in 2000
Experience	from 21.10.2000
Authorization for work as a part of air traffic control team in 2010	On December 9, 2009 by Order №114 by Chief of the Military Unit 21350
Authorization for work at Smolensk "Severny" airdrome	On April 6, 2010 by order №83 of Chief of Military Unit 06755

### Head of meteorological station, Military Unit 06755

Position	Head of meteorological station, Military Unit 06755
Sex	male
Year of birth	1974
Education	Higher, graduated in 2009 from the Russian State Hydrometeorological University (St. Petersburg) specialized in "meteorology"
Authorization	Authorized for meteorological support of flights by order № 558 of Chief of Military Unit 21350 of 23 December, 2009
Experience	5 months

<sup>8</sup> Any pilot may be appointed to perform DCATAC duties.

**Meteorologist on duty of Military Unit 21350 (Tver)**

Position	Meteorologist on duty of Military Unit 21350
Sex	male
Year of birth	1968
Education	Higher, Voronezh Higher Military Aviation Engineer School in 1990 specialization "engineer-meteorologist"
Authorization	Authorized for duty by Order of Chief of aviation base 6955 № 140 of 02.11.2009
Experience	20 years

**1.6. Aircraft Information**

The aircraft before the accident is shown on Figure 1.



**Figure 1**

**Aircraft Information**

Type of aircraft	Airplane, Tu-154M
MSN	90A837

Manufacturer, date of manufacture	Kuybyshev Aviation Plant, 29.06.1990
Registration	Tail number 101, Republic of Poland
Certificate of Registration	Sz-428 от 24.01.2005
Certificate of Airworthiness	Not provided by the Polish side
Owner	Republic of Poland
Operator	Ministry of Defense, Republic of Poland. The AOC was not issued.
Life in service	by 08.04.2010: 5143 hours, 3899 landings
Life since last overhaul	by 08.04.2010: 139 hours, 76 landings
Overhauls	3 overhauls, last on 21.12.2009 at Samara Aviakor Aviation Plant.
service life and life between overhauls limits	On the basis of the Tupolev Ltd. Conclusion on 10.12.2009 the aircraft was assigned: <ul style="list-style-type: none"> <li>– service life limit of 25 years 6 months within the service time of 30000 flight hours 15000 flights;</li> <li>– Life between overhauls 7500 flight hours, 4500 flights and 6 calendar years.</li> </ul>
Remaining service life	24857 flight hours, 11101 landings, 5 years 8 months.
Remaining life between overhauls	7361 flight hours, 4424 landings, 5 years 8 months.
Type of fuel, amount	Jet A-1, ~18,7 tons
Last base maintenance	23.03.2010 form Ф-1К according to Maintenance Regulation PO-86
Last line maintenance	According to the flight log on 02.04.2009, service time 134 flight hours after the last overhaul, 71 landings, form Ф-Б in accordance with Maintenance Regulation PO-86
Insurance	Insurance policy not provided

### Engine Information

Engine type	D-30KU-154	D-30KU-154	D-30KU-154
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	2 series	2 series	2 series
Engine number	1	2	3
MSN			
full	59319012423	59249012426	59219012414
short	190-423	490-426	190-414
Manufacturer	Saturn Enterprise	Saturn Enterprise	Saturn Enterprise
Date of production	31.03.1990	25.11.1990	25.03.1990
Life in service by 08.04.2010	4261 hours 2491 cycle	7066 hours 3760 cycles	3989 hours 2469 cycles
Service life limits, basis	24000 hours 11100 cycles	24000 hours 11100 cycles	24000 hours 11100 cycles
	Decision № 168/012-048/2006 SB № 1847-БЭ-АБ с 01.09.2007		
Overhauls	4	3	4
Maintenance organization that made last overhaul	Saturn Enterprise	Saturn Enterprise	Saturn Enterprise
Last overhaul	28.08.2009	26.08.2009	25.08.2009
Installation date	23.12.2009	23.12.2009	23.12.2009
Life since last overhaul by 29.03.2010 <sup>9</sup> (Section 10 maintenance log)	145 hours 69 cycles	145 hours 69 cycles	145 hours 69 cycles
Life between overhauls limits, basis	5000 hours 2310 cycles	5000 hours 2310 cycles	5000 hours 2310 cycles
	Decision № 560/12-04/88 SB № 1500-БЭ-АБ от 08.08.1989		
Service time between overhauls limits	6 years	6 years	6 years
Remaining service life by 08.04.2010	19739 hours 8609 cycles	16934 hours 7340 cycles	20011 hours 8631 cycles

<sup>9</sup> The difference in time after last overhaul of the aircraft and engine is connected with line maintenance including engine run before every VIP flight (the data are taken from the aircraft flight log found at the accident site)s.

Remaining life between overhauls by 08.04.2010	4855 hours, 2241 cycles	4855 hours, 2241 cycles	4855 hours, 2241 cycles
Remaining service time between overhauls by 10.04.2010	5 years 4 months 12 days	5 years 4 months 12 days	5 years 4 months 12 days

### APU Information

Type of engine	TA-6A
MSN	5136A022
Manufacturers	Hidravlika Enterprise, Ufa
Date of production	02.02.1985
Date of installation after the last overhaul	23.12.2009, Aviakor Aviation Plant
Time since in operation by 31.03.2010	1680 hours/1771 starts
Service life limits, basis	3400 hours/5000 starts, SB B9704-БЭ-Г
Assigned service time, basis	30 years, Decision of Aerosila Enterprise №063.180.163.04
Maintenance organization performing last overhaul	AviaCenter-411", Mineral Waters
Date of last overhaul	16.09.2009
Service life since last overhaul by 31.03.2010	141 hours/172 starts
Service life limits between overhauls	1000 hours, 1800 starts with following stage-by-stage extension to 1600 hours, 2500 starts
Life time limit after last overhaul	10 years
Remaining assigned service life by 31.03.2010	1720 hours/3229 starts, 4 years 10 months.
Remaining life between overhauls by 31.03.2010	859 hours/1628 starts, 9 years 5 months.

From 02.06.2009 to 23.12.2009 the aircraft underwent the third overhaul at Aviakor Aviation Plant (Certificate of Compliance №2021090164 issued by the Federal Air Transport Agency of the Russian Federation on 16.04.2009, valid till 16.04.2011. License for aviation maintenance №3811-A-AT-PM issued by the Federal Agency for Industry on 02.04.2007 valid till 02.04.2012 ) in accordance with the overhaul procedures and life extension SB 154-998 БУ/АБ. Besides within the period of the overhaul the maintenance work was performed in accordance with the Program of technical assessment of Tu-154M (№90A837) of the Republic of Poland to assess the aircraft technical condition, its parts and appliances in order to determine the practicability of

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extending the service life limit after the third overhaul to 7500 flight hours, 4500 landings, 6 calendar years and assigned service life limit to 25 years 6 months as well as release the aircraft to operation with assigned service time of 30000 flight hours and 15000 landings approved by Tupolev Ltd. On July 1, 2009. On the basis of the maintenance conducted a Technical Assessment Sheet was made up approved by the Chief Engineer of the Aviakor Aviation Plant on 16.11.2009 in accordance to which the faults affecting the aircraft operation and safety were eliminated and the Tu-154M aircraft MSN №90A837 with its parts and appliances is in satisfactory condition.

Engines and APU overhauls were performed within the airframe overhaul conduct time:

- engine D-30KU-154 2 series MSN № 59319012423 had 4 overhauls. Fourth overhaul (IAW TY 59-00-800YK) – 28.08.2009 at Saturn Enterprise;
- engine D-30KU-154 2 series MSN № 59249012426 had 3 overhauls. Third overhaul (IAW TY 59-00-800YK) – 26.08.2009 at Saturn Enterprise ";
- engine D-30KU-154 2 series MSN № 59219012414 had 4 overhauls. Fourth overhaul (IAW TY 59-00-800YK) – 26.08.2009 at Saturn Enterprise ;
- APU engine TA-6A №5136A022 16.09.2009 second overhaul at AviaCenter-411 in accordance with the current overhaul manual.

The aircraft and engine maintenance was conducted by the maintenance personnel of the special air regiments of the Ministry of Defense, Republic of Poland in accordance with Maintenance Regulation PO-86 applying all maintenance forms (base and line) at the constant site of basing in Warsaw.

The Maintenance Organization Certificate was not provided by the Polish side.

The last base maintenance form Ф-1К PO-86 was conducted 23.03.2010. Service time since last overhaul by then was 114 flight hours, 61 landings. The number of maintenance sheet was not recorded in the flight log.

According to the records in the flight log found at the accident site the last line maintenance form Ф-Б in accordance with PO-86 was conducted 02.04.2010 with service life after overhaul of 134 flight hours 71 landings. Information on the maintenance personnel authorization was only provided for one out of 11 specialists.

The Polish side provided a list of maintenance personnel who conducted maintenance of Tu-154M aircraft tail number 101 on 10.04.2010. According to the provided information only three out of 6 persons were authorized for this kind of maintenance.

According to the information in the Explanation of the Head of Maintenance of Tu-154M t/n 101 aircraft in the period from 08.04 to 10.04.2010 underwent maintenance of the radome

damaged by bird strike on 08.04.2010. There was no information provided by the Polish side on the type of damage, ways of troubleshooting as well as about release to service.

The provided flight, engine and APU logs have been analyzed.

According to the flight log all the current service bulletins were performed during the third overhaul in 2009 at Aviakor Aviation Plant. The faults found during the overhaul concerning maintenance prescribed by SB 154-998 БЭ-АБ and Program of technical assessment were eliminated.

The analysis of the engine logs revealed that there were no complaints of the operation and technical condition of the engines in the course of operation between the last overhaul and the accident as there were no records in the engine log on any shortcomings or incompliances.

On 16.02.2010, by 96 hours 40 cycles after the last overhaul, all engines underwent SB № 1530-БУ-АБ - checking the intershaft bearing. There were no complaints.

The engine maintenance according to the records in Sections 11 and 12 of the engine logs was conducted in accordance with the maintenance manual for engine D-30KU-154 2 series, aircraft maintenance regulations and current SBs.

According to the tech log of engine TA-6A the Aviakor Service staff performed maintenance form Ф-2 and Ф-3 PO-02M on 20.11.2009 and filled it with MC-8П oil 0 hours after the last overhaul (maintenance sheet №70) and on 10.12.2009 they performed maintenance form Ф-Б PO-02M 5 hours 4 cycles (maintenance sheet №76). On 23.03.2010 the maintenance personnel of the special air regiment of the Ministry of Defense, Republic of Poland performed maintenance form Ф-1К in accordance with Maintenance Regulation PO-86

The analysis of the engine TA-6A flight log revealed that there were no complaints of the operation and technical condition of the TA-6A engine in the course of its operation between the last overhaul and the accident.

The current aircraft's Airworthiness Certificate was not provided by the Polish side. At the accident site the investigation team found an Airworthiness Certificate that had expired on 20.05.2009. Also found at the accident site was an Airworthiness Certificate (valid till 28.04.2010) for a Tu-154M t/n 102 that was undergoing overhaul at Aviakor Aviation Plant at the time of the accident.

Before the flight the aircraft was refueled by 7.6 tons making the total of 18.7 tons of fuel.

The laboratory analysis of the fuel quality (Section 1.16.4) revealed that the fuel was satisfactory.

The aircraft takeoff weight, considering about 500 kg of fuel burnt during taxiing, was about 85800 kg (maximum takeoff weight is 100000 kg) and the center of gravity was 25.3 % MAC (the

center of gravity range on takeoff is 21-32 % MAC). At the time of the accident there remained about 11 tons of fuel on board, the estimated landing weight was about 78600 kg and center of gravity was 24.2% MAC (CG range at landing is 18-32% MAC). According to Para 2.5.1 (3) of the AFM the maximum landing weight is 80 tons, which is higher than the actual aircraft weight at the time of the accident. The estimations of the maximum landing weight for the actual conditions at Smolensk "Severny" airdrome are provided in Section 1.16.14.

### **1.6.1. Special features of interest in the aircraft information**

The aircraft had on board the FCOM in Russian. At the same time a Polish FCOM of the LOT airline was found at the accident site. According to the available records the latest modification to the FCOM was introduced in February 1994. The aircraft manufacturer does not confirm that the FCOM was officially translated into Polish.

The aircraft cabin layout provided seats for 90 passengers. The minimum number of cabin attendants in accordance with Para 2.3 of the FCOM is 4 persons. In fact, along with the passengers and flight crew there were three cabin attendants on board and a security officer.

According to Para 2.2.1 (3) of the FCOM the weather minima for the radar+2NDB approach is 100m for decision altitude<sup>10</sup> and 1200m as to visibility (100x1200).

The aircraft was equipped with the TAWS and FMS UNS-1D systems. Both systems were designed by the Universal Avionics Systems Corporation (UASC) USA.

The aircraft was also equipped with the multifunctional display MFD-640 displaying the graphical information:

- Weather radar.
- TAWS.
- TCAS.
- Flight Management System.

#### **TAWS**

The TAWS system serves to warn the crew on the emerging flight conditions that can lead to inadvertent collision with terrain.

The TAWS system fulfils the following functions:

- Terrain indication with relevance to the current and forecasted aircraft position;
- Triggering of early warnings on ground proximity;

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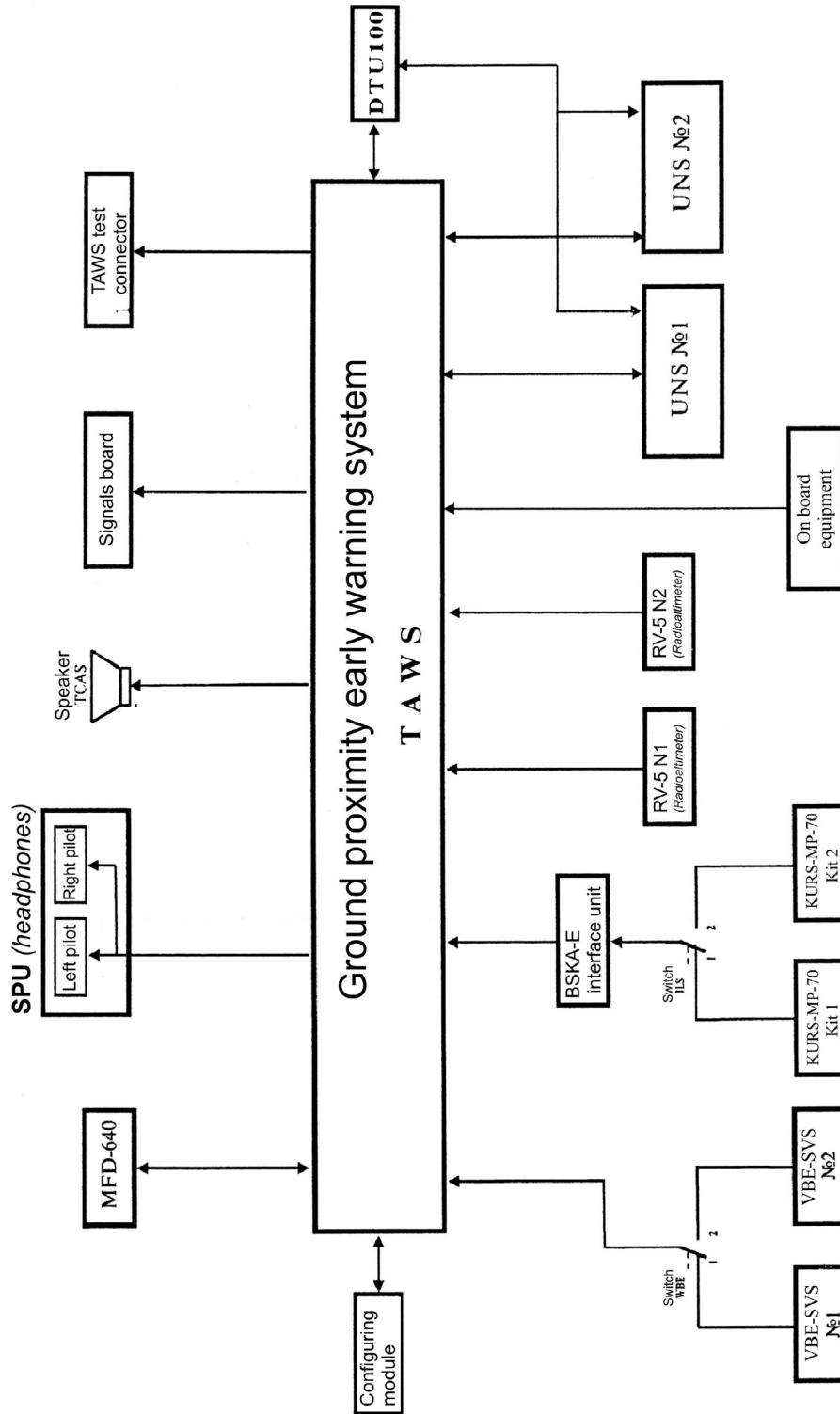
<sup>10</sup> The Tu-154M FCOM uses the term "decision altitude" regardless of the type of approach. Further in the Report the terms "decision altitude" and the "minimum descent altitude" are used as synonyms.

- Triggering of early descent warnings;
- Triggering of alerts in accordance with the functional modes of the standard GPWS system in the following modes:
  1. excessive rate of descent;
  2. excessive terrain closure rate;
  3. loss of altitude after takeoff or during a go-around;
  4. flight in the ground proximity in non-landing configuration;
  5. unallowable deviation below the glideslope.
- Emergency visual and aural alerts for the flight crew;
- Indication of the current flight plan from the FMS on the terrain background.

The structure of TAWS system and its interaction with the on-board systems and gauges is presented on the chart below (Figure 2 **Ошибка! Источник ссылки не найден.**).



**РУКОВОДСТВО ПО ЛЕТНОЙ ЭКСПЛУАТАЦИИ Ту – 154М**  
**ЭКСПЛУАТАЦИЯ СИСТЕМ И ОБОРУДОВАНИЯ – Пилотажные приборы и аппаратура**



Aircraft Tu-154M TAW S and on board equipment interaction diagram  
 Fig. 8.17.8a.1.

(прод)

**Figure 2**

The TAWS using information from the FMS, the air data reference system, the radio altimeter, the flap and landing gear position indicators, and the ILS signals determines the aircraft condition and in advance forms warnings and alerts on the potential danger. The system provides warnings on ground proximity by comparing the aircraft position parameters from the FMS with the relative terrain parameters. The terrain database in the system memory contains data on the points located every ½ miles around the world, and every ¼ miles between S60° and N70° within 15 nm of every large airport and every 0.1 miles within 6 nm of mountainous airports.

The Supplement to the Tu-154M FCOM for aircraft equipped with TAWS contains an additional limitation: “when landing at an airport not included in the airport database, the early ground proximity warning function of the TAWS system must be inhibited by pressing TERR INHIBIT to prevent false warnings”, while the standard GPWS modes remain available. Also Para 8.17.8a.1 of the Supplement contains a warning concerning inhibiting to use TAWS information displayed on MFD-640 for navigation”.

There is a feature of using TAWS while piloting using the QFE pressure altitude. To prevent false warnings, before setting the QFE at the pressure altimeter engage the QFE flight mode by pressing the relative light button (Supplement to the FCOM, Para 8.17.8a.2. (5)). However, the same FCOM Para contains a warning that simultaneous use of TERR INHIBIT and QFE modes is impossible. The QFE mode is also impossible to use if the system database does not contain the destination airport.

On the basis of flight tests of this system on Tu-154M type in 2002 a relative Act was made up with a general positive conclusion approved by the Deputy General Director of the State Research Institute for Civil Aviation “Aeronavigatsia” and Chief Designer of Tupolev.

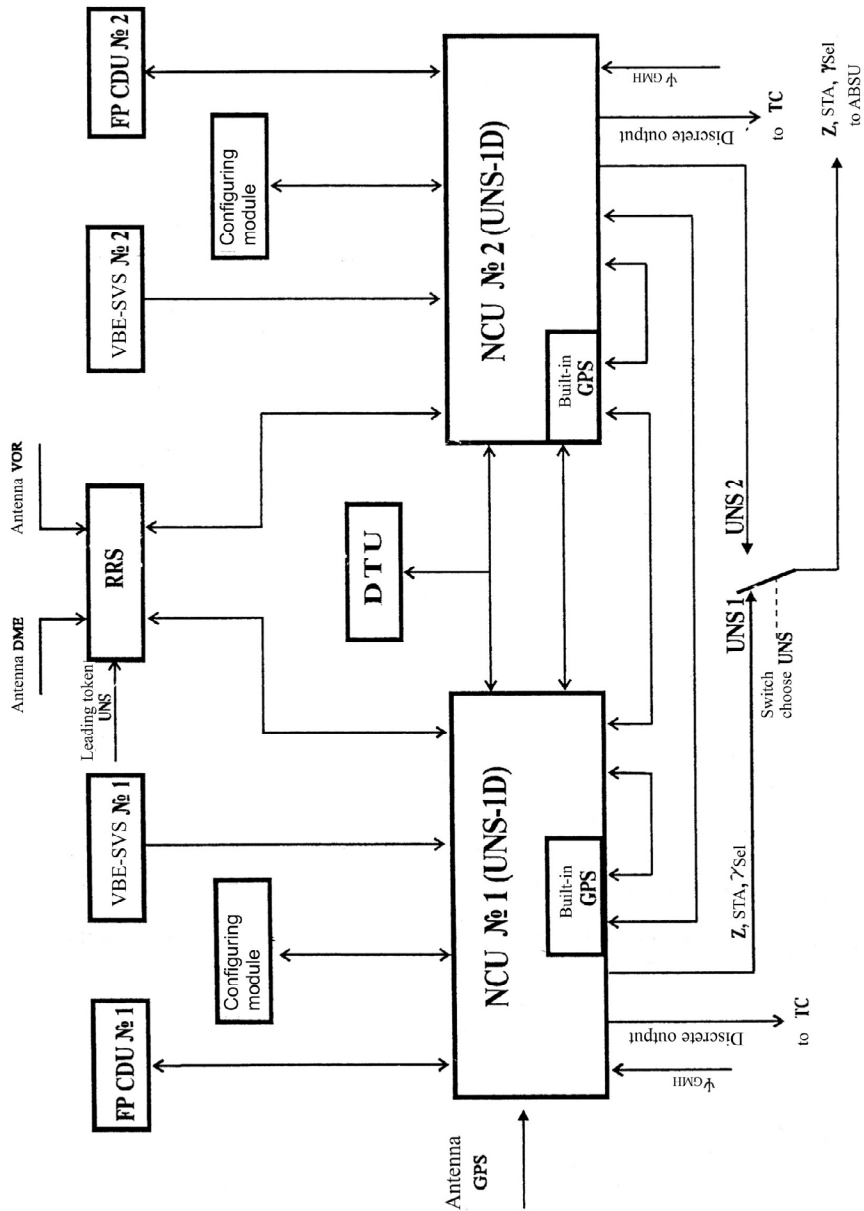
#### **Flight Management System UNS-1D**

The UNS-1D FMS serves for navigation functions when conducting flights all over the world. The aircraft has two sets of this systems installed. The UNS-1D structure and its interaction with the on-board system gauges is represented on the chart below (Figure 3 **Ошибка! Источник ссылки не найден.**).



РУКОВОДСТВО ПО ЛЕТНОЙ ЭКСПЛУАТАЦИИ Ту – 154М

ЭКСПЛУАТАЦИЯ СИСТЕМ И ОБОРУДОВАНИЯ – Навигационный комплекс



FMS and on board equipment interaction flow diagram  
Fig. 8.16.9.1.

(прод.)

Figure 3

Among other tasks the Flight Management System provides lateral control signal (target roll) to the autopilot as well as aircraft position information to the cockpit indicators along with the operability signal. The system does not provide vertical control signal (target pitch).

Section 8.16.9 of the Supplement to the FCOM restricts the use of the FMS:

- Use of the system during SID and STAR is allowed for reference only (no automatic control).
- Use of vertical navigation mode is allowed for reference only.

#### **AERO-HSD+ Satellite Communication System**

On agreement with the Chief Designer of Tupolev Ltd. in 2008 the aircraft was equipped with the AERO-HSD+ satellite communication system by Thrane & Thrane that does not affect the operation of navigation and other systems.

#### **Instrument Panels Layout**

The picture of the PIC and co-pilot's instrument panels is shown below (Figure 4). The second FMS control panel is on the central control panel (Figure 5) in front of the navigator's seat.





Figure 4





Figure 5

## 1.7. Weather Information

The following weather data and documents were analyzed:

- Circle weather charts for 10.04.2010 at 00:00, 03:00, 06:00, 09:00 UTC;
- Data from the stationary Meteosat-8 satellite for 03:00, 06:00, 08:00 UTC on 10.04.2010;
- Baric topography charts AT925hPa, AT850hPa, AT700hPa, AT500hPa for 00:00 UTC on 10.04.2010;
- Actual weather data for Smolensk "Severny" Airdrome on 10.04.2010;
- Weather forecasts for Smolensk "Severny" Airdrome for 10.04.2010;
- Complex radar charts for 00:00, 03:00, 06:00 UTC on 10.04.2010;
- Copy of the weather officer working log at Smolensk "Severny" Airdrome;
- Copy of the Weather log AB-6;
- Copy of the gale warning for area №3 of Smolensk "Severny" Airdrome;
- Copy of the meteorologist log for Tver airbase;
- Chart of visual references to determine the visibility from the weather station, BSKP, LMM-261, LOM-261<sup>11</sup> at Smolensk "Severny" Airdrome;
- Chart of weather facilities at Smolensk "Severny" Aircraft;
- Explanations of the head of the weather station, ATC, ATC CATC of Military Unit 06755, meteorologists on duty of Tver meteorological office;
- Weather observations of the weather stations of Smolensk Central Meteorological Service for 10.04.2010;
- Copy of the Act on cloudbase probes (DVO-2 and RVO-2M) check flight;
- Instruction to the meteorological shift on duty of the military unit 06755;
- Weather documents given to the crew of the Tu-154M before their departure from Warsaw: forecast an actual weather for Warsaw, Minsk and Vitebsk in TAF and METAR codes, Charts of significant weather forecast for FL 100-450 10.04.2010 for 06 and 12 UTC, Charts of wind and temperature for FL 240-400 and FL 300 10.04.2010 for 12 UTC, Chart of radar data of Poland for 10.04.2010 for 04:00 UTC, photo of clouds from the satellite on 10.04.10 for 00 UTC.

The analysis revealed the following:

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<sup>11</sup> This document uses out-of-date designations LMM-261 and LOM-261, instead of LMM-259 and LOM-259.

To conduct meteorological measurements the Smolensk "Severny" Airdrome in accordance with the Chart of Meteorological Objects approved by the Chief of Military Unit 06755 houses the following:

- Probes of cloudbase (DVO-2) at the weather station and middle marker (heading 259°);
- Recorders of cloud base (RVO-2M) at the CATC's station at BSKP and at outer marker (heading 259°);
- Wind parameter gauges M-49 at the weather station and at the CATC working place at the BSKP;
- Mercury cistern barometer at the weather station.

All the instruments are operable with certificates of compliance. The weather observations at Smolensk "Severny" Airdrome are conducted on the hourly basis within the working day of Military Unit 06755 and on command of Chief of Military Unit 06755 starting 10 minutes before the time of observation and finishing with the calculation of atmosphere pressure at the time of observation (00 minutes of every hour).

During the hourly observations the following is measured by instruments: cloud base, wind direction and speed at the ground surface, pressure at runway level and the following is estimated visually: amount and form of clouds, significant weather, horizontal visibility.

Results of the observations are recorded in the weather log AB-6 and are sent to the established addresses.

Actual weather at Smolensk "Severny" Airdrome is observed every hour in simple weather conditions and every half hour in complicated weather conditions within the airdrome minima (visibility 1000m, cloudbase 100m) and every 15 minutes lower than the aerodrome minima.

Significant weather is observed as it appears or disappears. Storm warnings in Military Unit 06755 are developed in order to provide flight safety and take timely measures to protect the aircraft at the airdrome from significant weather effect.

On 10.04.2010 the head of the weather station<sup>12</sup> was the only one in charge of the weather observations. The other employer "mechanic-driver-weather observer" was absent on sick leave.

Observations of the horizontal visibility on 10.04.2010 was performed by the head of the weather station in accordance with the Chart of visual references to determine the horizontal visibility from the Aviation Meteorological Station (Figure 6) and were monitored and clarified by the ATC CATC in accordance with the Chart of visual references to determine the horizontal visibility from the BSKP (Figure 7). Visibility determination from the weather station was hindered

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<sup>12</sup> Information on the head of weather station is given in Section 1.5.3.

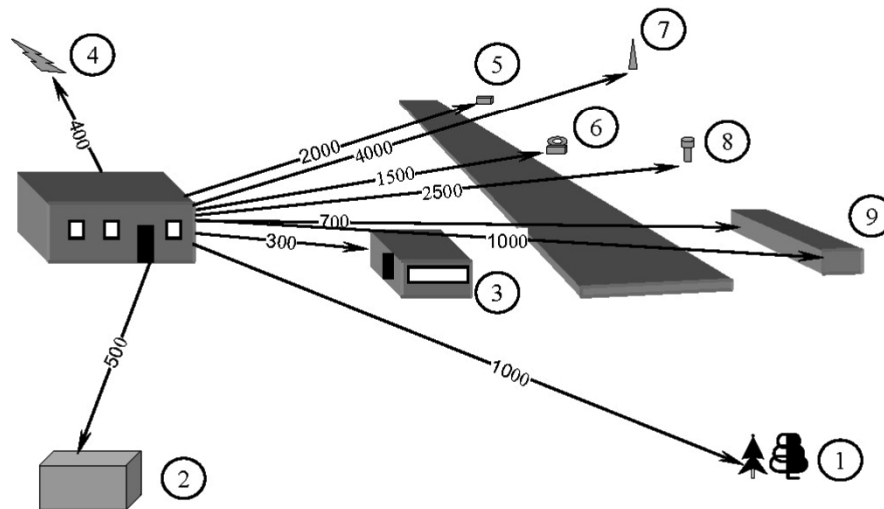
by the fact that a stand of suspended Il-76 aircraft is in the way of the visual range from the ground or the roof of the one-storey weather station building (from which the weather officer observes the weather).

**Note:**

*When checking the distance to the visual references at the Chart of visual references to determine the horizontal visibility from the Aviation Meteorological Station it was revealed an incompliance of the distance to reference 9 (Garages) 700 m (left side) and 1000 m (right side). In fact the measured distance to reference 9 made up 570 m (left side) and 650 m (right side). The distance to reference 6 (PCII) on the Chart is 1500 m, whereas in fact the distance was 1200 m. Distances on the Chart for the BSKP coincide with the actual distances.*

**Annex №14**  
**Smolensk (Severny)**

Chart  
of references for visual  
identification of horizontal  
visibility from AMS

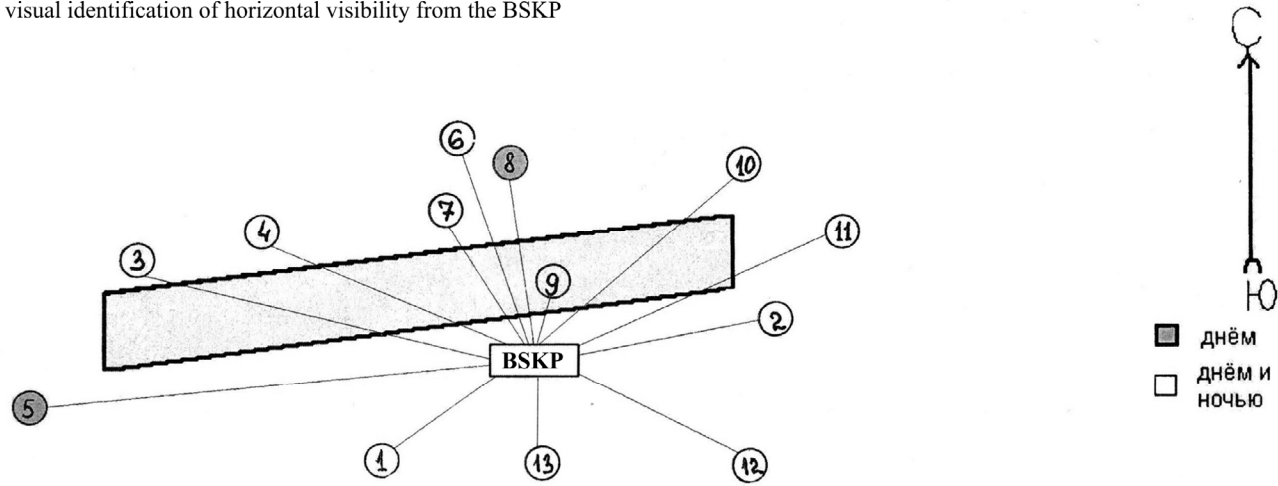


№п/п	Наименование ориентиров	Расстояние, м	Азимут, град.	Цветовая характеристика (цвет огней)	Фон ориентиров (день, ночь)
1	Деревья вдоль шоссе	1000	60	Темно – зеленый	Небо (Д)
2	Цех авиационного завода	500	170	Темно – серый (красный)	Небо (Д/Н)
3	БСКП	300	330	Серо – зеленый (белый)	Небо (Д/Н)
4	Памятник Миг-23	400	240	Зелено – коричневый	Небо (Д)
5	ДСКП	2000	275	Темно – серый (белый)	Трава, небо (Д/Н)
6	РСР	1500	285	Хаки (жёлтый)	Лес, трава (Д/Н)
7	Ретрансляционная вышка	4000	300	Красно – белый	Небо (Д/Н)
8	Водонапорная башня	2500	357	Темно – коричневый	Лес, небо (Д)
9	Гаражи	(700)1000	15	Серый	Кустарники (Д)

**Figure 6**

### Chart of references

for visual identification of horizontal visibility from the BSKP



№п/п	Наименование ориентира	Дальность	Азимут	Цвет ориентира	Факт
1	Учебный корпус	500	230	белый	не бо
2	Промежегор	330	70	зеленый	не бо
3	ДСКП	1700	273	белый	
4	РСП	1000	280	зеленый	
5	Ле сохозадея	6000	267	темный	не бо
6	Радиолахта	5000	335	темный	не бо
7	РСВН	400	330	зеленый	
8	Водонапорная башня	2200	342	серебристый	не бо
9	БВШП	80	355	серый	не бо
10	Гаражи	400	30	белый	
11	Фонари освещения шоссе	800	60	темный	не бо
12	Авиоагрегатный завод	900	120	серый	не бо
13	Авиационный завод	500	170	желтый	не бо

Figure 7



On April 10, 2010 the weather in Tula, Kaluga and Smolensk Regions was determined by the anticyclone ridge. In the morning thick mist, fog, and low stratified underinversion clouds formed. The atmosphere radio sounding over Smolensk at 04:00 from the ground level to 400-500 m revealed temperature inversion that was conducive to additional accumulation of condensation cores and formation of low stratified clouds, thick mists and fogs in the surface air layer with the relative moisture content of 90-98%. The altitude wind was south-easterly 140-160°, the fog area was gradually shifting with the air mass from the south-east to the north-west.

On April 10, 2010 in the Tula, Kaluga and Smolensk Region the fogs started forming in places in the second half of the night after 04:00 and in the morning the foggy area increased and shifted to the north-west areas of Smolensk Region.

The weather information designated as “storm” received from the weather stations on 10.04.2010 are listed below (Figure 8):

- Tula 04:10 fog 500m;
- Mosalsk 05:55 fog 800m;
- Kaluga 06:05 fog 600m;
- Sukhinichi 06:40 fog 700m;
- Spas-Depensk 07:39 fog 600m;
- Roslavl 07:30 fog 700m;
- Pochinok 07:50 fog 400m;
- Yelnya 08:15 fog 300m;
- Smolensk (South) 08:50 fog 500m.



**Figure 8**



The observation data from the M-2 weather station of Smolensk Southern Airport taken every three hours (00, 03, 06, 09, 12, 15, 18, 21 UTC) in SYNOP codes are transmitted to be displayed on the circle weather charts. The weather chart for 03:00 UTC at Smolensk (South) showed visibility 4km, mist, clear, the following chart for 06:00 UTC at Smolensk (South) showed visibility 500 m, sky overcast. Fog at Smolensk (South) was formed at 04:50 UTC.

Actual weather observations at Smolensk "Severny" Airdrome weather station started at 06:00 by the head of the weather station (meteorologist).

The actual weather measured for 06:00 was as follows: wind 130° - 2 m/sec, mist, smoke, clouds 3 points top, average, temperature +4,0°, dew point +0,6°, humidity 78%, QFE 744,7 mm mercury, QNH 767,5 mm mercury.

The weather forecast for Smolensk "Severny" Airdrome is made by the weather forecaster of the weather service of the first category air base of Military Unit 21350 (Tver).

The forecast for Smolensk "Severny" Airdrome was made by the weather forecaster at 05:30 for 10.04.2010 from 06:00 to 18:00: clouds 4-7 points top, at daytime cumulus clouds at 600-1000 m, mist, visibility 6-10 km, in the morning visibility 3-4 km, wind 120°-140°, speed 2-5 m/sec, temperature +14+17°.

The head of the weather station of Smolensk "Severny" Airdrome received the weather forecast by phone at 06:00. Then he transmitted the actual weather and the forecast to the ATC CATC and the dispatch officer<sup>13</sup> by phone.

The weather conditions at the airdrome started changing, the mist thickened and the meteorologist made an irregular weather observation at 06:36: visibility 4 km, mist, smoke, clouds 2 points top, scattered.

The regular weather observations according to the Weather log AB-6 were taken every hour at 07:00, 08:00, 09:00, the visibility and clouds did not change while the humidity increased to 86-89%.

07:00: wind 130° - 3m/sec, visibility 4 km, mist, smoke, clouds 2 points top, scattered, temperature +2,6°, dewpoint +0,5°, humidity 86%, QFE 744,7 mm mercury; QNH 767,5 mm mercury;

08:00: wind 120° - 2 m/sec, visibility 4 km, mist, smoke, clouds 2 points top, temperature +1,8°, dewpoint +0,2°, humidity 89%, QFE 744,5 mm mercury; QNH 767,3 mm mercury;

09:00: wind 140° - 2 m/sec, visibility 4 km, mist, smoke, clouds 3 points top, temperature +2,4°, dewpoint +0,5°, humidity 87%, QFE 744,5 mm mercury; QNH 767,3 mm mercury.

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<sup>13</sup> The duties of the dispatch officer are given in Section 1.17.3.

Actual weather information for 09:00 was transmitted by the head of the weather station to the ATC CATC and dispatch officer by phone.

After 09:00 the meteorologist observed the decreased visibility and formation of low stratified clouds and made an irregular weather measurement. At 09:06: visibility 2000 m, mist, smoke, clouds 6 points, broken at 150m.

The weather data was transmitted to the weather forecaster at Tver and dispatch officer by phone.

At 9:15 the weather forecaster amended the forecast for Smolensk "Severny" Airdrome: before 12:00 7-10 points stratus clouds, cloud base 150-200 m, visibility 1500-2000 m, mist, after 12:00 clouds 5-8 points, scattered, top, visibility 10 km.

At 9:15 this clarified weather forecast was transmitted by phone to the head of the weather station of Smolensk "Severny" Airdrome.

Then the meteorologist observed further decrease in weather conditions and made an irregular weather observation at the airdrome for 09:26: visibility 1000m, mist, smoke, clouds 10 points stratus at 100 m and transmitted it to the dispatch officer by phone.

At 09:36 the CATC requested the meteorologist on the information concerning the worsening weather: "weather... weather... why are you keeping silent... the fog descended". After that the meteorologist made an irregular weather measurement and noted the start of dangerous weather (fog) at 09:40: visibility 800 m, fog, clouds 10 points stratus at 80m."

This stormy weather was transmitted to the weather forecaster and dispatch officer on duty by phone.

**Note:**

*In case of fog or precipitation, when it is impossible to determine the cloud base as well as type and amount of clouds, the vertical visibility is determined instrumentally with the help of the cloud base probes. In this case the vertical visibility is correlated with the cloud base.*

*The cloud base determined instrumentally by the head of the meteorological station with the help of the cloud base probe DVO-2 provided there was actual fog at the airdrome corresponded to the actual vertical visibility in foggy conditions.*

*Thus, both terms actually reflect the same characteristic of the actual airdrome weather and are used as synonyms in the present Report.*

At 09:42 the deputy Chief of Military Unit 21350<sup>14</sup> from the BSKP requested the weather station: “Weather, how long is the fog going to stay? Weather. Roger, let’s coordinate with Moscow the forecast that did not come true, I mean the fog, when is it going to finish?”

On the basis of the worsening weather the head of the weather station compiles and coordinated with the weather forecaster of Military Unit 21350 a storm warning №3 for Smolensk airdrome area for the period from 09:40 to 11:00 expected due to advection of humid air 8-10 points stratus 50-100 m, thick mist, waved fog, visibility 1000-1500m in fog 600-1000m.

The storm warning was transmitted to the weather forecaster and dispatcher at 09:43.

At 09:50 the actual weather and storm warning were reported to the head of commandant’s office – chief of Military Unit 06755.

The regular weather observation was made by the meteorologist at 10:00.

10:00 wind 160°-2 m/sec, visibility 800 m, fog, visibility 10 points stratus 80 m, temperature + 2,0°, dewpoint +1,5°, humidity 96%, QFE 744,6 mm mercury, QNH 767,4 mm mercury. This actual weather was transmitted to the dispatcher by phone.

At 10:00 the weather forecaster of the weather station of Military Unit 21350 Tver (according to the weather log of regiment 21350) once again amended the forecast for Smolensk "Severny" Airdrome for 18:00: 7-10 points stratus at 50-100 m, improving after 12:00: 5-8 points top, scattered, mist, visibility 4-6 km; before 12:00 fog, visibility 400-800 m, wind 120-140°1-4 m/sec, temperature +8+11°C

At 10:00 the forecast was transmitted to the head of the weather station of Smolensk "Severny" Airdrome. This clarified forecast was not transmitted by the head of the weather station to the ATC CATC and dispatcher.

At 10:05 the ATC CATC made a phone request to the meteorologist: “What are you giving out now?.. Well, is storm issued”?” The meteorologist replied: “Now 80 by 800 reporting... stormy weather”.

At 10:15 the head of the weather station informed the head of Military Unit 06755 that before 11:00 further improvement of the weather is dubious.

The analysis of the BSKP communications record revealed that the ATC group was constantly monitoring the actual visibility using their reference plot. After they were contacted by the crew of the Tu-154M the latter was informed twice that the actual visibility was 400 m.

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<sup>14</sup> Information on this person is given in Section 1.17.3.

At 10:23 the head of the weather station upon request of the ATC CATC made a phone request of the weather for Smolensk Southern Airdrome: 10 points stratus at 50 m, fog, visibility 500 m, wind 100° - 2 m/sec, temperature +2.0°.

After this the meteorologist made an irregular weather observation for 10:28: visibility 600 m, fog, clouds 10 points stratus at 60 m.

10:40: Td+1.7°, Tw +1.4°, humidity 98%<sup>15</sup>, wind 120°- 2 m/sec;

10:52: Td+1,8°, Tw +1.6°, humidity 96%, wind 140°- 3 m/sec.

Irregular complete weather observation (test measurement) of the actual weather after the accident was not conducted.

The regular weather observation was made at 11:00. At 11:00: wind 120°-2 m/sec, visibility 600 m, fog, visibility 10 points, stratus at 60 m, temperature +1,8°, dewpoint +1,3°, humidity 96%, QFE 744,8 mm mercury, QNH 767, 6 mm mercury.

An irregular weather forecast was made by the head of the weather station at 11:38. At 11:38: visibility 500m, fog, clouds 10 points stratus 50m.

The regular weather observation was made at 12:00. At 12:00: 130°-3 m/sec, visibility 500 m, fog, clouds 10 points stratus at 50 m, temperature 1,8°, dewpoint 1,5°, QNH 745 mm mercury, humidity 98%, QFE 767, 8 mm mercury.

At 12:15 an irregular weather observation was made due to dispersing fog and its turning into mist. At 12:15: visibility 1200 m, mist, clouds 10 points stratus at 100 m.

At 12:17 the weather forecaster of Military Unit 21350 Tver reported the amended weather forecast for Smolensk "Severny" Airdrome by 14:00: 7-10 points stratus, 100-120 m, visibility 1-1.5 km; after 14:00 5-8 points stratocumulus at 400-600 m, top, scattered, visibility 4-6 km.

At 12:30 the weather conditions at the airport improved and the meteorologist made a regular measurement. At 12:30: visibility 2000 m, mist, clouds 10 points stratus at 140 m.

Thus the estimated actual weather at Smolensk "Severny" Airdrome at the time of the accident at 10:41 was as follows: surface wind 110-130°, speed 2 m/sec, visibility 300-500 m, fog, clouds 10 points stratus, cloud base 40-50 m, temperature +1+2°C, QFE 745 mm mercury.

The weather forecast for Smolensk "Severny" Airdrome for 10.04.2010 from 06:00 to 18:00 developed by the weather forecaster of Military Unit 21350 at 05:30 and amended at 09:15 did not come true as to the cloud base, visibility and significant weather – fog. However, the

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<sup>15</sup> Td и Tw are the indications of the dry and wet thermometers respectively, used to calculate the relative humidity of the air.

arrangement of the weather observations at Smolensk "Severny" airdrome allowed revealing the decreasing weather conditions and informing the crew of the Tu-154M in due time.

It should be also noted that on April 10, 2010 at 08:10 before departing from Warsaw to Smolensk "Severny" the crew of the Tu-154M tail number 101 signed for receiving weather documents that included TAF weather forecasts and METAR actual weather for Warsaw, Vitebsk, Minsk and Sheremetyevo. They also received: Charts of significant weather forecast for FL 100-450 10.04.2010 for 06 and 12 UTC, Charts of wind and temperature for FL 240-400 and FL 300 10.04.2010 for 12 UTC, Chart of CAPPI radar data of Poland for 10.04.2010 for 04:00 UTC, photo of clouds from the satellite on 10.04.10 for 00 UTC. The forecast and actual weather documentation for Smolensk "Severny" Airdrome were not given to the crew. The forecast for Vitebsk alternate airdrome was expired.

### **1.7.1. Temperature inversion in the lower atmosphere layer**

On the basis of the atmosphere radio sounding by the aerological station of Smolensk for 10.04.2010 at 04:00 the surface layer of the atmosphere from ground level to 400-500 m was characterized by radiation temperature inversion. Near the ground the temperature was +4,3°C, at 400 m +7,6°C and at 600 m +6,0°C which was conducive of formation and retaining of underinversion low stratified clouds with top at 400-500 m and retaining of fog in Smolensk area in the morning hours.

*Note: Radiation inversions emerge in anticyclone weather (at night time) characterized by still weather or slight wind at the surface, and strong wind over the inversion layer. Maximum wind is at the top edge of the inversion.*

Taking into consideration the weather conditions in the area of Smolensk "Severny" Airdrome on 10.04.2010 by the time of the accident: decrease in temperature at ground level to 1,7°C, increased temperature inversion at the ground level, slight surface wind 120° x 1-3 m/sec. at circle altitude (500 m) expected wind had maximum speed of ~10 m/sec, 110-130°.

## **1.8. Aids to Navigation**

Operation and maintenance of the nav aids at Smolensk "Severny" Airdrome is conducted by the Department for Communication and Aids to Navigation.

The Department for Communication and Aids to Navigation performs:

- Radar support of the flights.
- Release to service of aids to navigation and communication.
- Maintenance, repair and exchange of aids to navigation and communication.

- Calibration of aids to navigation and communication.
- Maintenance of electrical control panels, diesel generator serving for power supply to the aids to navigation and communication.
- Arranging technical training, release to unsupervised work, recurrent training for personnel operating the aids to navigation and communication.
- Arranging labor protection and safety measures and fire safety measures at aids to navigation and communication.

The personnel engaged at the Department for Communication and Aids to Navigation of Military Unit 06755 on April 10, 2010 was authorized for flight servicing by the Order № 264 of the Chief of Military Unit 06755 of November 25, 2009 and for unsupervised operation of the aids to navigation and communication by order of the Chief of Military Unit 06755 № 319 of December 31, 2009.

The preflight maintenance of the aids to communication and navigation was conducted from 7:00 to 8:00 on April 10, 2010 by the personnel of the shift on duty with relative records in the equipment logs. According to personnel statements the aids to communication and navigation were operating normally.

In accordance with the available information there were no interruptions in the power supply of the aids to navigation and communication.

The approach chart for runway 26 and current NOTAMs valid at the time of the accident are shown on Figure 9 and Figure 10.

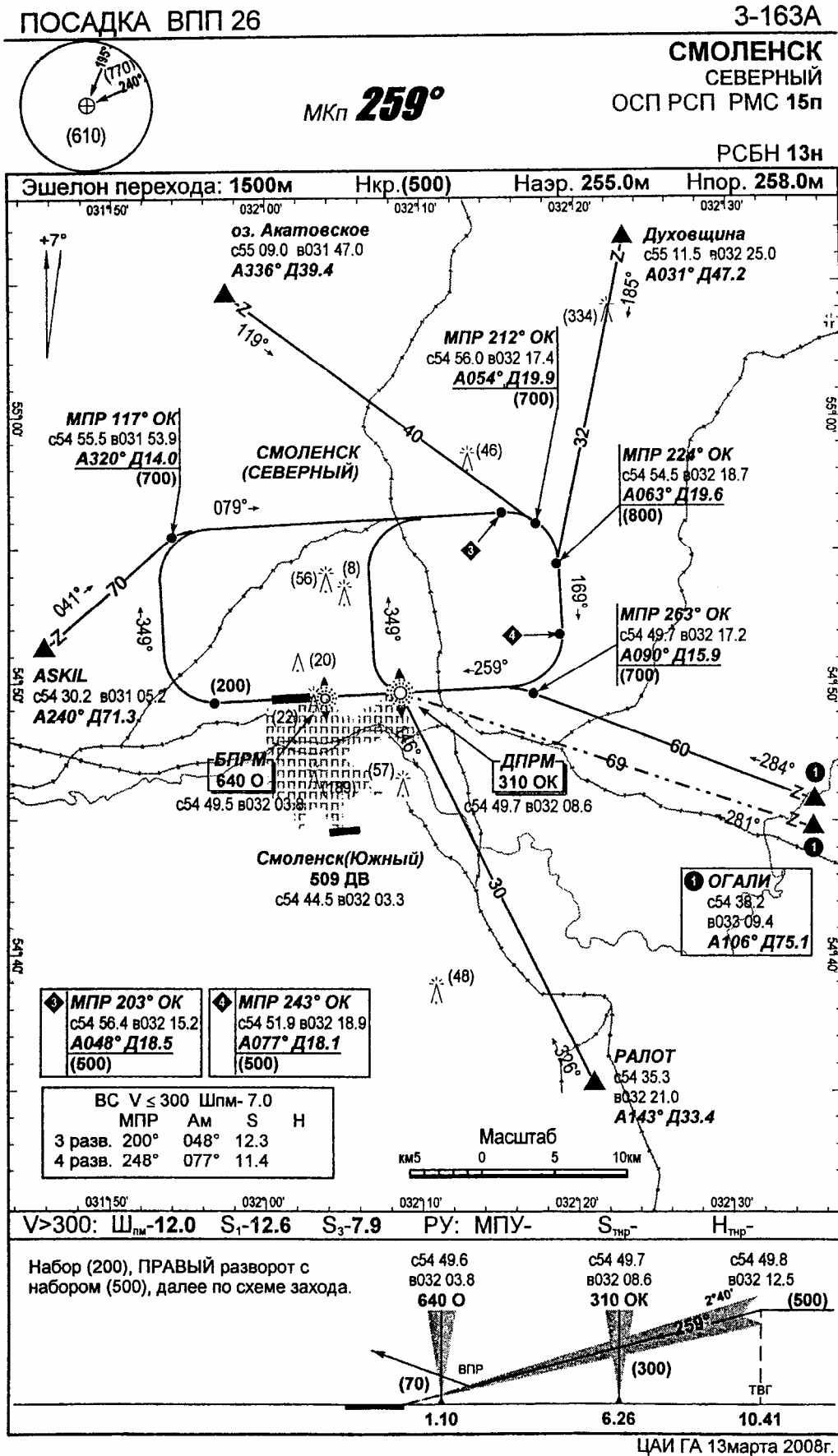


Figure 9

**НОТАМ серии М по аэродрому СМОЛЕНСК (СЕВЕРНЫЙ)  
(по состоянию на 10 апреля 2010г.)**

(М2113/09 НОТАМН  
А) БУБС Б) 0910150600 Ц) ПОСТ  
Е) АД СМОЛЕНСК (СЕВЕРНЫЙ)  
ВЫВЕДЕНЫ ИЗ ЭКСПЛУАТАЦИИ:  
РСБН-4Н  
ВПИ 08: ДПРМ. БПРМ. ССО. РМС  
ВПИ 26: РМС.)

(М2157/09 НОТАМН  
А) БУБС Б) 0910200600 Ц) ПОСТ  
Е) АД СМОЛЕНСК (СЕВЕРНЫЙ)  
ИСКЛЮЧЕНЫ ИЗ ИСПОЛЬЗОВАНИЯ КОРИДОРЫ ВХОДА/ВЫХОДА:  
НР 1 АМДОР-АКАТОВО-СМОЛЕНСК/СМОЛЕНСК-АМДОР  
НР 3 ОГАЛИ-СМОЛЕНСК/СМОЛЕНСК-ОГАЛИ  
НР 5 АСКИЛ-СМОЛЕНСК/СМОЛЕНСК-АСКИЛ.)

(М0044/10 НОТАМН  
А) БУБС Б) 1001200000 Ц) ПОСТ  
Е) АД СМОЛЕНСК (СЕВЕРНЫЙ)  
ЗАПАСНЫМ ДЛЯ ВС ГОС. АВИАЦИИ В МОСКОВСКОМ ЗЦ ЕС ОРВД  
НЕ ОБЕСПЕЧИВАЕТ.)

**Figure 10**

A list of aids to navigation and communication of the Department of Communication and Aids to Navigation:

№	Abbreviation	Full name
1	RSP-6M2	Radar Landing System
2	ARP-11	Automatic Direction Finder
3	PAR <sup>16</sup> -10C, E-615.5	Locator outer marker, landing course 259°M
4	PAR-10C, E-615.5	Locator middle marker, landing course 259°M
5	ATC Control Place	ATC Control Place

The following aids to communication and navigation<sup>17</sup> were used to provide flights on April 10, 2010 for the runway in use with landing course 259° M:

**Locator Outer with Marker**

The PAR-10C locator (NDB), MSN 1004567, in service since 1990 with a E-615.5 marker, MSN 59278, manufactured in 1989 is located at actual distance of 6280 m<sup>18</sup> from Runway 26 threshold. Frequency 310 kHz. The untypical position was approved and released to service

<sup>16</sup> Translator's note: here PAR is a model of NDB not the Precision Approach Radar.

<sup>17</sup> The findings of the flight check of the aids to navigation and communication conducted during the preparation of the airdrome to accept the flights of April 7 and 10, 2010 are described in Section 1.17.4, and the findings of a test fly-around of the airdrome's aids to navigation on 15.04.2010, conducted in the course of the investigation are given in Section 1.16.6.

<sup>18</sup> In accordance with the Reference Book of Aeronautical Information Center – at a distance of 6260 m, according to RTP for Smolensk "Severny" Airdrome – at a distance of 6100 m.



### **Locator Middle with Marker**

The PAR-10C locator (NDB), MSN 7643, released to service in 1981 with a E-615.5 marker, MSN 0147, manufactured in 1981 is located at an actual distance of 1050 m<sup>19</sup> from the runway 26 threshold, which complies with regulations concerning the positioning. Frequency - 640 kHz.

### **Automatic Direction Finder**

ARP-11 automatic direction finder, MSN 1135, released to service 1988, complies with regulations concerning the positioning. Range and accuracy comply with the established requirements.

### **Radar Landing System**

The RSP-6M2 radar landing system, MSN 9762, released to service 1989, complies with regulations concerning the positioning. The radar landing system functions in the modes determined by the performance specifications.

The radar landing system above all must include a Surveillance Radar (SR) and Landing Radar (LR). The radar landing system antennae must be located at 150-200 m from the runway centerline with allowable deviation from abeam the runway center of  $\pm 200$ m. Actually, the radar landing system antennae are located 200 m to the north of the runway, on the same distance of 1250 m from both thresholds.

The minimum and maximum range of the landing radar and its accuracy is determined by the landing zone controller for each mode. The minimum range is determined on the basis of the disappearing of aircraft blip on the radar screen in the active and moving aim selection modes and as the aircraft blip merges with the other local objects in the idle mode. The LR data are updated every 1 second.

The fly-around check of the LR at Smolensk "Severny" Airdrome revealed that the LR minimum range from RWY 26 threshold was 1 km in active and MAS modes and 1.5 km in idle mode. LR operating range horizontally is 20 km.

### **ATC Group Working Stations Equipment**

The working stations are equipped with VISIP-75T interface displays (remote brightness landing system indicators).

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<sup>19</sup> In accordance with the Reference Book of Aeronautical Information Center – at a distance of 1100 m, in accordance with Smolensk "Severny" RTP – at a distance of 1050 m.

The glide path lines and glide path tolerance areas are depicted on the demountable screen. The glide path tolerance areas are determined as a sector veering 0.5° up and down the glide path line on the screen. The line parameters of the allowable deviations depending on the distance from the runway are shown in the table below.

Distance from the runway (km)	Glide path tolerance area (m)
10	±90
4	±35
1	±10

### Airdrome Lighting Equipment

The Luch-2MU lighting equipment, MSN AK 14152045, released to service in 1991 is arranged in accordance with scheme SSP-1 with landing course of 259 degrees magnetic without the flashing lights. In accordance with the RTP for Smolensk "Severny" Airdrome the lighting position scheme is as shown below:

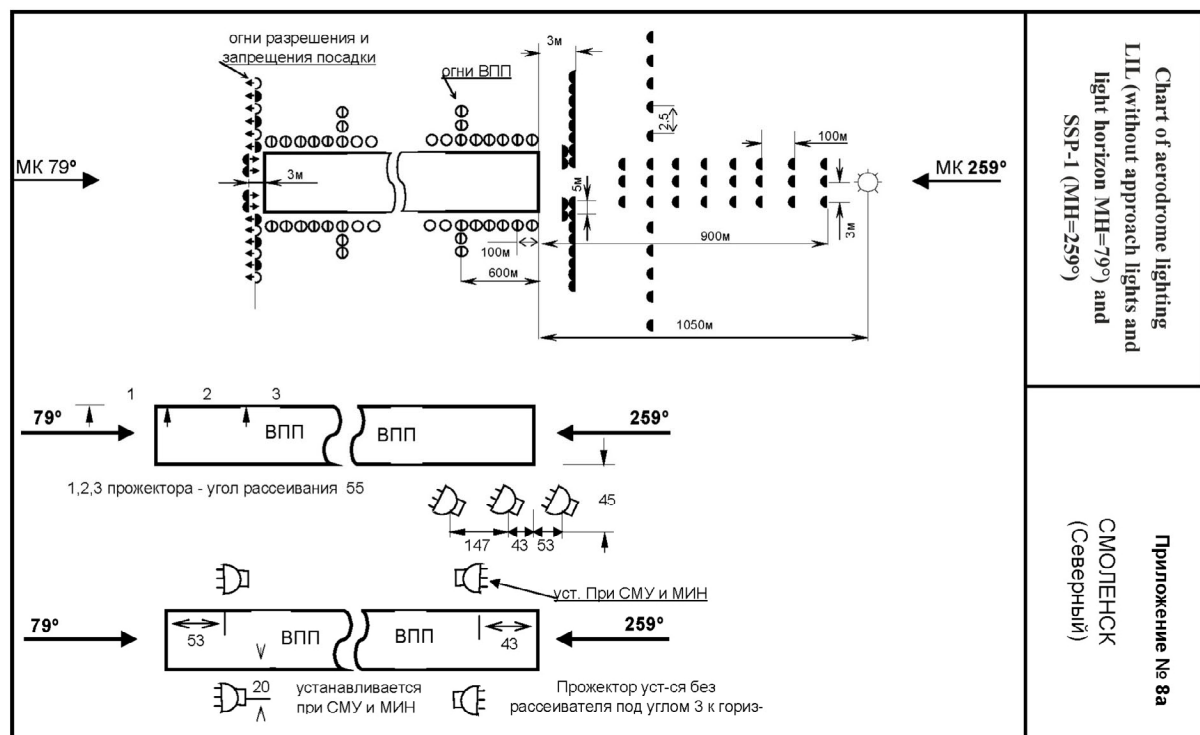


Figure 11

The fly-around check on 15.04.2010 (Figure 12, Figure 13) revealed that in comparison with the shown scheme, there is one more light line at a distance of 100 m from RWY 26 threshold, the actual number of threshold lights (green) is 6 instead of the 8 lights specified in the RTP. The lighting equipment check also revealed that depending on the aircraft position and

flight altitude the lights at a distance of 400, 700 and 800 m from RWY 26 can be shaded by the surrounding trees and bushes.

It was not possible to determine the condition of the lighting system at the time of the accident. According to the report of the projector driver on 10.04.2010 at 7:00 to 8:00 during the preflight test of the lighting equipment it was in good condition and operative. Right after the accident of the Tu-154M it was impossible to check the operability of the lighting equipment due to dense flight schedule at the airdrome up to 5:00 on 11.04.2010. The investigation team did not receive any complaints from the crews conducting flights in that period. The examination was conducted at 9:00 on 11.04.2010. It revealed that the lights of the second and third group (800 and 700 m from RWY 26 threshold) were missing, there were fragments of lights, the power cable was torn off. The light filters on the firsts group lights (900 m) were broken, only one of the three lights was operative. These light groups are beyond the airdrome, within the city area in easily accessible unsecured areas.

The lighting system was recovered on 14.04.2010 which is confirmed with the data of a fly-around on 15.04.2010.



**Figure 12**



**Figure 13**

The KNS-4U code beacon installed on the LIM (Figure 12, Figure 13), MSN LN 13419258, released to service in 1983, complies with the technical regulation concerning the positioning. The code beacon serves to depict the airdrome area with the light signals (it is not a part of the threshold and runway lights). The code beacon must emit two-letter authentication signal equal to the authentication signal of the LOM for the given landing course. Emission color – red. Flashing mode, frequency - 30-60 flashes a minute.

The investigation team revealed that at the time of the visual examination (on 11.04.2010) 2 out of 6 mandatory beacon lights were missing.

### **Airdrome Projector Stations**

In compliance with the location pattern for lighting equipment for Smolensk "Severny" Airdrome (Figure 11) at daytime with reduced visibility (in complicated meteorological conditions and in the airdrome weather minima) special projectors mounted on cars (Figure 14) serving to help the crew to align with the runway centerline shall be placed at the airdrome.



**Figure 14**

The APP-90P automatic projector, MSN. № EP 32952070, released to service in 1989, and the APP-90P automatic projector, MSN № EG 32952245, released to service in 1989 comply with the technical regulations.

According to the explanation of the Head of Department for Communication and Aids to Navigation of Military Unit 06755 on April 10 the projectors were set in daytime mode (turned in the approach direction with an angle of 3°) before the landing of Yak-40 aircraft about 9:00-9:05. According to the explanations of the crews of Yak-40 and IL-76, the projectors were lit and operative.

### **1.9. Communications**

There are three VHF radio stations: main P-845M4 msn № 2124960 released in 1991, standby radio station P-862 msn № 156323 released in 1991, emergency radio station “Polet-1” msn № 7169 released in 1989.

The special flight test of the VHF radio stations was conducted on March 25, 2010. The flight test (flight test protocol of March 25, 2010) revealed that the accuracy parameters of the VHF radio stations comply with the established standards and operational requirements. The VHF radio stations are suitable for flight support without restrictions.

The telephone and loud-speaking communication between the ATC centers and support services was arranged in accordance with the procedures of communication with the ATC and support services.

There were no complaints on the communications quality on 10.04.2010.

### **1.10. Airdrome Information**

Airdrome services of Smolensk "Severny" Airdrome are provided on the basis of Certificate of State Registration and Airworthiness № 86 of 25.05.2006 extended to 01.12.2014.

The Smolensk "Severny" Airdrome is joint airdrome housing:

- Military Unit 06755 Military Transport Air Forces (Ministry of Defense, Russian Federation);
- Test flight station of Smolensk Aviation Plant (Ministry for Industry and Trade, Russian Federation).

The Smolensk "Severny" Airdrome is located 3 km to the north of Smolensk railway station.

The Airdrome Reference Point is the geometrical center of the runway that lies 1250m from each runway threshold. The ARP elevation is + 255 m, and coordinates are N54°49'29" and E032° 01'34" (SK-42 system).

The Smolensk "Severny" Airdrome has one runway measured 2500 m by 49 m with concrete covering.

The landing and takeoff courses are 79°M and 259°M. Magnetic declination is +7°. The thresholds are designated 08-26. The runway edges location coincides with the runway thresholds.

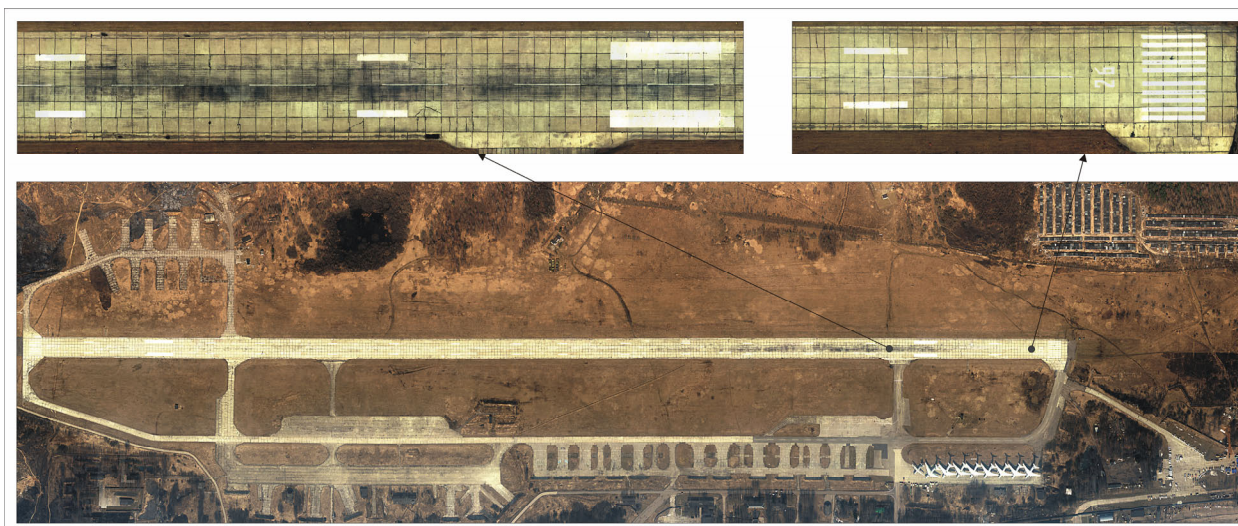
Each end of the runway has a graveled safety strip extended for 200 m from the east and for 250 m from the west.

The safety strip is a cleared and graded strip of land serving to mitigate the risk of aircraft damage. Both lateral and longitudinal slopes of the safety strips do not exceed 1 – 2 % and their directions do not change.

The safety strips contain the approach lights. The lights are mounted on light posts and have fragile bases.

The extended runway centerline is marked by the dashed line 0.5 m wide. The interval between the dashes is 30 m (Figure 15).





**Figure 15**

The runway threshold marking represents lengthwise lines 30 m long each, the width of the lines and distance between them is 1,8-2 m and the distance between the two lines nearest to the centerline is 3,5-4 m. The lines are symmetrical to the runway centerline, 15 m from its threshold.

The landing zone marking represent 5 pairs of rectangular symmetrical lines measuring 22.5 by 3 m parallel to the runway centerline in both approach directions. The distance between the inner sides of the lines is 18 m. The distance between the line pairs is 150m.

The airdrome is suitable for takeoff and landing of aircraft of Category A,B,C,D,E<sup>20</sup> with a restriction connected with the surface covering classification number.

There is no approval for international flights and the airdrome was not categorized according to ICAO standards (not applicable).

The airdrome services were supervised by a technician of Military Unit 06755. At the time of the accident on 10.04.2010 the airdrome service shift supervision was conducted by the technician on duty. The commander of the airdrome technical platoon was in charge of the cordon shift in accordance with Order of the Chief of Military Unit 06755.

The airdrome condition log contained the following entry of 10.04.2010: “runway, taxiways, main taxiways ready for arrivals and departures. Friction factor 0.55”.

### **Assessment of Obstacles on Course 259° Magnetic**

According to the airdrome Rules for Terminal Procedures the following obstacles are located in the clearway adjacent to the runway threshold with course 259°: buildings, posts, antennae, trees.

<sup>20</sup> The Tu-154M is a Category D aircraft, Yak-40 is a Category B aircraft, IL-76 is a Category C aircraft.

The test measurements conducted by the investigation commission were assumed as the basis data as to the position and height of the obstacles in the mentioned area.

In accordance with ICAO documents (PANS-OPS, Volume II, Part I, Section 4, Chapter 5, Para. 5.4.6 "Protection for the visual segment of the approach procedure") the limit of obstacle height surface for visual approach with glide path angle of  $2^{\circ}40'$  requires a slope of  $1^{\circ}33'$ . As comes from Figure 16 this requirement is complied with. Besides, according to ICAO PANS-OPS obstacles lower than 15 m in the clearway can be neglected when using radar + 2NDB approach. Thus, the glide path of  $2^{\circ}40'$ -  $3^{\circ}30'$  with course  $259^{\circ}$  M is suitable for international flights.

#### Visual Segment Surface - other approaches, normal stright-in approach, 2 NDB, PAR/SRE

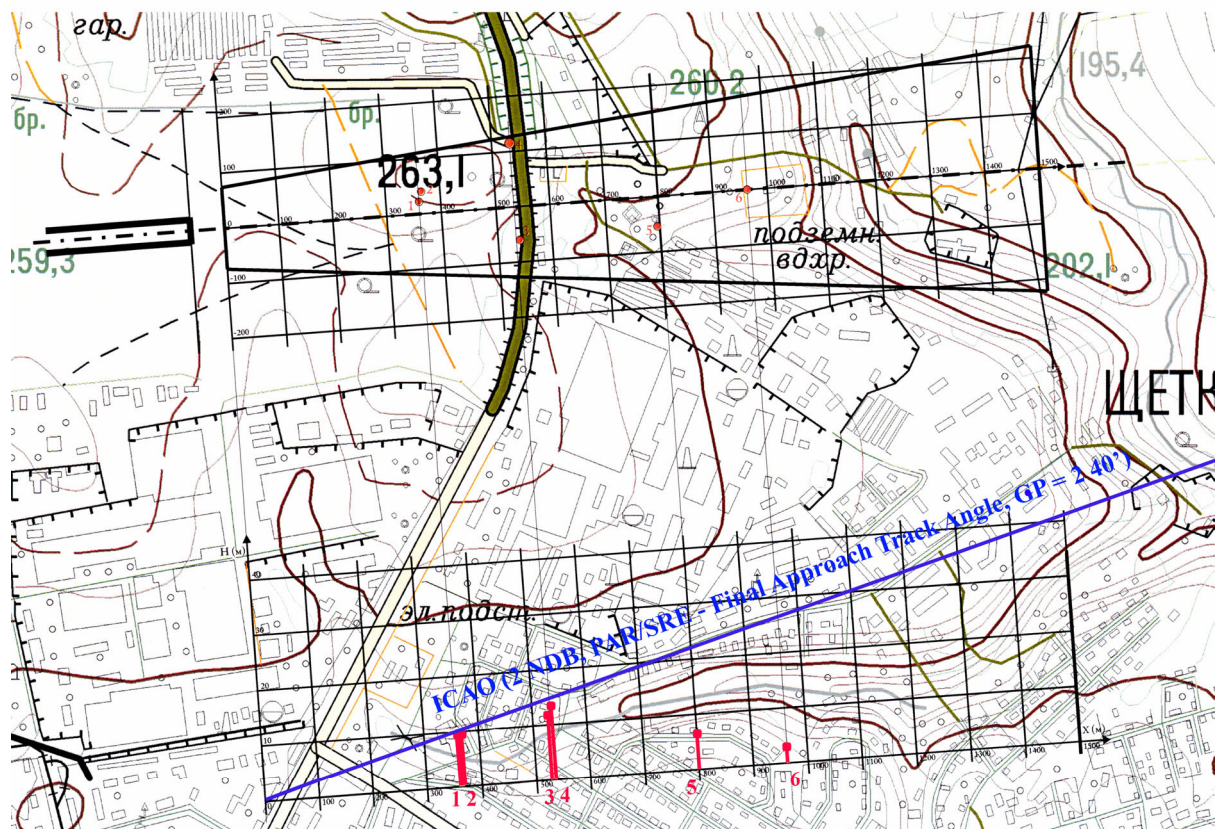


Figure 16

### 1.11. Flight and Ground Recorders

#### 1.11.1. CVR

The Tu-154M aircraft is equipped with protected MARS-BM CVR with about 30 minute recording capacity. The CVR was found mechanically damaged at the accident site. On 11.04.2010 the CVR was brought to the laboratory of the Interstate Aviation Committee for opening, readout and information processing. The casing opening and the information copying were conducted in the presence of aviation experts from the Republic of Poland as well as



representatives of the Inquiry Committee for the Russian prosecutor's office and military prosecutor's office of the Republic of Poland.

The casing of the tape moving mechanism 70A-10M № 323025 of the MARS-BM system was mechanically damaged, the cables were torn, the base and number plate were missing, no traces of high temperature influence was found (Figure 17).



**Figure 17**

The opening revealed that the tape was in good condition, loaded in the recording track, springs armed (Figure 18).



**Figure 18**

For readout purposes the tape was moved to the MARS-NV ground readout equipment.

The data copying, readout and processing was made with use of MARS-NV recorder and special data readout and processing software Sapphire and WinSis. The readout and processing revealed that the tape contained sound data recorded during the accident flight. The sound quality in the 1<sup>st</sup> and 2<sup>nd</sup> tracks is satisfactory, and unsatisfactory in the 3<sup>rd</sup> track (area mike) with a high level of noises. A transcript of the cockpit communications with overall length of about 38 minutes was completed on the basis of the readout.

The transcript of the communications and the voice identification of the crew members as well others people having been in the cockpit was conducted by the representatives of the Republic of Poland. In order to make the recorded speech more distinct various methods of noise reduction were used. For the purposes of correctness of voice identification concerning voices of persons who were not members of the crew (Director of Protocol and the Commander-in-Chief of the Polish Air Forces) other experts were engaged who knew well the mentioned persons, and also methods of phonogram instrumental identification were applied. Thus, upon request of the investigation team, the Forenex Company (Saint-Petersburg) conducted instrumental identification of the voice that said the following phrases:

10:26:43,6	10:26:44,8	A	So we have a problem. {Director Kazana }	No, to many problem...{dyrektor Kazana }
------------	------------	---	--	--

10:30:32,7	10:30:35,4	A	Yet there is no decision of the President what to do next. {Director Kazana}	Na razie nie ma decyzji prezydenta, co dalej robić. <i>{dyrektor Kazana}</i>
------------	------------	---	---	---

which was identified by the Polish experts as probably belonging to the Director of Protocol. The findings of the instrumental examinations using the voice and speech samples of the Director of Protocol provided to the investigation team by the Republic of Poland confirmed these results.

On May 31, 2010 on the basis of the Memorandum of Understanding as to the transfer of the Tu-154M tail number 101 flight recorder information, the Polish side was handed a copy of the CVR and Version 1 of the communications transcript. Despite relative requests, until the time of the preparation of this report no additional information has been provided to the investigation team. Thus, the present Report is prepared with consideration of Version 2 of the communications transcript signed by the Russian and Polish experts on June 17, 2010.

### 1.11.2. FDR

The Tu-154M aircraft is equipped with the MSRP-64M-6 FDR (further referred to as MSRP-64) recording about ~25 hours of flight. The tape driving mechanism MLP-14-5 of the MSP-64 system was found mechanically damaged at the accident site. On 11.04.2010 the FDR was brought to the laboratory of the Interstate Aviation Committee for opening, readout and data processing. The casing opening and the data readout were conducted in the presence of aviation experts from the Republic of Poland as well as representatives of the Inquiry Committee for the Russian prosecutor's office and military prosecutor's office of the Republic of Poland.

The casing of the protected MLP-14-5 № 90969 was significantly damaged mechanically, the mounting frame and casing lid were missing, the linkages were torn. The catch gear was filled with earth (Figure 17). The visual examination of the FDR after the opening revealed that the tape was on spools, but out of the recording track. The tape was in good condition, the mode switch in Automatic position (Figure 19).



**Figure 19**

The tape was manually rewound from the spool and placed in the playback device BVS-3.

The data readout and processing was conducted in a standard way with use of ground readout BVS-3 playback device and WinArm32 readout software. The readout revealed that the tape contained data on the accident flight; the quality of the recorded data is unsatisfactory with a large number of missing data (failures).

### **1.11.3. Quick Access Recorder**

On 14.04.2010 the BLM-1-1 tape drive series 2 №390130 of the KBN-1-2 series 2 №390130 tape memory unit found at the accident site was brought to the IAC laboratory. The disassembly and data copying was conducted on 14.04.2010 with the participation of aviation experts of the Republic of Poland as well as representatives of the Polish Military prosecutor's Office.

This QAR is non-protected and records the same list of parameters as the FDR for the last 17...30 hours. The QAR casing was found deformed (Figure 20), the KS-13 series 2 № 461195 tape memory unit was extracted from its normal place after the QAR geometry was recovered.





**Figure 20**

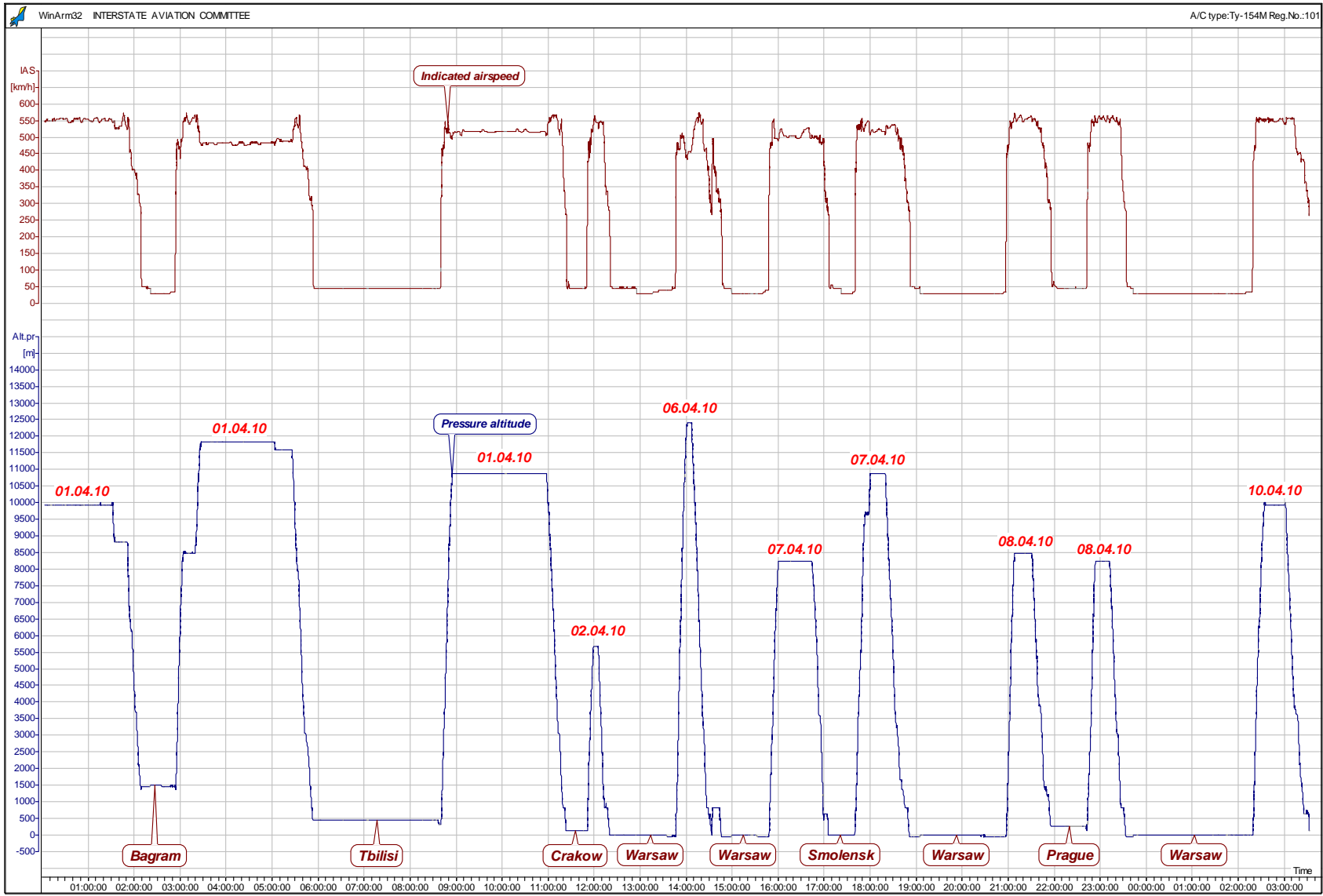
The memory unit featured insignificant damage. It was disassembled and the damaged tape drive mechanism was recovered and the tape put in its place.

The readout and data processing was conducted in a normal way with use of readout equipment UVZ-5M and WinArm32 software. The readout revealed that the tape contained information on the accident flight and the data quality was satisfactory.

#### **1.11.4. Flight Data Processing**

Flight data processing was conducted using the MSRP-64 sensor calibrations (12.11.2009) listed in Supplement №2 to ПИ-30-385 provided by Aviakor Aviation Plant by Letter №81/111 of 12.04.2010.

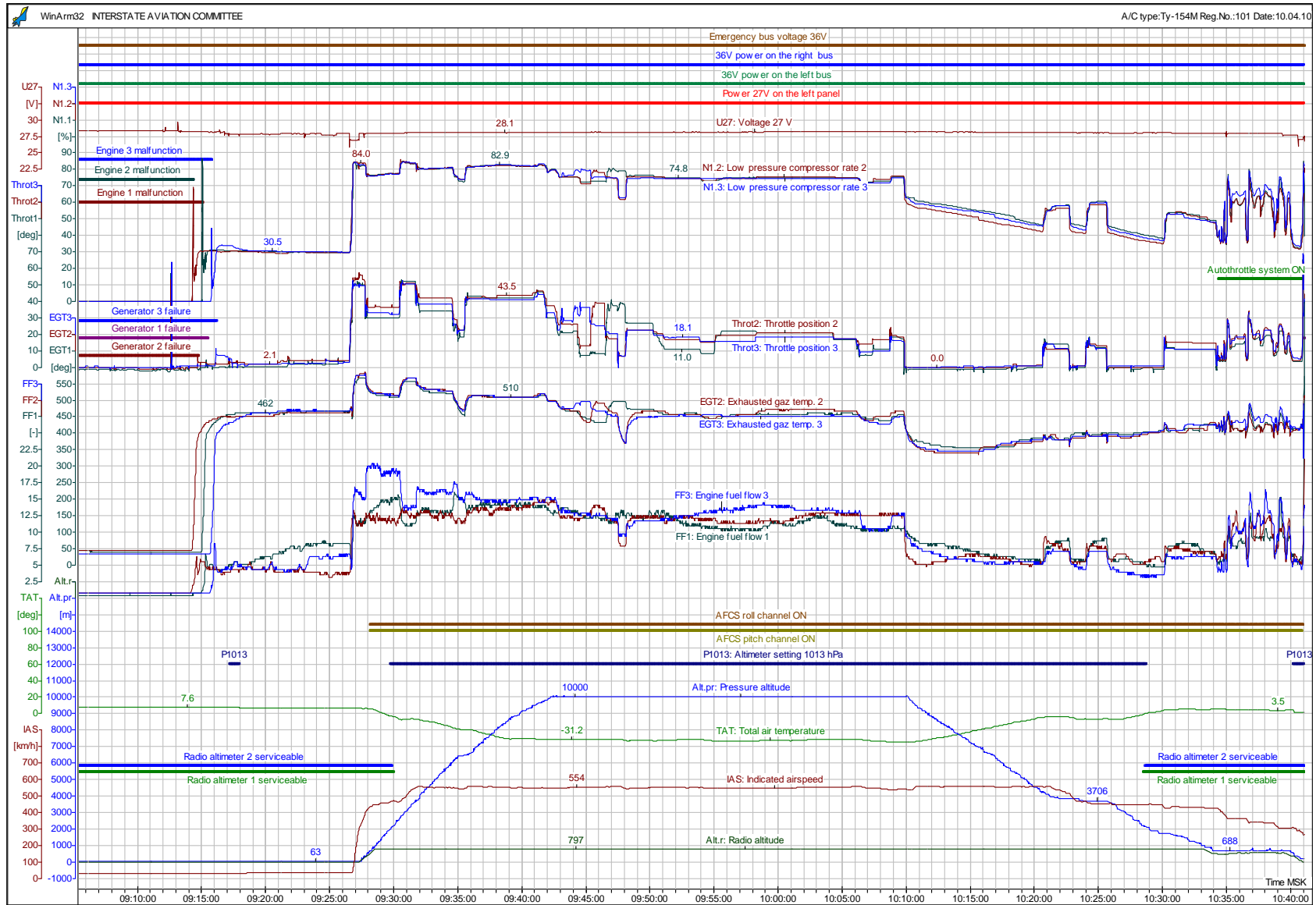
In the course of the data processing systematic and random data failures were partially eliminated. The data of the QAR were taken as the basis as containing record of higher quality. All in all the MSRP-64 tape contains data of 10 flights of aircraft number 85837 starting from 1.04.2010 with the overall record length of 27.5 hours. The following charts were plotted on the basis of the readout (Figures 21-25). Figure 21 (overall chart) shows the total record duration and information on all recoded flights. Figures 22...25 (accident flight) are represented in local time which is 2 hours ahead of Warsaw time recorded by the MSRP-64.



Aircraft TU-154M TailNo 101 (Republic of Poland) flight parameters during the accident happened on April 10, 2010 near the aerodrome Smolensk "Severny" (FDR MSRP-64 overview plot)

Figure 21

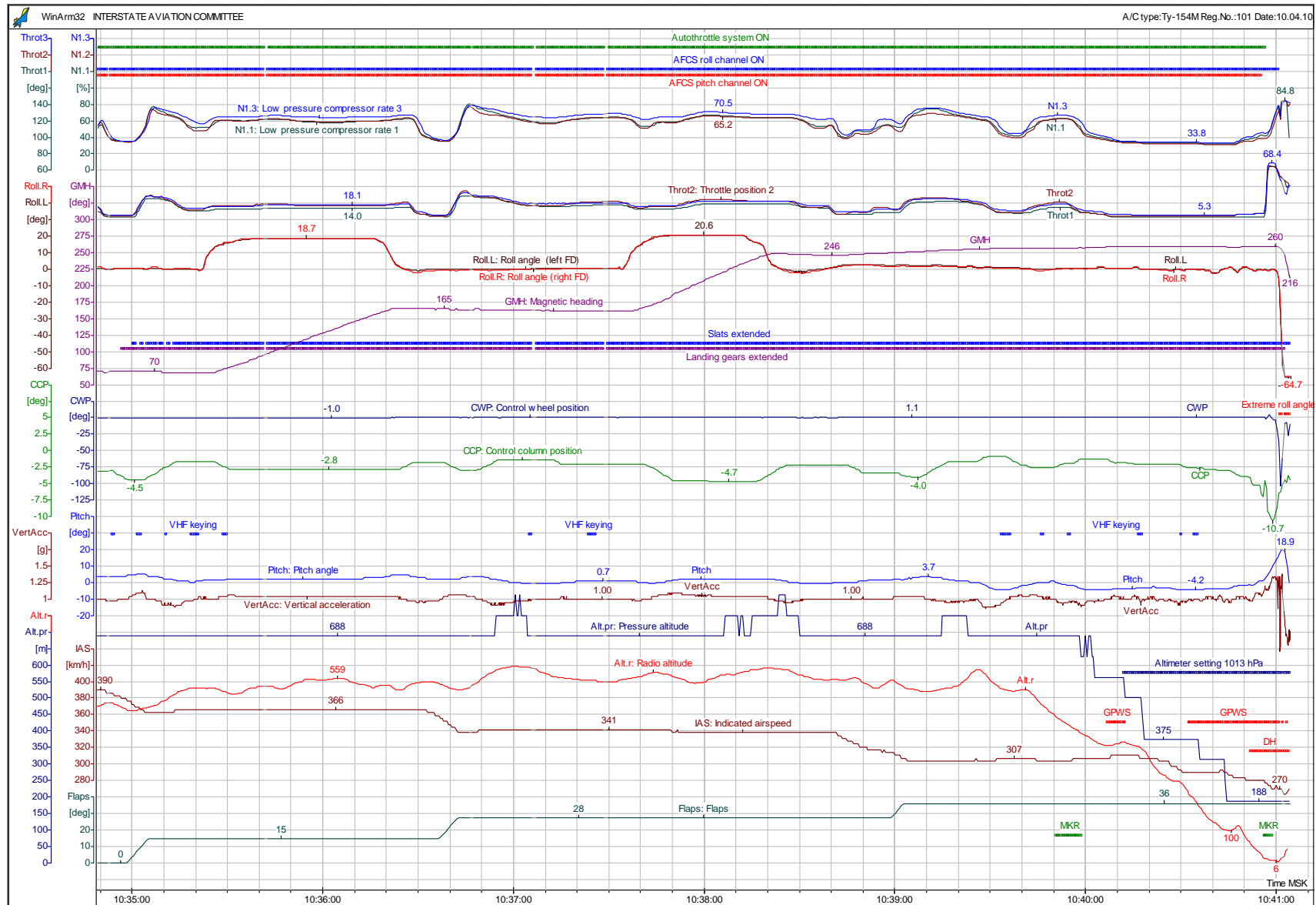




Aircraft TU-154M TailNo 101 (Republic of Poland) flight parameters during the accident happened on April 10, 2010 near the aerodrome Smolensk "Severyn"

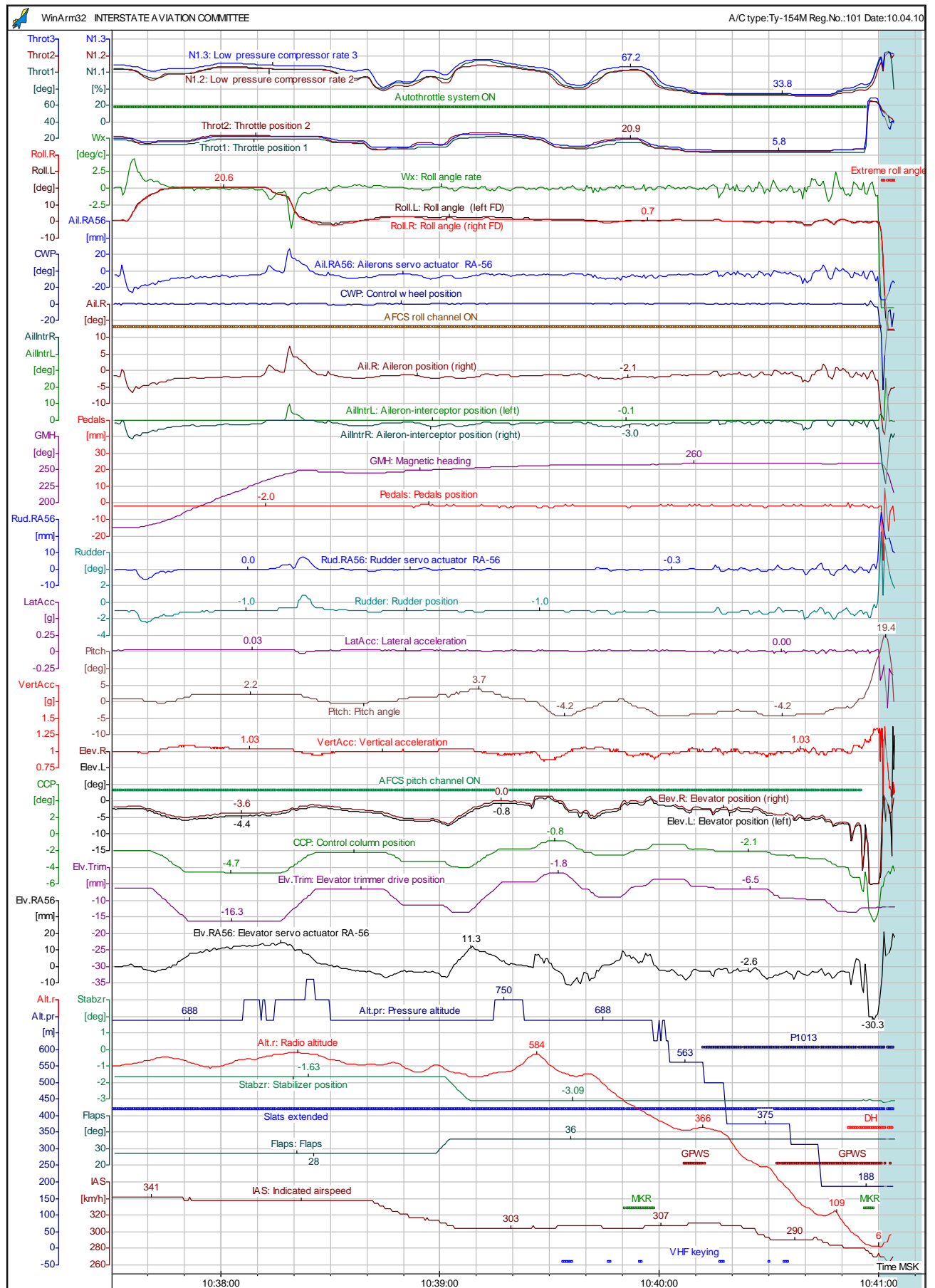
Figure 23





Aircraft TU-154M TailNo 101 (Republic of Poland) flight parameters during the accident happened on April 10, 2010 near the aerodrome Smolensk "Severny"

Figure 24



Aircraft TU-154M TailNo 101 (Republic of Poland) flight parameters during the accident happened on April 10, 2010 near the aerodrome Smolensk "Severyn"

Figure 25

### **1.11.5. ATM Quick Access Recorder**

The ATM-QAR manufactured by ATM (Republic of Poland) was also found at the accident site. On April 17, 2010 the ATM-QAR was disassembled at the Technical Institute of the Polish Air Forces (Warsaw) with an IAC representative to recover the ATM-MEM15 memory unit MSN 0158/91. The disassembly revealed that the memory unit was not damaged. The data copying was done using the ATM-RD3 playback equipment and ATM-FDS32 software. The readout revealed that the QAR recorded the flight data on 10.04.2010. The QAR is connected to the MSRP-64 data cable (parallel to the KBN-1-2 QAR) and its list of recorded parameters is identical to the parameters recorded by the MSRP-64 (apart from additionally recorded engine vibration and two on/off signals). The installation of this QAR was not agreed upon with the aircraft manufacturer ("Tupolev" Design Bureau) or the MSRP-64 FDR designer ("Pribor" Enterprise). The QAR data were analyzed that revealed its general compliance with the MSRP-64 data. However, in a number of parameters this record sometimes differs by 1-2 codes (less than 1%) from the MSRP-64 FDR information. The ATM record finished 2.5 seconds earlier than the records of the KS-13 and MLP-14-5 of the MSRP-64 FDR.

### **1.11.6. K3-63 three-component recorder**

The K3-63 three-component recorder was not found at the accident site. This recorder is an electromechanical film-based quick access recorder and can record the values of speed, altitude and vertical acceleration. As the same parameters are recorded by the MSRP-64 FDR system the absence of the K3-63 recorder did not affect the investigation.

### **1.11.7. Ground Recorders**

The aids to communication and navigation at Smolensk "Severny" Airdrome are equipped with standard recorders:

- Two tape recorders P-500 № 08/806, № 19/600;
- Tape recorder MS-61 №03/400;
- Three tape recorders MN-61 № 24/013, № 15/681, №465/18;
- Two tape recorders P-503II № 600058, № 699140;
- Two cameras PAU-476 № 540116, № 1522J11;
- Camera PAU-476-1A № 1532K3;
- Tape marking device UML-1-400 № 089085.

Additionally, the landing zone controller's working station is equipped with a non-standard Sony SLV-X711 video recorder with a video surveillance camera.

### P-500 Tape Recorders

These tape recorders are the main sound recording means.

Recorder number	08/806	19/608
Reel number	9	5
Date and time of reel installation	07.04.2010 at 21:30	08.04.2010 at 09:45
Operating time 07.04.2010	21:30 - 23:30	-
Operating time 08.04.2010	07:00 - 08:30 09:45 - 10:45 16:05 - 18:15	09:45 - 10:45 16:05 - 18:15
Operating time 10.04.2010	07:15 - 10:45	07:15 - 10:45
Date and time of reel removal	10.04.2010 at 10:45	10.04.2010 at 10:45

### Content of record on the tracks

	Reel № 9	Reel № 5
Track number	Content of record	Content of record
1.	communication at 124.0 MHz	(not used)
2.	(not used)	communications at 124.0 MHz
3.	(not used)	(not used)
4.	Area mike at the controller's working station	P-862 №3 (CATC's working station)
5.	LOM signal (--- -..)	(not used)
6.	(not used)	(not used)
7.	CATC phone	Loudspeaker CATC - weather station
8.	Dispatcher's Loudspeaker	(not used)
9.	(not used)	(not used)
10.	Time channel	Time channel

The data were copied from tracks 1, 4, 5, 8 of reel №9 and tracks 4, 7 of reel №5 in cooperation with aviation experts of the Republic of Poland.

The readout revealed that track 7 (Loudspeaker CATC – weather station) on reel №5 misses information of the CATC's communication with the weather information service on April 10, 2010 but contains an old record of October-November 2009 which indicates the failure of erasing and recoding heads of this track.

In accordance with Act of Airdrome Inspection of March 27, 2010 the camera film of the PAU-476M cameras does not comply with the required standards. No photo laboratory or flight data monitoring group are on the staff of Military Unit 06755. Thus, the PAU-476 cameras were not used on April 10, 2010.

The playback of the video tape revealed that the record was missing. During the preflight preparation on April 10 only the operability of the recorder was checked with no assessment of the record quality. The analysis revealed that the record was not made due to twisting (bridging) of wires between the video camera and the video recorder. After the wires were insulated the video recording was resumed.

### **1.12. Wreckage Information**

The accident site represents crossed terrain with hills and forest, trees going as high as 25 m, with elevation 230-260 m above sea level and significant swamped areas.

The first impact (aircraft structure not destroyed) was on a tree top at a height of about 11 m near the middle marker at a distance of 1100 m from runway 26 threshold and lateral deviation of 35 m left from the extended runway centerline at a point located N54°49.521' E32°03.65' (Figure 26 and Figure 35). The terrain elevation near the middle marker and place of first impact is 233 m; runway 26 threshold elevation is 258 m. Thus, when passing the middle marker the aircraft was about 14 m lower than runway 26 threshold.

No aircraft elements were found before the place of the first impact.



**Figure 26**

Further the aircraft hit a group of trees at about 4 m AGL and at a distance of about 170 m from the point of first impact. The hits did not destroy the aircraft structure; no aircraft fragments were found at the place of impact with these trees. According to the damage sustained by the trees the aircraft was proceeding with a heading close to landing course, a bit left from the runway centerline.

At a distance of 244 m from the first impact with lateral deviation of 61 m left from the extended runway centerline at a height of about 5 meters the aircraft hit a birch with a trunk measuring 30-40 cm in the diameter (Figure 27 and Figure 35).





**Figure 27**

In the area of the impact the investigation team found fragments of the left detachable part of the wing including: fragments of left detachable part of the wing panel jammed in the tree trunk, a fragment of the left aileron spoiler, the fairing of the flap jack screw, fragments of the left slat, fairing of the left outer flap, the left flap track, a flap housing. All the fragments found along the aircraft flight path for the following 150-200 m were elements of the left detachable part of the wing (Figure 28).





**Figure 28**

The found fragments and their position assume that on impact the wing was destroyed, the left detachable part of the wing was ripped off (about 6.5 m long) followed by an intensive left roll which is confirmed by the absence of damaged trees to the left of the flight course right after the impacted birch and further aircraft deviation to the left. The analysis of the trees damages and terrain relief at that site also assumes that by the moment of impact the aircraft was slightly climbing. This is confirmed by the increasing height of impact traces on the trees (starting with 3-4 m up to 5 m considering the general increase of terrain elevation (elevation of the site of impact on the birch is 248 m).

While rotating and moving farther the aircraft got further structural damages caused by the impact on the trees. The nature of the tree rip-off at a distance of 465 m from the first impact assumes that by that moment the left bank was over 90° (Figure 29 and Figure 36); at a distance of 530-550 m from the first impact the investigation team found fragments of the wing primary structures partition, fragments of the left stabilizer panel with elevator and rudder and elevator rods.





**Figure 29**

The first ground impact was at a distance of about 580 m from the first impact (Figure 30).

The site of ground impact has a furrow made by the stabilizer and fin leading edges up to 0.5m deep and 22 m long with fragments of the SI-2U light of the SMI-2KM lighting set as well as a furrow made by the left wing up to 0.4 m deep and 22 m long with fragments of the left wing panel and rod №154.83.5711-090-009.





**Figure 30**

The traces of the impact on the ground and their distribution allow to conclude that the impact occurred when the aircraft was rolling left and on impact the aircraft was inverted with a left bank of about  $200^{\circ}$  - $210^{\circ}$  (Figure 36).

On impact the right stabilizer panel with elevator, the fin with rudder (Figure 31), tail cone and stabilizer roots were ripped off and found 590-620 m from the point of the first impact.





**Figure 31**

The wreckage area along the aircraft path is about 130 m long and 30-50 m wide, with lateral deviation from the extended runway centerline of 100 to 160 m. Within the whole wreckage area there are multiple fragments of airframe and aircraft systems (Figure 32). The center of this area is located N 54°49.450' and E 32°03.041' at a distance of 670-680 m from the place of first impact (about 420 m from the runway threshold).





**Figure 32**

As the aircraft moved farther on the ground surface heading about 230° it was further damaged:

The tail part of the aircraft with Engine №2, pylons of Engines №1 and №3 and other engine fragments is located along the aircraft path (aircraft was moving upside down) at a distance of 436 m from the runway threshold and turned 180° against the movement direction. Engine №3 was torn off the mounts in the tail part of the fuselage and lies at a distance of 467 m from the runway threshold inverted (Figure 33). Engine № 1 was torn off its mounts and lies inverted near the tail part of the fuselage.





**Figure 33**

The lower fuselage from frame 44 to frame 60 with the left and right side skin panels was ripped open and inverted at 454 m from the runway threshold on the aircraft path, heading across the trajectory. The skin panels bear multiple tears and deformations, the linkages were interrupted at tears. The cargo compartment door is ripped off its fittings. The lower part of the fuselage from frame 19 to frame 40 with right skin panels was 389 m from the runway threshold on left side leaning against trees. The skin panels featured multiple tears and deformation.

The forward fuselage with the cockpit was totally destroyed. A fragment of the nose with nose gear strut was at 397 m from the runway threshold (Figure 34). The upper and side skin panels were destroyed. The nose landing gear was in extended position.





**Figure 34**

The right detachable part of the wing was found at the aircraft path 390 m from the runway threshold, inverted. Caissons of the detachable part of the wing are torn. The slat sections №3 and №4 of the right detachable part of the wing were extended.

The middle section of the wing was on the aircraft trajectory, broken along rib № 3 (left) into two parts. Both parts were inverted. The right part of the middle section of the wing with the main gear bay was found at 380 m from the runway threshold heading across the movement trajectory. The left part of the middle section of the wing with the main landing gear bay was found at 362 from the runway threshold heading across the movement trajectory. The panels of the middle section of the wing feature tears, dents, deformations, the linkages and load-bearing elements were destroyed at fractures. The middle and outer flaps were extended in landing configuration. The flap screws position reveals that the flaps were extended at 36°. The leading edges of the middle section of the wing and slats are destroyed, the front spar of the middle section of the wing was destroyed. The left and right main landing gear were at their normal places, extended.

The aircraft fragments revealed no evidence of in-flight fire. The aircraft was destroyed as a result of unexpected load forces on impact with the trees and ground and during its further motion on the ground surface.

The following table contains the complete list of the aircraft fragments on the wreckage plot (Figure 35).

**Table 1**

**Wreckage list**

item №	Fragments	S longitudinal (m)	Z Lateral (m)
1	Inner Marker (landing course 259° M) N54° 49.538' E032° 03.612'	1050	0
2	Site of impact №1 on the tree, H=10,8m. N54° 49,521' E32° 03,650'	1100	-35
3	Site of impact №2 on a tree, H=4,1m.	931	-58
4	Site of impact №3 on a group of trees.	925	-47
5	Site of impact №4 on a group of trees.	871	-55
6	Site of impact №5 on a group of trees.	872	-28
7	Site of impact №6 on a tree, H=4,8m.	853	-33
8	Fragments of the left wing in the tree trunk, H=5m. N54° 49,494' E32° 03,422'	856	-61
9	Fragment of the left aileron, left flap fairing. Fragment of left slat.	845	-42
9.1	Left outer flap tip.	838	-36
9.2	Left outer flap tip fairing, TM-4, D-10ARU №00900002.	838	-37
9.3	Left flap track, slat fragment, flap housing.	837	-42
10	Fragment of left wing skin panel.	839	-30
11	Spoiler track drive fragment №15483514131 of the left outer wing.	810	-43
12	Fragment of the outer slat tip of the left outer wing.	805	-65
13	Fragments of left wing skin panels, flap drive gear box fragment.	791	-68
14	Flap drive fragment.	782	-48
15	Collision with power lines and wire tear off.	760	-56
16	Fragment of left outer wing with a fragment of slat, left aileron.	745	-40
17	Fragment of left wing lower skin panel.	697	-31
18	Site of impact on a tree, H=8.1m.	715	-58
19	Flight control linkage screwdrive with slat fragments.	702	-77

20	Fragment of left slat №23 drawing. 154.8336.23.100.	698	-53
21	Fragment of left slat, flap carriage, left wing deflector.	694	-51
22	Fragment of inner flap of the left wing.	674	-73
23	Fragment of the left wing in the tree trunk.	660	-64
24	Fragment of left wing flap.	642	-44
25	Site of impact on a tree.	635	-70
26	Site of impact on a group of trees.	620	-79
27	Outer flap deflector of the left wing.	605	-75
28	Flap drive fairing of the left wing.	609	-47
29	Left stabilizer tip.	595	-60
30	Fragments of the left wing skin panel.	588	-85
31	Fragment of the primary wing structures.	562	-69
32	Elevator rod, fragment of stabilizer skin panels.	567	-89
33	Fragment of left stabilizer with elevator.	522	-106
34	Rudder fragment.	543	-94
35	Screw jack fairing of the outer flap, fragment of heated stabilizer leading edge.	534	-81
36	Site of impact on the ground (trace of the right stabilizer, stabilizer fairing and fin). Fragment of tail light SMI-2KM.	520	-104
37	Site of impact on the ground (trace of the left wing). Fragment of the left wing panel. Rod №154.83.5711-090-009.	511	-96
38	Right stabilizer. At a distance of 3,5m were the fin front spar, RA-56 of the elevator and RA-56 of the rudder.	483	-123
40	Fragment of tail fuselage skin panel.	490	-117
41	Fragment of the Engine №3 cowl.	487	-130
42	Fragments of Engine №3 cowl.	482	-127
43	Fragment of the passenger cabin decoration (frame 58 to 59).	487	-139
44	Fragment of Engine №3 pylon. Pylon №154.03.6100.040.009.	474	-138
45	Flap carriage №154.83.5734.010.	482	-119
46	Fragment of airframe with fragment of fuel line №104038.	470	-113
47	Fragment of fin spar, flap carriage. Carriage №154.83.5734.020.	481	-112
48	Fragment of the right outer wing upper skin panel with ID-3 probe.	463	-110
49	Fragment of fin front spar.	475	-106



50	Slat screw jack №154.83.5732.020. with gear box.	471	-122
51	KURS MP-70 control panel.	470	-128
52	Fragment of fuselage skin.	469	-120
53	Tail fuselage (starboard) with emergency exit door. Oxygen bottle 1-2-2-210.	468	-125
54	Fin with fragment of fairing. Stabilizer control mechanism MUS-3PTV.	472	-140
55	Engine №3 D-30KU-154 2 series №59219012414.	467	-134
56	Fragment of lower wing skin panel with aileron spoiler, RP-59 actuator.	460	-119
57	Fragment of lower skin of the right outer wing, flap leading edge, outer flap.	451	-114
58	Engine №3 air inlet, heat exchanger.	439	-120
59	Fragment of slat with track and screw jack.	447	-125
60	Aileron rods №08-09-010-011, 085-095-85-095.	451	-128
62	Fragment of middle fuselage from frame 40 to frame 64. Rear baggage compartment, wing leading edge, storage battery 20HKBH25Y3.	454	-137
63	Engine №1 air inlet, passenger cabin emergency exit.	451	-149
64	Tail part of the fuselage from frame 65 to frame 83, Engine №2 D30KU-154 2 series №59249012426. Engine №1 D30KU-154 2 series №59319012423.	436	-137
65	Fragment of the primary structures of the front spar of the middle wing.	427	-117
66	Engine №2 cowl. Fragments of passenger seats in the radius of 6m.	412	-139
67	The pilot control panel PU-46 (ABSU-154) with a plug (from spare parts set). Center panel with speed indicator.	411	-141
68	Fragment of central fuselage skin panel, front toilet. Service galley door.	402	-147
69	Right wing, outer flap, screw jack fairing EPV-8PM, aileron.	390	-158
70	Fragment of the nose, nose landing gear, shutter with the tail number 101. Cockpit appliances, units, cockpit accessory compartments.	397	-144
71	Fragment of lower middle fuselage with primary structures from frame 16 to frame 24.	389	-134

72	Fragments of lower middle fuselage with primary structures from frame 24 to frame 38. Fragments of lower middle fuselage with primary structures from frame 38 to frame 42.	381	-133
73	Two spare wheels KT-141E assembly.	374	-141
74	Left part of the middle wing with left main gear assembly and inner flap.	362	-142
75	Right middle wing with right main landing gear assembly with fragment of inner flap.	380	-153
76	Fragment of middle wing leading edge, cooling turbine 3318. Air conditioning system units.	368	-160
77	Trash container, spare wheel KT-183.	348	-151

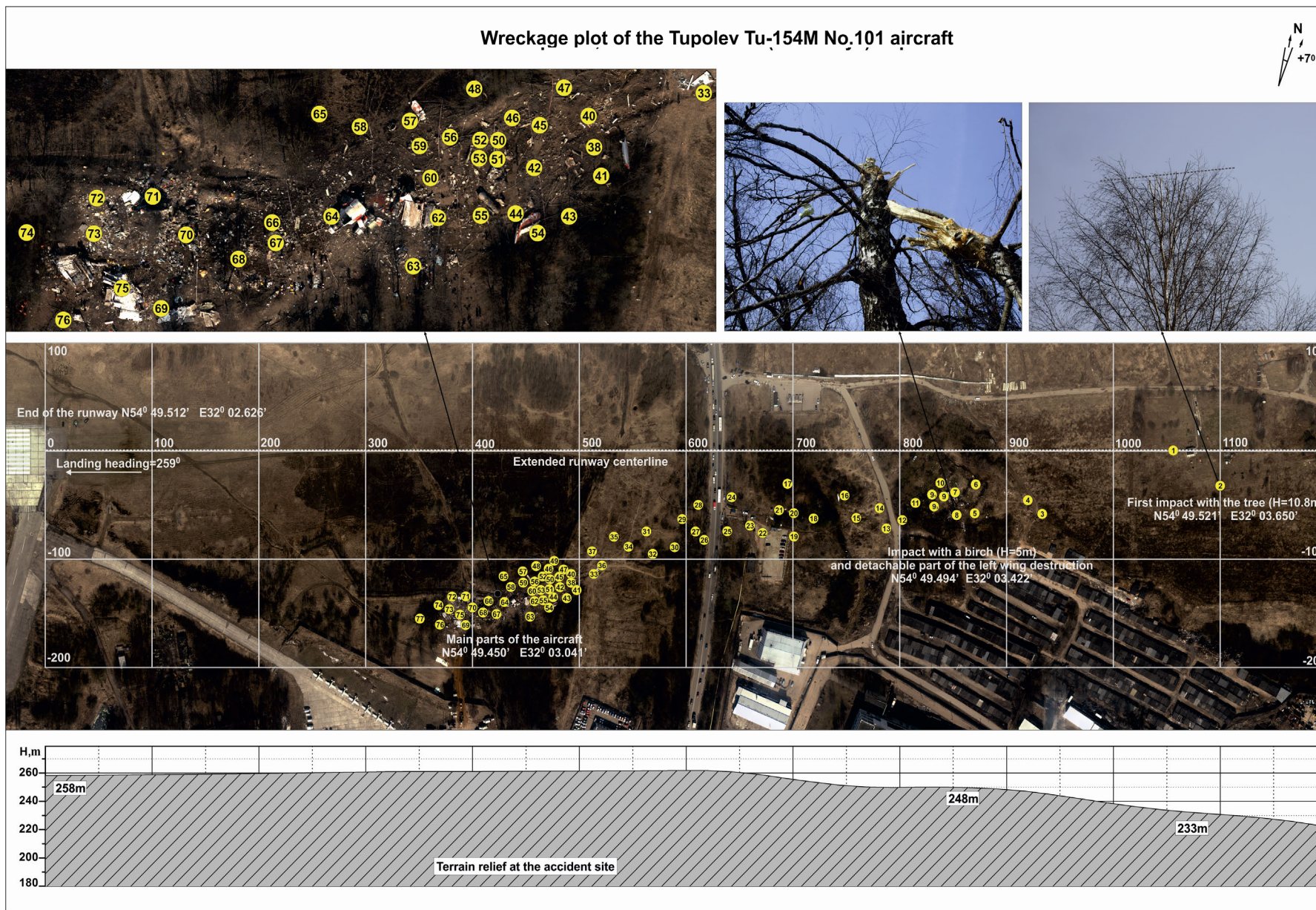
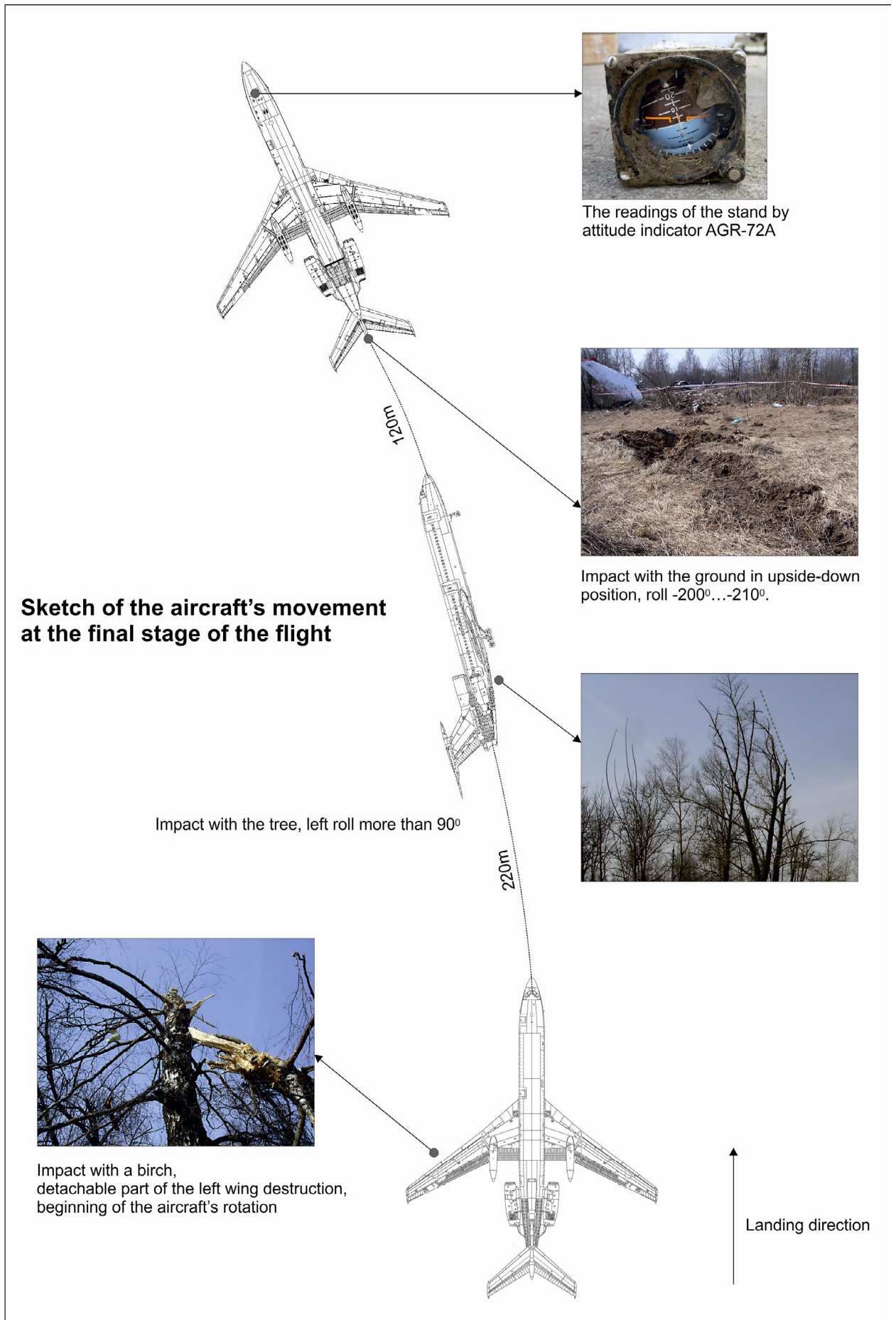


Figure 35





**Figure 36**

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

All crew members had valid medical certificates. There are no facts revealing incapacitation of any crew member in flight.

The conducted expertise did not reveal any evidence of prohibited substances consumed by the crew members.

The Chief ATC and landing zone controller who were controlling the aircraft passed medical examination before duty at 5:15 and 6:50 respectively. No health deviations were detected. Released to air traffic control by the doctor on duty of the medical station of Military Unit 06755.

#### **1.13.1. Medical Tracing Examination**

For the purposes of assessment of crew members position, condition, postures and actions an analysis of the nature and location of their injuries sustained during the accident was conducted. The analysis data (considering the impact sequence) were compared with the findings of the experimental modeling of formation of probable primary injuries of the crew members in the cockpit of Tu-154M. In the course of investigation the crew member bodies were examined and their distal limb parts were x-rayed.

On aircraft collision with any obstacles bodies of people on board are exposed to braking acceleration. Under this acceleration the bodies are shifted in the direction opposite to the acceleration force and hit on the appliances and cabin furniture ahead which results in the so-called primary injuries of special localization on the bodies, clothes and shoes. These injuries characterize the body position of a certain person at a certain place by the moment of cabin deformation or damage.

The location of primary injuries in the cockpit of a certain type of aircraft depends on the direction and amount of acceleration, fastening system, posture and actions of the crew members.

The aircraft crashed in a swampy area after the impact of the left wing on the tree and quickly (within 3-4 seconds) developing left bank, actually inverted. According to the aircraft movement trajectory on the ground the crew members were exposed to braking acceleration in the back-to-front direction. Despite the inverted aircraft position the usage of fastening belts allowed the crew to retain active postures in their seats.

According to the nature of head injuries (multifragmented skull fractures with ejected brain substance), chest and spinal chord injuries, the crew member bodies for a short period of time were exposed to impact forces of about 100g and more, which resulted in informative

primary injuries that allowed to judge on the postures and probable flight control actions of the crew at the time of the impact.

**Примечание:**

*In accordance with the Manual on the medical investigation of the air accidents, the analysis of the nature of the injuries sustained by the crew that takes into consideration the biomechanical characteristics of the human tissues (e.g. the nose bones can sustain acceleration of up to 30g, lower jaw up to 40g, cheek bones up to – 50g, tooth area up to 100g, forehead area up to 200g) allows determining approximate deceleration at the time of the impact.*

**Pilot-in-Command**

The back of the left hand and left forearm of the pilot featured damage typical of hand slipping from the steering wheel handle and hitting the control panel. This allows concluding that the left hand was on the steering wheel with relatively slight grip on the steering wheel which is not typical of stressful situations with real threat for the pilot's life. Usually pilots reflexively grip the steering wheel which is accompanied with traumas of palms. Most probably this untypical situation was connected with spatial disorientation of the pilot caused by the unusual aircraft position and reflectory distribution of the muscular tension in order to retain suitable posture in the pilot seat.

The back and palm of the right hand bear no injuries typical of gripping of the control wheel by the time of the braking acceleration impact. Most probably the right hand of the PIC was on the engine throttles on the central pedestal to the right of him, where it was brought in order to set the engines to takeoff mode.

As for the pilot's legs, on impact while being in inverted mode the pilot was trying to reach the pedal with his right foot and press it to compensate the left roll which is confirmed by the fixed stretched position of the right foot as a result of the early postmortem rigidity (caused by intensive development of emotional stress).

Thus, the medical tracing analysis revealed that on impact the PIC was in the left pilot seat fastened by the seat belts, retaining an active working posture. His left hand was gripping the steering wheel while the right hand was loose and most probably was on the throttles. The completely stretched right leg (including the foot) was trying to press the right pedal most probably in order to compensate the quickly developing left bank.

## **Co-pilot**

The back of the hands and outer sides of both forearms bear injuries typical of hands slipping from the steering wheel handles and hitting the control panel. This allows concluding that on impact the pilot's hands were on the steering wheel. Just like in the PIC's case, his hands were not gripping the steering wheel too tightly as this happens in stressful situations, most probably due to spatial disorientation caused by extensive bank and roll of the aircraft which led to the re-distribution of the muscular efforts in order to retain the optimal posture in the pilot's seat.

As for the co-pilot's legs' position by the impact, just as with the PIC's posture change due to the quickly developing left bank, the co-pilot was trying even in the inverted position to reach the pedal with his right foot and press it in order to compensate the roll.

Thus, the medical tracing analysis revealed that by impact the co-pilot was in the right pilot's seat inverted (head down), fastened by the seat belts, in active working posture. His hands were holding the steering wheel (not too tightly). His right leg was stretched trying to press the right pedal in order to compensate the quickly developing left bank.

## **Navigator and Flight Engineer**

The injuries sustained during the accident by the navigator and flight engineer confirm that on impact they were in their working seats fastened (navigator behind and between the pilots' seats, flight engineer on the right of the cockpit).

### **1.14. Survival Information**

There were 96 persons on board, including 4 flight crew members and 3 cabin crew members. The medical tracing examination revealed that as the aircraft was destroyed on impact, inverted, the persons on board were exposed to acceleration over 100g. On the basis of the medical expertise, death of all persons on board occurred instantaneously at the time of the collision due to numerous mechanical injuries incompatible with life obtained due to traumatic effect of the outrageous impact deceleration forces and destructed parts of the aircraft (see also Sections 1.13.1 and 1.16.8).

### **1.15. Search and Rescue Information<sup>21</sup>**

The search and rescue measures at the accident site were conducted by the Ministry of Emergency, Regional Search and Rescue Service, municipal and federal administrations:

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<sup>21</sup> Translator's remark: Due to translation difficulties see the Russian version of the report for complete description of brigades and forces that participated in Search and Rescue operation.

The search and rescue measures at the accident site were taken in the following order:

**April 10, 2010**

10:42 – Information on lost radio communication with the aircraft received by the officer on duty of the Regional Search and Rescue Service (RSRS) via the chief of Military Unit 06755;

10:43 – emergency declared by the head of the RSRS and order for the shift on duty to depart;

10:46 – fire truck Kamaz-43108 of the fire fighting service of Military Unit 06755 departing for the accident site;

10:48 - GAZ-4795 NPSG car (3 persons) of the RSRS departed from Smolensk “Yuzhny” Airdrome for Smolensk "Severny" Airdrome;

10:50 – information on the accident received by the officer on duty of the local emergency service for Smolensk Region from the head of the RSRS;

10:51 – departure of the emergency service shifts on duty for the accident site (Fire Service-3 – duty on Smolensk “Severny” Airdrome from 8:00 for supporting VIP flights, Fire Service-5, Sanitary Service-2) – total of 40 persons and 11 cars;

10:53 – Head of the Chief Emergency Office of the Russian Federation orders all emergency services to arrive at the accident site;

10:54 – the police and local security service for Smolensk Region cordon off the accident site in the diameter of 500 m, by 180 persons and 16 cars.

10:55 – first fire fighting brigade of Fire Service-3 arrived;

10:57 – information received by the Regional Center for Crisis situations from local emergency service for Smolensk;

10:58 – notice received Regional Center for Crisis situations from Russian Air Navigation Agency;

10:58 – first emergency sanitary brigade arrived at the accident site;

10:59 – open fire extinguished at the accident site;

11:00 – rescue brigade on duty for Smolensk Region (4 persons., 1 car), rescue brigade on duty for Smolensk, (4 persons, 1 car), rescue brigade for water areas for Smolensk Region (4 persons, 1 car), go team of Federal Security Service (7 persons, 7 cars), go team of local police (40 persons, 12 cars) departing for the accident site.

11:00 – READINESS №1 for the complete Emergency Service for Smolensk Region;

11:00 – Head of Chief Emergency Office for Smolensk Region ordered all the officers to gather;

11:00 – cordoning off of the accident site by Smolensk police;

11:03 – complete fire extinguishing;



11:03 –go team of the federal emergency service for Smolensk Region (head of Chief Emergency Office for Smolensk Region, as well as 3 persons, 1 car) with the mobile video communication equipment (5 persons, 1 car);

11:05 – emergency service headquarters arranged at the accident site;

11:10 – 7 ambulances arrived at the accident site;

11:25 – car GAZ-4795 NPSG RPSB arrived at the accident site;

11:40 – READINESS №1 for all personnel of federal emergency services for Bryansk and Kaluga Regions;

11:40 – determination of the absence of survivals at the accident site, the 7 ambulances departed from the accident site;

11:50 – NPSG RPSB joined the general emergency liquidation forces;

12:15 – READINESS №1 for the Chief Emergency Office for Moscow Region;

13:00 – head of medical coronary expertise arrived at Smolensk "Severny" Airdrome accompanied with 7 persons as well as 16 pathoanatomists chief of them being the head of the regional pathoanatomy institute;

13:00 – meeting of the Emergency Committee at the emergency administration of Smolensk region chaired by the governor of Smolensk Region;

13:02 – two flight recorders found at the accident site;

14:00 –special communication service arranged in the Novy Hotel;

14:27 – BK-117 helicopter (№01885) arrived at the accident site bringing the Ministers for Emergency Situations and Home Affairs of the Russian Federation;

14:58 – Mi-8 helicopter with the Minister of Transport of the Russian Federation arrived at the accident site;

14:58 – places for the bodies arranged: city morgue 100 places, 1<sup>st</sup> clinic of Smolensk – 5 places;

15:12 – evacuation of the dead bodies initiated, the accident site divided into 14 sectors;

16:10 –go team arrived at the accident site (headed by the deputy director, 6 persons, 1 car);

16:10 –search and rescue brigade 1 arrived at the accident site (4 persons, 1 car) from Mozhaysk, Moscow Region;

16:20 –25 bodies found at the accident site;

16:30 – mobile complex for video communication arrived at the accident site (6 persons, 1 car);

16:35 –one more go team arrived at the accident site (4 persons, 1 car);

16:45 - 5 go teams departing for the accident site (go team-5 (4 persons, 1 car, Chekhov), go team-6 (3 persons, 1 car, Odintsovo), go team-11 (6 persons, 1 car, Krasnogorsk), go team-17 (5 persons, 1 car, Podolsk), go team-19 (3 persons, 1 cars, Volokolamsk) from the Moscow Region (total 21 persons, 5 cars);

16:59 –Mi-26 helicopter arriving at the accident site from Dobrynskoye Airdrome (Military Unit 42663) of Vladimir Region with rescue personnel – 3 persons;

17:00 –go team-18 arrived at the accident site (5 persons, 1 car, Naro-Fominsk) from Moscow Region;

17:15 and 17:35 - two Mi-8 helicopters arrived at the accident site from Ramenskoye Airdrome, Moscow Region with rescue personnel of Leader center – 24 persons;

17:35 –special go tem-28 arrived at the accident site (8 persons, 1 car, Mozhaysk) from Moscow Region;

17:45 –central go team arrived at the accident site (13 persons, 2 cars);

19:00 – bodies loaded to the Mi-26 helicopter;

19:36 –Mi-26 helicopter (№06285) arrived at the accident site from Astafyevoye Airdrome, Moscow;

19:45 – Head of Regional Center arrived at the accident site;

20:23 – Tu-134 A3 arrived with the Chairman of the Russian Government;

20:54 – Mi-26 helicopter departing to Domodedovo Airport, Moscow with bodies of the dead persons on board;

23:01 – 2 pneumoframe modules arrived at the accident site from Kaluga (5 persons, 2 cars);

23:05 – a pneumoframe module arrived from Zvenigorod at the accident site (7 persons, 4 cars).

The rescue operations at the accident site were conducted till April 16, in total 1110 persons, 7 cynologists with dogs and 221 cars were involved in the operations at the accident site. 425 policemen were involved in cordoning off 1.5 hectares of the accident site.

On April 16, at 16:00 by the Act signed by the Investigator-in-Charge for the technical investigation from IAC, the Head of Inquiry and Head of Chief Emergency Office for Smolensk Region, upon agreement with the Accredited Representative of the Republic of Poland, the accident site was handed off to the Administration of Smolensk.

On April 19 the accident site was exposed to sanitary disposal.

General conclusion: Actions of all search and rescue services were correct and timely, which allowed preventing the development of the ground fire and provide custody for the flight recorders, elements of the aircraft, and bodies of the persons on board.

## 1.16. Test and Research

### 1.16.1. Aircraft Element Layout

From 13.04.2010 to 16.04.2010 the aircraft fragments were evacuated to the secured site and the aircraft airframe (Figure 37), avionics and flight control systems were laid out.

The airframe layout revealed that:

- the aircraft was separated into multiple fragments due to the impact with the ground and trees;
- The largest fragments are: left and right middle sections of the wing with root parts of the detachable parts of the wing and main landing gear, tail with power plant 2, engines 1 and 3 D-30KU-154, fragments of the front and middle fuselage, left and right detachable parts of the wing, fin with fragments of fairing, left and right stabilizer.

As the aircraft impacted the ground inverted the radome, cockpit light and upper part of the fuselage from frame 4 to frame 67A were totally destroyed into small fragments difficult to identify.

On the basis of the layout analysis it can be definitely concluded that the destruction of the aircraft structures and systems was caused by the unexpected impact forces, no traces of the in-flight fire were detected.



**Figure 37**

### 1.16.2. Mathematical Simulation

The purpose of the mathematical simulation was confirming the compliance of the actual stability and controllability characteristics to the type aircraft characteristics as well as assessment of time instants in the accident flight when the missed approach was still possible in case a number of conditions were met.

For the simulation a mathematical model was used which lies in the basis of the Tu-154M flight simulator.

On the first stage of the simulation the good model convergence with the accident flight data was shown by direct simulation of the final 28 seconds of descent (from 10:40:32 to 10:41:00).

On the second stage variants of missed approaches were modeled with the acceleration of 1.2, 1.3 and 1.4g with analysis of actual altitude loss during the missed approach. The missed approaches were simulated from the height of 40 m by selecting the elevator deflection that would simulate the modeled acceleration with complete simulation up to the moment of starting the missed approach of the changes in indicated air speed and vertical speed of the accident flight. The nature and tempo of the initial elevator deflection complied with the crew input in the accident flight with following “addition” until the selected acceleration was reached. The increase of engine thrust simulated the actual thrust in the accident flight. The simulation showed that the loss of altitude for the abovementioned vertical acceleration values is 28, 22 and 20 m respectively.

On the third stage the go-around modes were simulated in such a way as to select such a line change in elevator deflection 3 seconds long that would not lead to an increase in the angle of attack over the operational limits (so that not to reach SPS firing angles of 12° on the angle of attack indicator for 36° flaps,), meanwhile all engines were set to takeoff mode for 6 seconds. The simulation showed that safe go-around in that case was guaranteed from the height of about 40 m.

### 1.16.3. Operational Assessment of the Crew Actions<sup>22</sup>

This operational assessment was conducted by:

- An honoured test pilot of the Russian Federation, test pilot of Gromov Flight Research Institute;
- an honoured military pilot of the USSR, Commander-in-Chief of the Russian Air Forces for 7 years, having experience on over 20 aircraft types including Tu-

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<sup>22</sup> The operational assessment is provided in full, with the original texting.

104Б, Tu-22M2, Tu-160;

- a pilot-instructor of the Azerbaijan Havo Yollary airline having flying experience of over 19500 flight hours, including over 14000 hours on Tu-154 and authorized for VIP flights;
- a pilot-instructor of the Flight Instruction Department of the Uzbekiston Havo Yullari airline Training Center having flying experience of over 19000 flight hours, including over 8000 hours on Tu-154;
- an honoured scientist, Doctor of Medical Science, Professor of Psychology, Academician of the Russian Academy of Education and International Academy of Sciences.

The operational assessment was made on the basis of:

- Transcript of communication of the Tu-154M crew with the Ground Control Services, with Yak-40 crew and within the cockpit;
- Flight data records from the FDR.
- Findings of the operations subcommission;
- Tu-154M FCOM.

Analysis of the Tu-154M crew communication with the ground controllers and the crew of the Yak-40, Polish Air Forces, that had landed at Smolensk "Severny" Airdrome an hour and a half before the accident (at 09:15) revealed that the crew of the Tu-154M was not once (during descent and approach) warned by the ground controllers and crew of the Yak-40 on the unfavorable weather conditions for landing at Smolensk "Severny" Airdrome:

- at 10:14 during descent to WPT ASKIL from FL330 (10000 m) to 3900 m the crew was informed by Minsk Control that visibility at Smolensk "Severny" Airdrome was 400 m;
- at 10:24:40 to 10:24:51 the Ground Control of Smolensk "Severny" Airdrome informed that "at Korsazh: fog, visibility 400m...no conditions for arrival";
- at 10:24:16 to 10:25:11, contacting the crew of Yak-40 at 123,45, the crew had information on the decreasing visibility. The crew of Yak-40 informed that visibility was 400 m, and cloud base much lower than 50 m, and also noted that they "were lucky to land at the last moment". However, while warning on the bad weather conditions, the Yak-40 crew added that "you might try..." to approach (at 10:25:07);
- at 10:29:40 the crew of the Yak-40 aircraft informed that the Russian IL-76 "...made two approaches and left". (In fact, Il-76 tail number 78817, that was to land after the Yak-40

could not land due to weather conditions and after two approach attempts left for the alternate airdrome.);

- at 10:37:01 after the base turn the crew of Tu-154M was informed by the crew of Yak-40 on the decreased visibility to 200 m ("...Arek, now visibility 200").

The weather conditions at Smolensk "Severny" Airdrome by that time had really decreased due to the shift of fog and clouds from the south-east. It should be noted that the actual visibility at the accident site (near the middle marker) was probably even worse than at the airdrome, as the terrain is much lower (about 30-40 m) in that area than the runway level. As experience shows, fog is much denser in such places while the horizontal and vertical visibility may decrease to 50-100 m and 15-30 m respectively. The detailed analysis of the flight data at the attempt to avoid collision with obstacles (10:40:55) allows assuming with high probability that the vertical visibility near the middle marker could not possibly exceed 20-25 m.

The PIC actions analysis at that moment reveals that these actions in control wheel steering mode were done in an unusual way (not provided by the FCOM) and do not comply with the missed approach procedures prescribed by the FCOM of the Tu-154M.

The FCOM prescribes the following order of actions during a missed approach (Section 4.6.10 FCOM, Missed Approach Procedures):

- increasing thrust to takeoff mode and simultaneous callout "Takeoff mode, go around";
- switch from descent to climb with simultaneous retracting flaps to 28;
- landing gear retraction after vertical speed turns positive.

The procedures under consideration were initiated at 10:40:55 at radio altitude of about 30 m.

1. The PIC abruptly pulled up control column by applying about 15 kg of forces which overpowered only the AP pitch channel. During usual missed approach procedures in control wheel mode the AP is switched off by pressing the quick switch-off button on the pilot's control wheel.
2. After 1 second the throttles were shifted within 1 second into takeoff position .
3. The control column deflection and deflection tempo were much higher than during a timely go-around.

Most probably the actions of the PIC could be caused by one thing – that at that very moment he could see the ground or obstacles (trees), estimate the height visually and assess the critical situation. In that situation the PIC's actions were instinctive.

## **FAULTS AND VIOLATIONS MADE BY THE CREW DURING THE APPROACH**

1. Despite the weather conditions were lower than the PIC's, aircraft and Smolensk "Severny" airdrome minima for a non-precision approach, the crew did not take the correct decision to go to alternate airdrome. The decision for a test approach could be only justified if the aircraft had enough fuel for further flight to the alternate airdrome (the Tu-154 had extra fuel for half and hour of flight on board) and in case of strict compliance with the main rule – not descending lower than the minima established for the airdrome and the aircraft for the used approach system (100m). The latter condition was violated during the descent on glide path.

2. Late start of descent on the glide path (an error of about 1.5 km), which led to an error in the altitude of passing the outer marker of 120 m higher than established and necessity to increase the vertical speed to 7-8m/sec to catch the glide path. (At 10:39:50 at a distance of 6,2 km from the runway the aircraft was over the outer marker at about 420 m, which is significantly higher than the altitude of 300 m established by the standard approach pattern).

3. Applying unjustified high vertical speed of descent to compensate the altitude error. After passing the outer marker the crew, obviously realizing they were above the glide path, increased the vertical speed of descent to 8 m/sec (to correct this error the vertical speed should not exceed 5-6 m/sec). However such vertical speed (8 m/sec) was retained until the start of actions to avoid collision with obstacles (H=30m), i.e. up to the intolerably low height. No attempts were made to decrease the vertical speed even when reaching the altitude of the airdrome minima of 100 m.

It should be noted that even when approaching in simple meteorological conditions (when the pilot can clearly see the runway and visually monitor the height) the vertical speed of descent should be reduced to the standard speed of 4-5 m/sec before reaching the height of 40-50 m to conduct a safe landing. The more so, in complicated meteorological conditions it is completely not acceptable to descend after passing 100 m with the rate of descent of 7,5-8,5m/sec (i.e. 2 times higher than estimated). The FCOM of Tu-154 states that the minimum missed approach height with speed of descent of 4 m/sec is 4-6 m, and 15 m for speed of descent of 5 m/sec.

*Note: loss of altitude while the Tu-154 aircraft terminates descent with the flight parameters equal to those in the accident flight ( $V=280\text{km/hour}$ ,  $V_y=7,5-8\text{m/sec}$ ), with vertical acceleration of  $N_y=1,3$  in case of correct and timely actions is 30 m.*

Thus, it can be concluded that the PIC was not monitoring the vertical speed at the final stage of descent (below 100m). Air accident investigation experience shows that such situations occur when the PF (PIC) distracts his attention from the instruments “turning his eyes and attention to the space outside the cockpit” in order to search for the runway or ground references

(mainly lights: threshold or approach lights), while the other crew members such as the co-pilot are not monitoring the instruments.

4. The PIC did not do the main action – he did not terminate descent and did not go around when reaching the minimum descent altitude of 100 m while not seeing either the runway or the ground references. The go around was not made even when reaching the height of 60 m by radio altimeter when the decision height warning was triggered.

5. Neither of the pilots took immediate measures to terminate descent and initiate climb when the TAWS "PULL UP, PULL UP" alert was fired at 105 m by radio altimeter (about 85 m with relevance to the runway threshold). In case such alert is fired the PIC must immediately climb until the alert stops. The alert was fired at 10:40:43, i.e. for 12 seconds (until actions to avoid obstacles were initiated) there was no reaction from the crew.

6. Absence of CRM when approaching in complicated meteorological conditions:

- The PIC did not precisely distribute the crew responsibilities when making the test approach and did not discuss the missed approach procedures.
- The crew did not discuss the AP usage procedure nor the minimum altitude of disengaging the AP during the approach.

*Note: The Tu-154M FCOM does not prescribe using the autopilot during a non-precision approach. Setting the rate of descent (when the VNAV mode is not available) is only possible by using the DESCENT-CLIMB wheel which sets the target pitch (not vertical speed). Controlling vertical speed with required accuracy with this wheel requires certain pilot skills. Usually pilots use this wheel during climb or descent stages of flight that do not require high accuracy of vertical speed control and time in which the pilot would select the necessary pitch angle to maintain constant flight speed is not so important. When the approach mode requires quick and highly accurate setting of vertical speed the use of the DESCENT-CLIMB wheel is not practicable as it requires significant time to establish vertical speed which usually implies resetting. This is mainly explained by a significant delay of the vertical speed indicator (especially TCAS VSI) and a long chain of feedback: pilot – DESCENT-CLIMB wheel – autopilot – aircraft – VSI – pilot. Due to this reason the use of DESCENT-CLIMB wheel is not practicable for controlling the vertical speed of descent during approach as it requires much attention and time, distracts from other flight data monitoring and increases the workload on the pilot.*

*The FDR record and the calculations show that starting from the distance of 10 km and up to 6 km (before passing the outer marker) the pilot handling the DESCENT-CLIMB wheel tried to select the needed vertical speed. Experience of Tu-154 crews shows that during a non-precision*



*approach control column steering mode (manual mode) is to be used.*

- The approach speed and vertical speed of descent on the glide path were not calculated and called out by the crew.

*Note: The estimated speed on the glide path with 2°40' slope angle for 77-78 tons is 265 km/h while the vertical speed is 3.5 m/sec. Provided the actual airspeed on the glide path was 300-280 km/h accompanied with tailwind component the vertical speed had to be about 4.0 m/sec. Actually the crew was flying on the glide path with slope angle of over 5 degrees (vertical speed of about 8 m/sec) which the aircraft could not provide without increasing the speed. The autothrottle being set to maintain airspeed of 280 km/h moved all throttles to idle during descent after the outer marker, so the aircraft could not maintain the selected speed.*

The co-pilot did not take a wide range of safety actions during the descent on the glide path:

- He did not callout high vertical speed of descent (at vertical speed over 5m/sec he should have called out “steep descent”) or airspeed deviations over 10 km/h (“high airspeed”) (Section 4.6.3, FCOM);
- He did not follow the missed approach procedures when the aircraft descended lower than decision height provided no decision from the PIC followed (he just called out "Go around!" at H=65m but did not take any relative measures). The FDR data analysis revealed that at 10:40:51 when the "Go around!" call out sounded the steering wheel was slightly pulled up but not enough to disengage the autopilot and less than enough to go around. Most probably this action was instinctive of the co-pilot who realized the critical nature of the situation better than the other crew members.

*Note: Section 4.6.10 (6) of the FCOM: If at decision height the PIC does not callout “Land” or “Go around” the co-pilot must warn the crew by calling out “Takeoff mode. Go around”, set thrust to takeoff mode and pull up to terminate the descent.*

The navigator also did not take a set of safety measures during the descent on the glide path:

- He did not call out the glide path capture point neither the target vertical speed of descent;
- He did not report explicitly the actual altitude on passing the outer marker;
- Having FMS information on the distance to the ARP he did not inform the crew about it. Information on the distance to the runway threshold could have helped the pilots to estimate the current position on the glide path using the current altitude. There is a simple

formula to determine the aircraft position on the glide path with slope angle of  $2^{\circ}40' \dots 3^{\circ}$ :  
 $H(m)=D(km):2 \times 100$ ;

- The navigator monitored the altitude by radio altimeter though when making an approach with ICAO Cat I minima (cloud base 60 m) and better, maneuvering, decision making and altitude monitoring must be conducted with use of only pressure altimeter. The incompliance with this rule could have misled the PIC concerning the flight altitude with reference to runway threshold ;
- He did not call out “DECISION” 30 m before the decision altitude;
- He did not warn the crew on reaching decision altitude. This extremely important action was not even done when he decision height warning was triggered at the radio altimeter at H=60m;
- Most probably it was the navigator who made an error by setting standard pressure of 1013 hPa at the PIC’s pressure altimeter when the aircraft was on glide path.

The pressing of the standard pressure selector at the electronic pressure altimeter on final (at about 350 m) was absolutely illogical and was probably caused by mixing with the QFE button located near the MFD-640 of the TAWS that had to be pressed at the transition level. The pressure selector at the pressure altimeter could only be reached by the PIC or the navigator who was seated between the pilots. It is improbable that the PIC who was engaged with the flight control at that moment could do this. Besides, the PIC out of all the crew members had the longest experience on this aircraft type. As for the navigator, he had insignificant experience on Tu-154 (total 59 hours and unsupervised 26 hours, with a break of 2.5 months) and most probably was the one who could do this action.

The switch of pressure on the electronic pressure altimeter from 745 mm mercury to 760 mm mercury led to a change in the altimeter indication – increasing by about ~160 m. This could have misinformed the PIC in case he was monitoring altitude. However, if the PIC was monitoring the altimeter he could not have missed the abrupt change in its indications and unauthorized navigator’s actions concerning the pressure switch on the altimeter. Besides, a lot of other information (high vertical speed, radio altitude indication called out by the navigator, firing TAWS “PULL UP, PULL UP” warning, co-pilot’s callout :Go around”, Controller’s instruction “Horizon, 101!”) was quite enough to take the only correct decision to go around.

#### **PROBABLE CAUSES THAT LED TO THE AIRCRAFT DESCENDING LOWER THAN DECISION ALTITUDE AND LACK OF GO AROUND ACTIONS**

After being informed by the ATC on abrupt negative change of the weather conditions

the crew discussed this information several times not only among themselves but also with other persons who were in the cockpit expressing concern about the possibility of landing at the airdrome. The PIC realized that it was difficult to approach in such conditions but considering the importance of the task and possible negative reaction of the Main Passenger in case of leaving for an alternate airdrome without a trial approach takes a decision to make a test approach: "... well, if possible, we can try approaching, but if there is no appropriate weather we'll go around" (10:25:01). As has been mentioned, this decision could only be justified if the remaining fuel was enough for further flight to the alternate airdrome (the fuel on board was enough for 1.5 hours of flight) and in case the main rule is strictly followed, namely not descending lower than the minima established for the airdrome and the aircraft for the used approach system (100 m). Most probably the PIC was planning to do so at the moment. At 10:32:59, being on downwind leg the PIC informed the crew: "Approach for landing. In case of missed approach going around in autoflight mode." Besides, when making the base turn and being warned by the Controller "Polish 101, from 100 m be ready to go around" the PIC replies with a brief military reply "Yes, sir!"

However the fact that there were other persons in the cockpit during the approach who were accompanying the Main Passenger obviously intensified stress and distracted the crew from their duties. The background noise parameters recorded by the CVR revealed that the cockpit door was open. A number of phrases recorded by the CVR (at 10:30:33 "Pan Director": "So far no President's decision what to do next" and at 10:38:00 unidentified voice<sup>23</sup>: "He'll go crazy if...") show that the PIC was in psychologically difficult position. It was obvious that in case of missed approach and proceeding to the alternate airdrome the PIC could have to face negative reaction of the Main Passenger. As the phrase "He'll go crazy if..." was said during the final turn the PIC could have changed his previous decision and decided to take the risk of descending lower than the decision altitude hoping to finally establish visual contact with the runway and land. The change of decision required change of action plan: setting an inner barrier, i.e. reasonably safe altitude to initiate the go around and informing the crew about it. However, due to time deficiency (the aircraft was on final) and growing stress the PIC could not realize that plan.

Besides, it can be most probably assumed that the PIC experienced psychological clash of motives. On the one hand, he realized clearly that landing in these conditions was unsafe (this was confirmed by his initial decision to go around from 100 m), on the other hand he had strong

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<sup>23</sup> The flight operations assessment was conducted with the use of Version 1 communications transcript, where this speaker was not yet identified. Further it was confirmed that the phrase in question was said by the navigator .

motivation to land at that airdrome. In terms of aviation psychology this situation is known as clash of motives. When a person experiences clash of motives his attention gets narrower and the probability of inadequate decisions increases. These two causes (lack of new clear plan of actions and psychological clash) explain the passive behavior of the PIC on final (lack of reaction to the high vertical speed, to radio altimeter information called out by the navigator, to the TAWS "PULL UP, PULL UP" warning, to the co-pilot's callout "Go around", and to the Controller's instruction to terminate descent "Horizon, 101!") and his late and inadequate recovery actions.

It should be also noted that the attempt to recover from descent made by the PIC led to a decrease in vertical speed of descent but due to lack of delta height and excessive vertical speed could not prevent the collision of the aircraft with the obstacle (birch) which the aircraft hit with its left wing at a height of about 5 m. However the climb maneuver was so abrupt that by the time of the impact the aircraft had angles of attack close to stall AOA. The rate of AOA increase was about 3-3.5 degrees per second. This means that if not for the collision, in 1.5 – 2 seconds the aircraft would have stalled which would also end up in an accident.

Thus, the accident was caused by severe violation of flight safety principles during approach in weather conditions below minima which included:

- Failure to go around and descending lower than decision altitude down to an intolerably low height with vertical speed of descent 2 times higher than normal;
- Lack of important CRM and violations of the SOP.

The inadequate decisions took by the PIC and the crew actions were backed up by high level of psychological stress induced by the understanding of importance of landing at the destination airdrome as well as by the presence of high-ranked officials in the cockpit. During the approach the latter not once discussed with the crew the weather conditions, the decisions to continue the flight and the possible negative reaction of the Main Passenger.

It should be also noted that the crew for the VIP flight was formed without considering the required proficiency level and experience. Recurrent simulator training including non-precision approaches and emergency procedures was not conducted. The PIC's minima (60x800) had expired.

#### **1.16.4. Fuel and Oil Analysis**

Upon request of the investigation team the State Research Institute of Civil Aviation examined the fuel and oil samples drained at the accident site. According to Conclusion №55-2010 of the Aviation Fuel and Lubricants Certification Center of 14.05.2010 the drained samples

were identified as Jet A-1 fuel, “in general there was nothing unusual in the physical and chemical characteristics of the fuel samples quality taken from the Tu-154M PFL 101 fuel system”. Some deviations in the chemical and physical characteristics detected in the fuel samples and some bottles according to the conducted research are connected with foreign agents penetrating the fuel in the course of sample selection, due to the aircraft destruction and due to interaction with polymeric materials”.

Nothing unusual was detected in the quality of the MS-8P oil.

#### **1.16.5. Findings of TAWS and FMS Examination**

The examinations were conducted at the manufacturer’s facilities, Universal Avionics Systems Corporation (UASC) at Redmond USA with participation of representatives of the IAC, Republic of Poland, NTSB and FAA. Despite significant mechanical damage of the units, most of the data were successfully read out and processed. This section contains only those findings that were used for this Report. The complete examination findings are in the investigation file.

#### **TAWS**

Part Number – 3010-00-00, serial number – 237. TAWS contains two data sources that can be used for investigation purposes: the nonvolatile memory device of the CPU/Video board stores alerts and faults while the flash board contains the terrain and airport databases. Both modules were successfully read out. The analysis revealed the following:

At the time of the accident, the TAWS unit was operating using TAWS configuration file format version 10.6.2, dated August 8, 2002. The TAWS unit was using Terrain Database 0209, released September, 2002 and Airport Database 0304, released April, 2003. The Smolensk “Severny” Airdrome was not in Airport Database 0304. Universal Avionics indicated that the Smolensk “Severny” Airdrome was not included in the airport database in effect at the time of the accident.

The Smolensk “Severny” Airdrome was never included in any of Universal Avionics Airport Databases.

In the flight of April 10, 2010 TAWS was on and operative. Three faults logged in the Fault Log refer to the time interval after the impact that led to the structural disintegration of aircraft and were induced by the destruction process and disappearing of signals from the relative sensors.

The system received the positioning and navigation data from the FMS UNS-1D units. The height data were received from the RV-5 radio altimeters. The air data computer provided the air data.

TAWS was configured to display terrain on the MFD-640 screen.

During the accident flight TAWS recorded 4 alert events. In all these cases the aircraft was on approach, landing gears down, flaps in landing configuration. The Terrain Inhibit and QFE modes were not used.

At the time alert recording starts TAWS logs some aircraft movement parameters (aircraft position, altitude, speed, etc.) and aircraft systems configuration (flaps, landing gears).

The alert events were logged at 10:40:06, 10:40:32, 10:40:39, 10:40:46<sup>24</sup> and coincides with the records of the same events on the FDR and CVR.

The first two events were of ROC\_CAUTION (Required Obstacle Clearance Caution) type. The third event was of ROC\_WARNING (Required Obstacle Clearance Warning) type. Both types are FLTA (Forward Looking Terrain Alert) events. ROC\_CAUTION is accompanied by the “TERRAIN AHEAD” artificial voice, and ROC\_WARNING – by the “TERRAIN AHEAD, PULL UP” artificial voice. The fourth event (TERRAIN\_IMPACT\_WARNING) was accompanied by the MODE\_1\_SINK\_RATE event. The MODE\_1\_SINK\_RATE event was not announced due to higher priority of Terrain Impact Warning. Terrain Impact Warning event was also accompanied by the “TERRAIN AHEAD, PULL UP” artificial voice.

The analysis of data recorded by the system at the time these events were formed, allowed adjusting the flight path horizontally as well as calculated altitude and vertical speed. Data recorded by TAWS were used as terminal conditions while calculating the flight path in horizontal and vertical planes.

The TAWS data analysis of barocorrected altitude confirms that the standard pressure (1013 hPa) was set at the PIC’s altimeter in the course of descent on final between the first and second alerts.

### **FMS UNS-1D**

The aircraft was equipped with two identical FMS consisting of a Control Display Unit (CDU) mounted in the cockpit, a Navigation Computer Unit (NCU) and application units. The NCU contains several computer boards including the Central Processing Unit (CPU) board. The random access memory (RAM) on the CPU board is battery-backed and if the external power to the FMS is removed the CPU board memory is frozen. Thus a number of parameters are logged in case there is external power loss and can be further recovered if internal battery is intact.

The data were copied from NCU part number 1192-00-111101, serial number 281. The second NCU (serial number 1577) had suffered significant damage and no reliable data were copied.

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<sup>24</sup> Considering the difference in time zones three extra seconds were added to TAWS time to be synchronized with the FDR.

The analysis revealed that NCU 281 was mounted in position 2 (co-pilot).

As both systems exchange data, analysis of one system only allows assuming that both FMS were on and operative in flight.

The FMS power was lost (memory frozen) at 10:41:05 at a barocorrected altitude of about 15 m, with IAS 145 knots (about 270 km/h) at N54°49.483' E032°03.161'.

The FMS memory contained active lateral flight plan for route: EPWA – a number of waypoints from RW29.BAMS1G Departure – ASLUX – TOXAR – RUDKA – GOVIK – MNS (Minsk-2 VOR/DME) – BERIS – SODKO – ASKIL – DRL1 – 10XUB – DRL – XUBS. All the waypoints excluding the latter four are taken from the FMS navigation database (valid till May 6, 2010). The last four waypoints were user-defined. The coordinate analysis revealed that DRL1 has coordinates of the former outer marker for approach with the heading 79° at Smolensk “Severny” Airdrome (now out of service). 10XUB is a point 10 nm (about 18.5 km, azimuth 79°M) from the ARP. DRL is LOM-259, XUBS is ARP. The coordinates of both outer markers and ARP were obviously taken from the air navigation charts that the crew had (in the SK-42 coordinate system, without conversion to WGS-84 system which is used by GPS).

The FMS vertical navigation mode was not engaged and there was no flight plan for vertical navigation.

At the time the power was lost the flight was conducted in compliance with the active flight plan from DRL to XUBS.

The FMS keeps a running history of up to 100 of the most recent key presses the crew entered to the CDU (not time-stamped). The analysis of the used keys revealed that at some moment the CMD HDG mode was selected on the NAV page and then course 40° and further 79° was selected (the system was working in magnetic course mode). Further the CMD HDG mode was changed to NAV mode (was active until the power was lost).

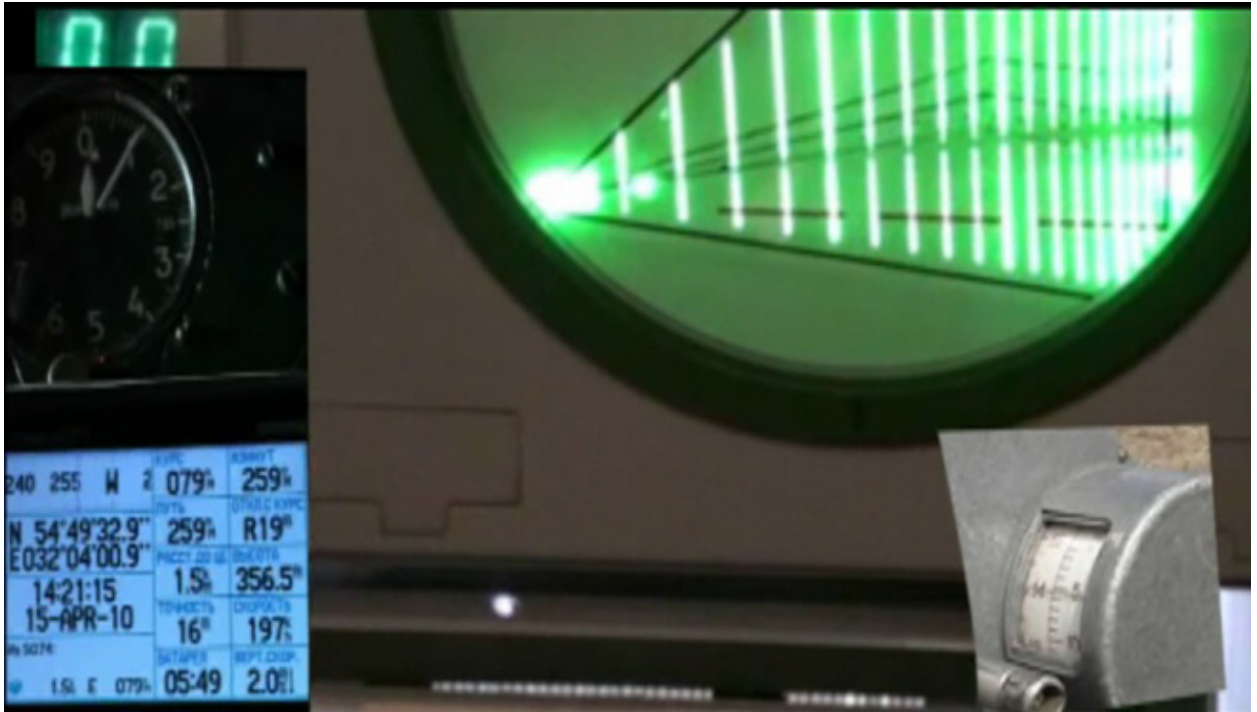
Also the data analysis revealed the split of barocorrected altitude indication between the pressure altimeters of the PIC and the co-pilot of about 170 m at the time of the power loss which corresponds to the pressure difference of ~15 mm mercury.

#### **1.16.6. Navaid and Lighting Equipment Test Fly-Around**

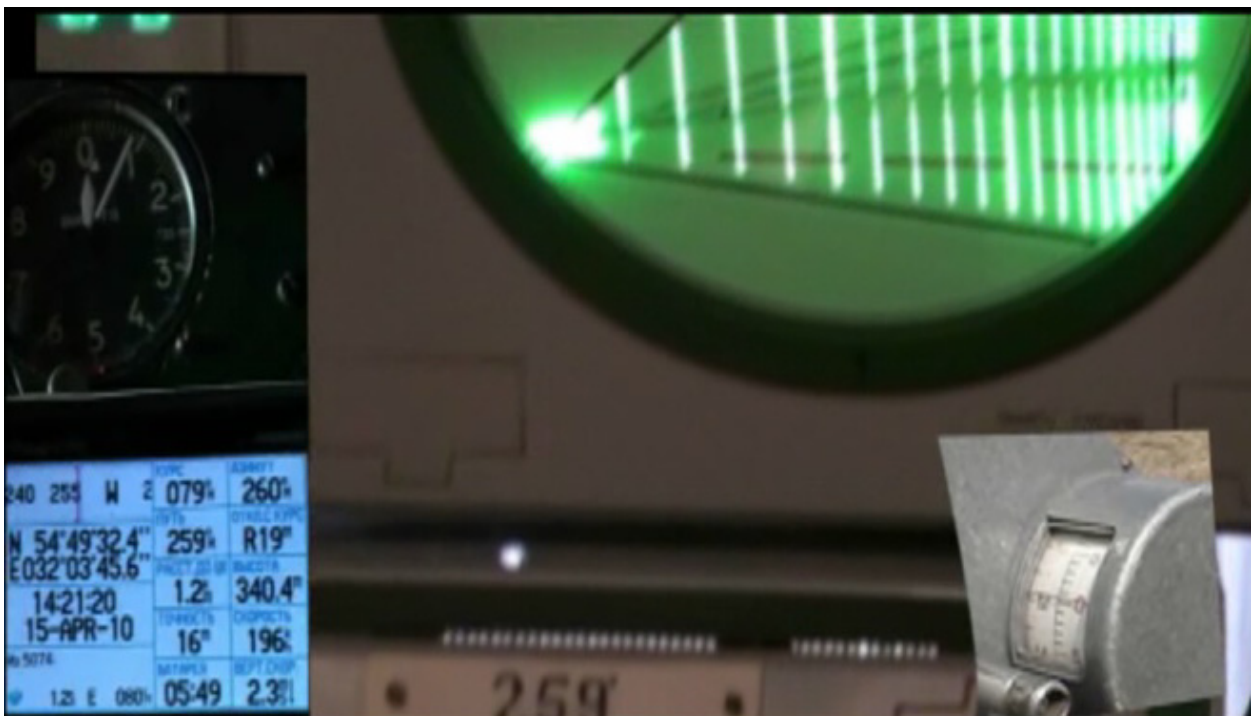
On April 15, 2010 upon request of the investigation team the An-26 t/n 147 of Military Unit 21350 aircraft laboratory made a test fly-around of the airdrome navigation aids and lighting equipment. According to the results of the standard checklist for fly-around the mentioned navaids and lighting equipment were operative which was confirmed by the relative task sheets.



The minimum required landing radar range of 1.5 km in the passive mode (used in the accident flight) (Figure 38) and of 1 km in the active and moving aim selection modes is provided. In the passive mode the blip disappears about 1.2 km from RWY 26 threshold (Figure 39).



**Figure 38**



**Figure 39**

One of the purposes was to check the compliance of the aircraft blip on the landing radar with the actual aircraft position.

Two video cameras were used to record the flight parameters and the radar indications (one on board and one at the radar). The on-board camera recorded the Garmin 276C GPS and pressure altimeter indications. The radar-based camera recorded the landing radar screen. Before the operations both cameras were synchronized with the GPS time.

Several approaches were made. Due to the absence of instrumental glide path at the airdrome the aircraft was additionally vectored from the ground with the help of a special binocular. On the basis of maintaining the glide path angle of  $2^{\circ}40'$  the second approach was selected for further calculations.

The analysis findings are shown on Figure 40 and Figure 41. The first chart shows the changes in altitude in the test flight as a function of the distance from RWY 26 threshold. The chart also shows the nominal glide path, the area of tolerable deviations and the so-called momentary glide path angles. These angles are calculated as arctangent of the quotient from dividing the current altitude by distance to the touchdown point when following the nominal glide path (the touchdown point is 320 m after the runway threshold).

The analysis led to the following conclusions:

- 1 The landing radar screen mounted for the experiment (and during the accident flight) had lines approximately designating the following angles (shown in black on the chart):
  - Lower line -  $2^{\circ}42.3'$ ;
  - Central line -  $3^{\circ}12.3'$ ;
  - Upper line -  $3^{\circ}42.3'$ ;
- 2 The landing radar underrates the indications of the aircraft distance from the runway threshold by about  $90 \div 150$  m (depending on the distance of the aircraft from the runway threshold).

Thus, in the accident flight the landing zone controller saw the aircraft blip on the radar as being referenced to glide path of  $\sim 3^{\circ}10'$ . The inaccuracy was about  $0.5^{\circ}$ , which is equal to the tolerance area range.

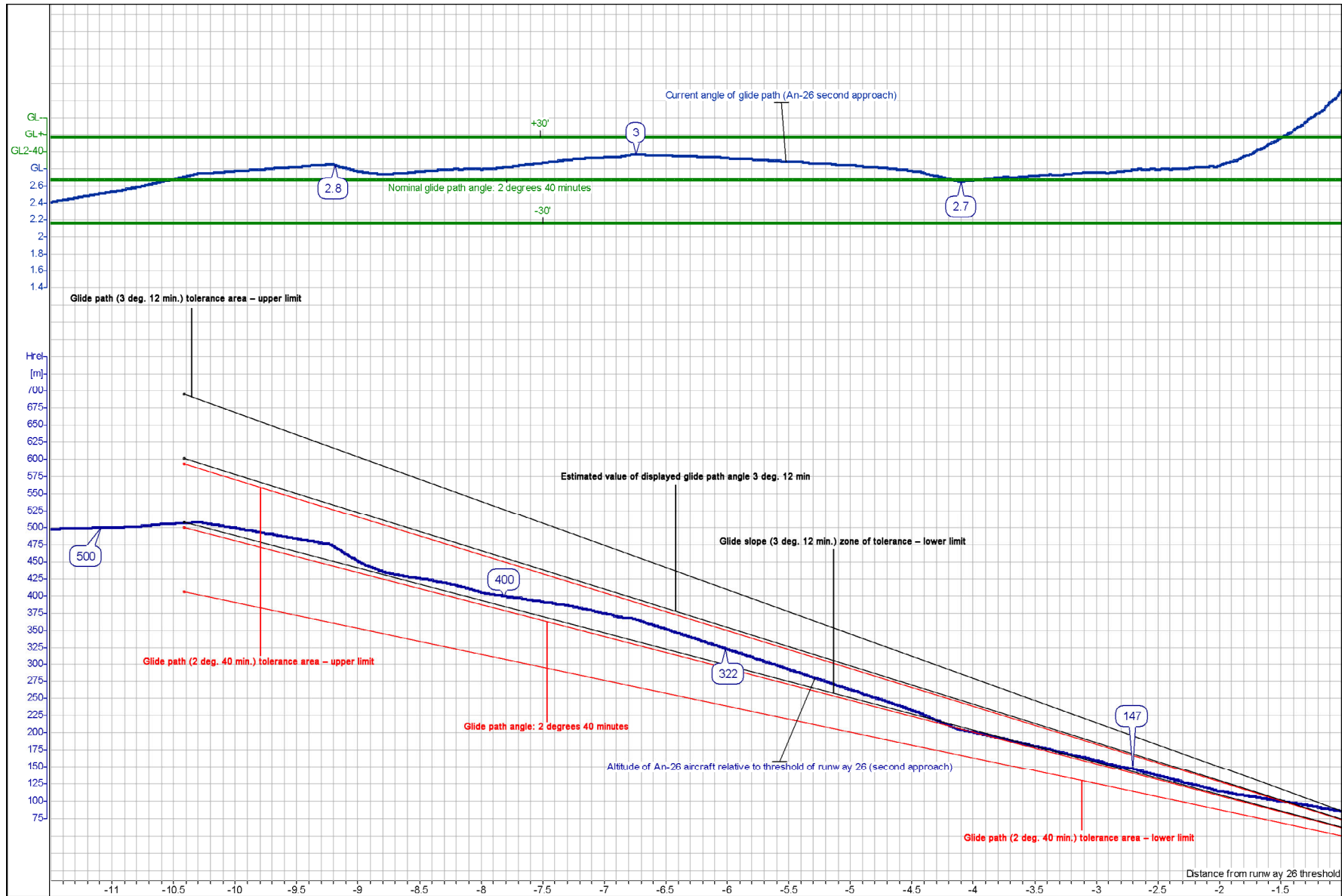


Figure 40

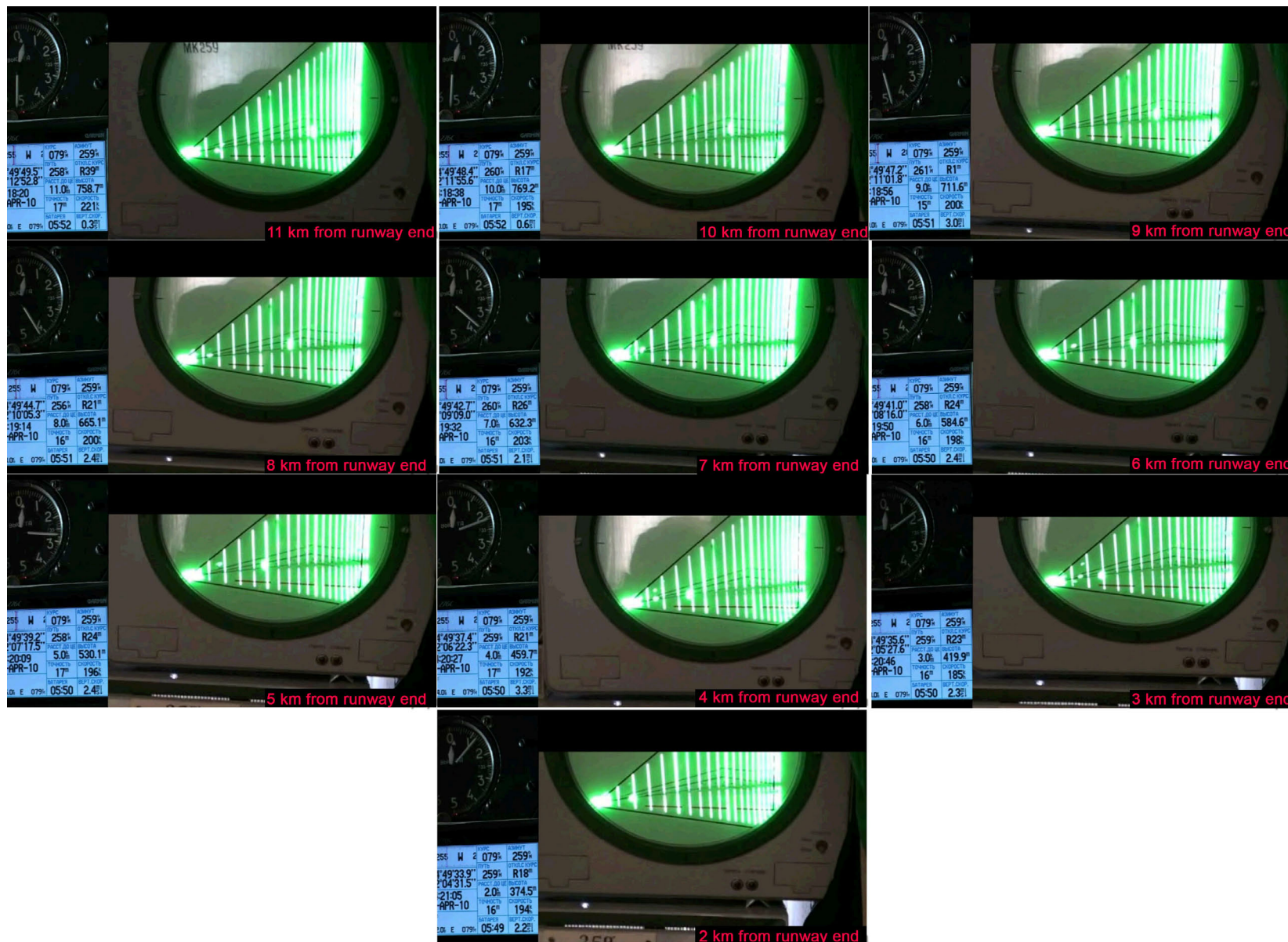
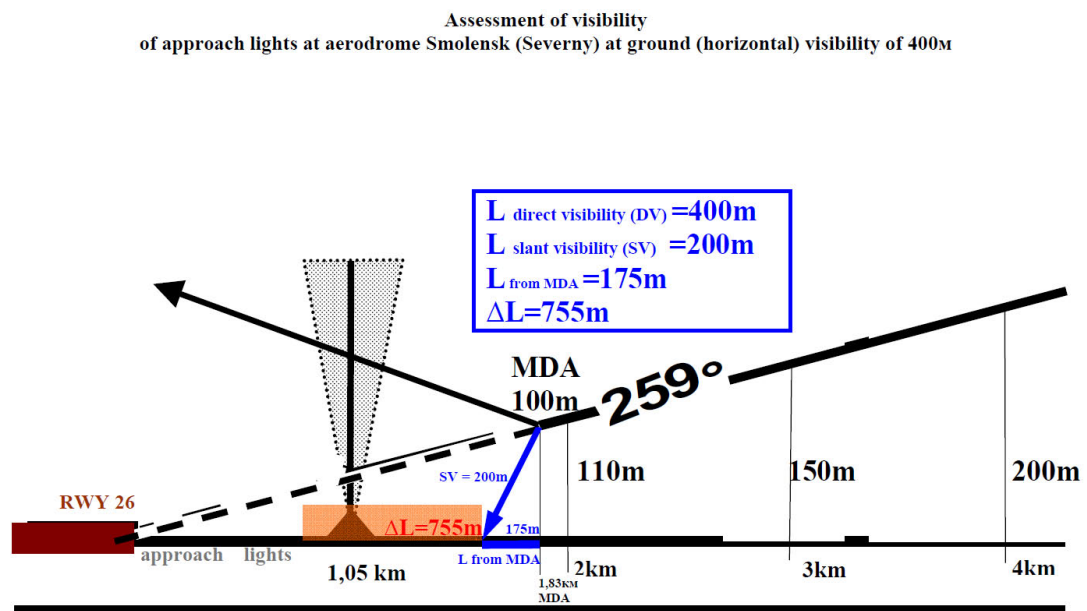


Figure 41



### 1.16.7. Assessment of the Lighting System Visibility.

To assess the visibility of the lighting system elements in actual weather conditions a relative chart was prepared (Figure 42). For the assessment purposes the direct visibility was taken as 400 m. The Ratsimor method was used to converse the direct visibility to slant one:  $L(\text{slant visibility}) = k * L(\text{direct visibility})$ . If the cloud base is lower than 100 m  $k = 0.2 - 0.45$ . To make the calculations the conversion coefficient of 0.5 was taken with a margin. Thus the calculated slant visibility was 200 m. When on the glide path the aircraft should have passed the decision altitude (100 m) at a distance of 1800-1850 m from RWY 26 threshold. The following chart shows that the crew could not have established visual contact even with the first line of approach lights (900 m from the runway).



### 1.16.8. Expert Conclusion on the Possibility of an Unauthorized Person's Presence in the Cockpit by the Time of the Impact

The ground for analysis was the fact of probable presence of a non-crew member in the cockpit for the last minutes of the flight, which is reflected in the Transcript of Crew Communications. Two minutes before the accident the CVR recorded a phrase told by a person whose voice was identified as the voice of the Commander-in-Chief of the Polish Air Forces.

In this respect the materials of the medical coronary expertise of the 92 bodies of persons who were on board at the time of the accident were examined<sup>25</sup>.

<sup>25</sup> The results of similar examinations concerning the crew members are shown in Section 1.13.1.

Considering the peculiarities of the collision of the aircraft with the ground and destruction character it can be assumed that the most significant injuries must have been sustained by the persons in the forward part of the passenger cabin, and those passengers who were seated near the tail must have sustained less significant injuries. Besides, bodies of persons who were not fastened by seat belts in their seats are more prone to dissection as when the aircraft is inverted they stick to the cabin ceiling and on impact inevitably find themselves in the epicenter of the airframe destruction and sustain multiple secondary injuries from the wreckage of the moving and destructed aircraft parts.

The analysis of the coronary expertise and pictures of all passengers and cabin crew on board made it possible to divide them (by the nature of injuries) into three groups:

- Seated in the passenger seats in the rear part of the passenger cabin and fastened by seat belts (president's security, part of the delegation and one cabin attendant);
- Seated in the passenger seats in the forward part of the passenger cabin and fastened by seat belts (part of the delegation);
- Seated mainly in the forward part of the passenger cabin, not fastened and therefore exposed to multiple dismemberment (almost all high-ranked officials from the Ministry of Defense, two delegation members and a cabin attendant).

As for the unauthorized person who could have been present in the cockpit during the impact, that person being not fastened and finding himself on the ceiling in the limited area of the cockpit must have sustained severe squashing injuries. Besides, considering the evolutions of the aircraft before the impact (intensively developing left bank), the initial impact force must have affected mainly the left part of the person's body who instinctively tried to lift himself from the ceiling, leaning on the left hand.

The Expert Conclusion of Coronary Expertise №37 which provides detailed examination of the body of a person identified on the basis of genetic expertise as the person whose voice was identified on the CVR revealed that the main traumatic impact affected the left side of the chest, abdomen and pelvis with the dismemberment of the left arm. This complies with the abovementioned mechanism of probable injuries sustained by a person who was present in the cockpit not fastened by the seat belts in a certain place. Besides, the protocol of the accident site examination shows that the body of the person in question was found in sector №1 which corresponds to the nose part of the aircraft. The navigator's body was found in the same sector.

Thus, the medical tracing examination of the injuries sustained by the Commander-in-Chief of the Polish Air Forces are consistent to his being in the cockpit at the time of the impact.

Besides, Expert Conclusion № 37 contains information that 0.6‰ of ethanol was found in the blood of the Commander-in-Chief of the Polish Air Forces, which corresponds to light

alcohol intoxication, no ethanol was found in the kidney. Thus, most probably the alcohol was consumed during the flight.

#### **1.16.9. Expert Conclusion Analyzing Actions of the ATC Group of Smolensk "Severny" Airdrome on April 10, 2010**

This expert conclusion has been prepared by:

- A Class I air traffic controller, in service since 1966;
- A board member of the Flight Safety International Foundation, a Class I air traffic controller, in service for over 30 years;
- Head of the Air Traffic Control Department, Center of the Combat Training and Flight Crew Training;
- Main assistant of the Chief ATC of Chkalovsky Airdrome.

The experts have concluded the following:

According to the flight schedule for 10.04.2010 two international flights on a Yak-40 (PLF 031) and on a Tu-154M (PLF 101) were planned to Smolensk "Severny" airdrome.

At 09:15 the Yak-40 aircraft (Flight PLF 031) landed. Official weather data for 09:06: clouds, cloudbase 150 m, visibility 2000 m. The weather conditions kept getting worse.

The Yak-40 landed with visibility 1000 m. Observing the flight height over the runway threshold level (higher than the estimated) the CATC instructed the crew to go around, but the crew did not follow the instruction and landed.

There were no complaints of the work of the ATC group or the operation of the navigation aids and lighting equipment expressed by the Yak-40 crew.

There have been a number of previous cases when the flight rules and ATC instructions were not followed by Polish crews at Smolensk "Severny" airdrome. Thus, according to the chief air traffic controller's report, on 07.04.2010 a Tu-154M aircraft during approach made unauthorized descent from the cleared altitude of 500 m to 300 m. Upon the controller's instruction the aircraft returned to 500 m.

On the same day a «CASA» after obtaining the takeoff clearance and departure information, after liftoff at a height of 15-20 m, making a significant roll, initiated turn in climb violating the departure pattern.

At 09:08 the CATC informed the arriving IL-76 aircraft: «visibility has dropped, mist 1000 m». After making two unsuccessful approaches with visibility 1000 m the IL-76 aircraft (the aircraft visibility minimum is 1000 m) was forwarded to alternate airdrome of Vnukovo at 09:39. The aircraft landed at Vnukovo airport at 10:31.

At 09:40 storm warning was issued based on the actual weather: fog, visibility 800 m, clouds 10 points, stratus, cloudbase 80 m.

According to the CATC's explanation, at 09:40 he was informed on the Tu-154M aircraft PLF 101 that had departed from Warsaw at 09:27; there was no preliminary request for arrival permission from Warsaw. The estimated flight time enroute was 1 hour and 15 minutes.

After receiving the information on the departure of Flight PLF 101 from Warsaw the CATC, considering the further worsening of the weather conditions tasked the dispatch officer to discuss the possibility of forwarding the aircraft to the alternate airdrome on the phone with the ATM area center and the officer on duty of the control center of the military transport aviation. Simultaneously the information on the unfavourable weather conditions was transmitted to a transit aircraft for further transmission to Flight PLF 101 and the ATM services.

When the Tu-154M PLF 101 was in the airspace of the Republic of Byelorussia, the ATC transmitted the information to the crew. However, the crew did not show any concern and did not request recommendations as to the alternate airdromes.

According to the crew to ATC radio communications record, at 10:23 the crew of Flight PLF 101 contacted the Smolensk "Severny" Airdrome, CATC informed the crew on the airdrome weather (fog, visibility 400 m, no conditions for landing). The crew confirmed that they received that information. On first contact the crew did not report their intentions concerning the approach system to be used, which could mean, provided the weather conditions were unsuitable for landing, that the crew were going to approach using the on-board equipment. The crew did not request radar either.

As it was an international flight, in compliance with the Russian AIP the CATC cleared the crew, upon their request, to descend to FL 1500 m to downwind turn in order to approach with the course of 259 degrees.

The crew is entirely responsible for the safety of the flight, approach and actions during the approach under the weather conditions lower than the established minima, as they were warned that the weather conditions were not appropriate for landing.

This provision refers to the international flight rules. In state aviation of the Russian Federation flights (approaches and landings) are not to be performed at the PIC's discretion. The ATC instruction is mandatory for the PIC in the state aviation of the Russian Federation. Further the ATC group only informed the PIC on the aircraft position using the radar information.

After the crew was cleared for base turn the CATC instructed the crew to be ready to go around from decision altitude of 100 m. The crew confirmed receiving the information (Reply: "Yes, sir!")



As the weather conditions were not appropriate for landing, the air traffic control group was sure that the crew would follow the instruction to go around from decision altitude of 100 m, as they were only cleared to approach under these conditions.

As a result of the analysis the experts arrived to the following conclusions:

- The ATC group actions during the approach did not contribute to the accident.
- The professional level of the ATC group of Smolensk "Severnoy" Airdrome complied with the regulations.
- The crew was timely informed on the worsened weather conditions below the minima, but despite the warning they decided to approach. In accordance with the Russian AIP the crew was cleared to approach, but all the responsibility for the consequences was to be taken on by the crew because there were no conditions for landing. The ATC group, using the available equipment informed the crew on the aircraft position on approach down to the established decision altitude.
- The crew did not report to the CATC on the selected approach system, nor did they request the landing radar.
- The operation of the nav aids and lighting equipment as well as the runway condition did not affect the accident causes. The discrepancies detected in the glide path depiction on the landing zone controller's radar screen did not affect the flight consequences, the flight was performed with a greater obstacle clearance margins and the crew was not to descend lower than the minimum descent altitude established by the ATC.

#### **1.16.10. Assessment of the PIC's Psychoemotional Status**

A joint group of Russian and Polish expert doctors and psychologists made an assessment of the psychoemotional status of the PIC. The analysis of the PIC's individual personality traits was conducted on the basis of testing results provided by the Polish side. The psychological examination of the PIC was performed in accordance with the "Criteria of Psychological Assessment and Estimation Methods for Flight Crew Examination", developed by a group of psychologists of the Faculty of Psychology of the Military Institute of Aviation Medicine and approved by the Institute Director in 2005. The experts also conducted a psycho-linguistic analysis of the cockpit communications recorded by the CVR.

The expert assessment, among all, noted that the results of the psychological tests reveal the dominating conformity (complaisance, subordinacy) in the PIC's character traits.

**Note:** *Conformity is a person's complaisance to the actual pressure exposed by the group; it is reflected in the change of their behaviour and intentions in accordance with the views of the majority that they did not initially share. Psychologists distinguish between the external (public) conformity and internal (personal) conformity. Despite the differences, both types are similar in a way that they serve a specific way of solving a conscious conflict between the personal opinion and opinion dominating in the group to the benefit of the latter: the person's subordinacy to the group makes them find agreement with it, either a real one or a virtual one, and conform their behaviour to etalons that seem alien or wrong. (Psychological Dictionary, S.Y.Golovin, 2001.).*

On the basis of the PIC's test findings it can be assumed that he had a good level of emotional control, a tendency for commutability, cooperation, experimentation, open-mindedness. The domination of conformity over other character traits makes a person gentle, flexible, and dependent on the opinions of a group or authority due to their strong desire to avoid conflicts. One of the components of conformity is anxiety as a personal quality. An enhanced level of conformity implies an enhanced level of anxiety as a component part. Also, enhanced conformity leads to proportional decrease of independence as a personal quality.

Therefore, when the PIC was commissioned, the psychologists should have paid attention to the conformity scale and make a deeper analysis considering the possibility of its effect on the way of behaviour including that in stressful situations.

It should be noted that testing is done in quiet conditions, in normal working status. And those character traits that dominate during the testing in quiet conditions get sharper and more pressing in extreme situations and can stipulate further behaviour.

The long period of the PIC working as a co-pilot could have also influenced the formation and consolidation of his conformity. From 1997 to 2006 he flew Yak-40 as a co-pilot. From 2000 to 2008 he was trained and simultaneously flew as a Tu-154 co-pilot. Only in 2006 he became Captain of Yak-40 and in 2008 Captain of Tu-154, but being a Captain he was still flying as a co-pilot. Therefore the behavioral skills of the PIC were not really formed. The assistant pilot role decreases the level of responsibility for the flight and does not form the decision-making skills. Overtime keeping of the PIC-to-be playing secondary parts harms the formation of vital personality traits in a professional way.

On the basis of the assessment the expert group came to the following conclusions:

- A long time of the PIC working as a co-pilot and acting as a co-pilot while being a PIC was not favourable for the formation and consolidation of stable leader qualities. The formation of such qualities as leadership, independent decision-making, responsibility, vigour, supervision style etc. must be completed in the college and maintained during the whole flying career. Psychological skills of decision-making in emergency situations can be successfully trained in cockpit simulators.
- For the last 25 minutes of the accident flight (from the moment the crew were informed on the weather at the destination airport) due to the changing actual situation on board the PIC was suffering increasing psychological pressure which was internally reflected in the clash of motives – either to land by any means (disregarding the flight safety) or to proceed to an alternate airdrome.
- As the emergency situation emerged and was developing, due to ambiguity and changing actual flight conditions as well as his conformity, the PIC experienced a gradual increase in psycho-emotional stress accompanied with narrowed attention, fragmentation and deformation of perception of the actual situation, which finally affected the consequences of the flight.
- Indifference of the Commander-in-Chief of the Polish Air Forces to solving the emerging extremely hazardous situation influenced the PIC's decision to descent below the decision height without establishing contact with ground references.

#### **1.16.11. Findings of the Medical Psychological Expertise of the Crew Actions Conducted by the State Research Institute of Military Medicine of the Russian Ministry of Defense**

The following issues were introduced for consideration of the expert group of doctors and Candidates of Medical Sciences and Psychology, aviation psychologists and pilots:

1. What peculiarities can be displayed in the behaviour of the PIC during an approach in the weather conditions below minima considering the PIC had breaks in flights in the conditions of the established weather minima of over 5 months?
2. What peculiarities can be displayed in the behaviour of the PIC during an approach in the weather conditions below his minima when operating the aircraft in the control wheel steering mode provided that during all his flying experience as a PIC of Tu-154 since July 2008 he had conducted only 6 flights with CWS approaches all of them in simple meteorological conditions?

3. What effect on the PIC (and the crew as a whole) can be produced by the presence of a high-ranked aviation official in the cockpit during the approach in weather conditions below the PIC's minima?
4. What effect on the PIC's psychological state was produced by the combination of the abovementioned factors?

On getting acquainted with the pertinent materials the expert group of the State Research Institute of Military Medicine of the Ministry of Defense, Russian Federation, on the basis of the scientific data available at the institute obtained in the course of researches, gave the following answers to the set questions (complete answers are given below excluding personal information):

1. A characteristic feature of the PIC's actions during the approach in the weather conditions below his minima is distraction from monitoring the instruments in order to find the outside references and the runway. Researches reveal that in such conditions a pilot experiences a specific psychological condition of expectation of leaving the clouds which leads to inadvertent (not always conscious) distractions of his attention from the instruments and to unconscious transfer of sight into the space outside the cockpit.

If flights in complicated meteorological conditions are regular, skills of alternating monitoring are formed which allows distracting from monitoring the instruments to find the runway for not longer than 0,5-0,8 seconds. In case the level of training is not sufficient or there have been breaks in flights for over two months the mentioned skills get weaker, which leads to distribution of attention between the instrument indications and search of the runway and therefore increases the probability of partial or even complete spatial disorientation by two or three times.

In the case under consideration, as the break in the PIC's flights was over 5 months, it can be concluded that his uncertainty in successful landing led to the increase of psychological stress, abnormal coordination of movements in aircraft controlling, abrupt focus of attention to separate flight parameters to the prejudice of complete image of flight.

Experiments examining the effect of breaks in flight on the quality of crew actions revealed a regular increase in the number of incorrect actions especially on the glide path in clouds that lead to deviations from the target course and glide path and to late go-around decision.

2. The main psychological trait of the PIC's behaviour during the approach in weather conditions below his minima is lack of self-confidence which finally leads to explicit psycho-emotional stress reflected in the attention focus disturbances, non-coordinated control actions, narrowed periphery vision, concentration on separate secondary parameters that increase the discrepity of monitoring main instruments (vertical speed indicator, altimeter, etc.) The absence

of experience in manual aircraft control adds to the uncertainty in actions. In the accident flight it was confirmed by the PIC's report that landing in the actual conditions was unsafe and he expected proceeding to alternate airdrome. In this case the psycho-emotional stress was complicated by the emerging psychological state of internal personality conflict. It is confirmed by the inconsistency in the PIC's words and actions. Thus, after explicitly confirming the controller's instruction to continue approach until the decision altitude of 100 m by saying "Yes, sir!" he continued further descent. After the co-pilot reported "going around" at the height of about 60 m the PIC continued descent. At the decision altitude of 100 m he did not make the decision either to go around or to land.

Internal personality conflict is a clash of opposite incompatible motives in the PIC's mind. In the accident flight on the one hand there was a motive to go around. The PIC recognized the complicated and dangerous nature of the situation, his own lack of training to continue flight in complicated meteorological conditions below minima he was authorized for. On the other hand there was a motive to complete the tasks and wishes of the Main Passenger. These wishes were not explicitly pronounced but there was evidence that the crew were expecting possible negative reaction in case they did not land at Smolensk "Severny" Airdrome. The expectation of punishment in case of proceeding to alternate airdrome formed the dominant idea of landing by any means and drove them to take unjustified risks. Besides, in 2008 there was an example of strict measures applied to a PIC who refused due to safety reasons to land in Tbilisi (the PIC of the accident flight was a co-pilot in the flight in question).

3. The experience in investigation of air incident involving the presence of chiefs on board reveal that it often led to negative emotional state.

In the accident flight the Commander-in-Chief of the Polish Air Forces was aware of the weather conditions but did not require that the crew should proceed to an alternate airdrome. He kept himself aloof from the emergency situation, by this confirming the motive of completing the task of mandatory landing at the destination airdrome.

4. The PIC's psychological status was affected by a number of factors (professional, psychological, social, personal, etc.):

a) decrease in horizontal and vertical visibility due to surface fog which significantly complicated the flight;

b) lack of professional skills on the part of the PIC to conduct lettered flights in complicated weather conditions;

c) negative psychological climate induced by the presence of a high-ranked aviation official in the cockpit;

d) lack of experience in landings in the weather minima and in manual steering mode of Tu-154M;

e) fear of punishment on the part of the senior officers in case of failure to land at the destination airdrome and proceeding to alternate airdrome.

The contributing factors to the accident were the navigator's callouts of the radio altitude instead of the appropriate barocorrected ones.

All these factors, separately taken can have a negative effect on the PIC's professional activity and in combination could lead to tragedy, which happened as a result.

#### **1.16.12. Results of the Experiment on the Flight Simulator**

The objectives of the simulator experiment were:

- Assessment of the possibility of go around in automatic mode without ground based instrument landing system.
- Assessment of the go around characteristics in the automatic mode with the coupled ICAO Cat II instrument landing system.
- Assessment of the Tu-154M flight parameters in the longitudinal channel when going around from different altitudes (100m, 60m, 40m, 20m).

The experiment was conducted at Aeroflot Flight Personnel Training Center on the Tu-154M Full Flight Simulator.

The experiment was conducted at the Aeroflot Training Center on a Tu-154M full flight simulator. The experiment reconstructed the initial flight conditions of the Tu-154M tail number 101 during the approach at Smolensk "Severny" Airdrome: simulated visibility 30x350 m, aircraft weight ~78000 kg, fuel weight 11 tons, center of gravity 24.2% MAC, Flaps 36, landing gears down, autopilot engaged in pitch and roll channels, autothrottle engaged.

The approach simulation was conducted to a runway of Sheremetyevo airport, course 66° magnetic. A member of the investigation team, Hero of Russia, Deputy Director and Director of Flight Research Center of the State Research Institute for Civil Aviation, honoured test pilot of the Russian Federation was conducting the experiment as the PIC.

Based on the findings of the experiment the following conclusions were drawn:

- The simulation experiment confirmed that during an approach without the ILS signals, without engaging the APPROACH and GLIDE SLOPE modes it is not possible to go around in automatic mode (by pressing GO-AROUND button).
- The simulation experiment confirmed that when going around in automatic mode from the height of 30 m provided the glide slope descent was done in autoflight with

engaged APPROACH and GLIDE SLOPE modes the aircraft provides safe flight profile while going around with a loss of height of about 10 m.

- The experiment confirmed that during approaches in conditions similar to the flight conditions of the Tu-154M tail number 101 on 10.04.2010 at Smolensk with a similar flight profile with vertical speed of descent of 7-8 m/sec and following go-arounds, in compliance with the SOP recommended by the Tu-154M FCOM the loss of altitude is 20-25 m. In the accident flight the aircraft characteristics guaranteed safe go around without exceeding the operational limitations as to acceleration and angle of attack from the height of 40 m (without taking into consideration of the possible obstacles and terrain along the flight path).
- The attempt to go around from the height of 20 m after descending with the vertical speed of 7-8 m/sec within the framework of the simulator experiment led to CFIT.

#### **1.16.13. Findings of the Instrument Examination**

Upon the task of the investigation team, on the basis of the Technical Task and Working Program agreed upon with the Accredited Representative of the Republic of Poland, with participation of the representatives of equipment manufacturers and aviation experts from the Republic of Poland, the Federal State Enterprise “13<sup>th</sup> State Research Institute of the Russian Ministry of Defense examined the following items found at the accident site:

- Radio compass ARK-15M: receivers MSN E9905, И349, control panel MSN E9905;
- Radiomagnetic indicators RMI-2B (MSN 480638, the indicator of the second RMI-2B was found without the MSN);
- Height indicators A-034-4 MSN 71941, MSN 71948 (part of the radio altimeter set);
- Pressure altimeter VM-15PB MSN 1188008;
- Parts of the SVS-PN-15 set: pressure altitude indicator UVO-15M1B MSN1196652, indicator scale of one of the main electronic pressure altimeters VBE-SVS (no MSN), БСКА-Э unit MSN 1190100946.

According to the technical task, the objective of the examination was to examine the equipment found at the accident site in order to get the following information:

- Evidence of equipment failures;
- Determination of the pressure values set at the VM-15PB, UVO-15M1B and VBE-SVS altimeters;
- Determination if NDB frequencies of Smolensk "Severny" airdrome were set at the control panel and radio compass receivers;

- Determination of the indications on the radiomagnetic indicators RMI-2B (radiostation bearing, heading) and receivers of the radio compass;
- Determination of the decision height values set at the height indicators A-034-4 of the radio altimeter/

The examinations revealed the following:

1. Elements of the altimeter VM-15PB № 1188008 do not show any evidence of defects that could have led to the instrument failure in the accident flight. At the time of the impact the altimeter elements retained the set barometric pressure of about 745 mm of mercury.

2. Elements of the altitude indicator UVO-15M1B № 1196652 do not show any evidence of defects that could have led to the instrument failure in the accident flight. At the time of the impact the altitude indicator elements retained the set barometric pressure of about 745 mm of mercury.

3. No defects were detected during the investigation of the ARK-15M control panel MSN E9905, the receiver of the ARK-15M MSN E9905, the receiver of the ARK-15M MSN И549, radiomagnetic indicator RMI-2B MSN 480638, part of radiomagnetic indicator RMI-2B without MSN, height indicator A-034-4 №1, height indicator A-034-4 №2, transceiver of the radio altimeter ПП-5M1Д1 MSN № 72041, transceiver of the radio altimeter ПП-5M1Д1 MSN № 72045.

5. The examination of the ARK-15M control panel in order to determine the set frequencies revealed that the HY «I» contact group position (left) of the channel corresponded to 630 kHz. The HY «II» contact group position (right) of the channel corresponded to 306,5 kHz.

6. At the time of the destruction the mode switch on the ARK-15M control panel was in the COMPASS position.

7. The destruction of the glower of the ARK-15M control panel lights is typical for deenergized conditions.

8. It was not possible to determine the position of the bearing needles of the ARK-15M receivers MSN E9905 and MSN И549 at the time the power was lost due to great inertia of the kinematic system of the goniometer unit.

At the time the ARK-15M receivers MSN E9905 and MSN И549 were destroyed the bearing needles positions were about  $165^{\circ}$  and about  $140^{\circ}$  respectively.

9. The indications of the radiomagnetic indicator RMI-2B MSN 480638 at the time of destruction:

position «1» of needle (1) corresponding to BEARING1  $\approx 162^{\circ}$ ;

position «2» of needle (2) corresponding to BEARING2  $\approx 120^{\circ}$ ;



magnetic course  $\approx 165^0$ .

10. It is not possible to determine the indications of the radiomagnetic indicator RMI-2B that was found without the MSN.

11. Indications of the decision height bugs A-034-4:

A-034-4 №1 – not determined;

A-034-4 №2  $\approx 60$ -65 meters.

12 The examined indicator is part of the VBE-SVS № 0390003. On the basis of the record in the passport of the VBE-SVS № 0390003, the instrument was fitted on the side of the right pilot's seat.

13 The mechanical parts of the rack gears «H3» и «P3» as well as the «ft/m» button do not show any evidence of defects before the crash. Elements of the «P3» rack gear electrical network are serviceable.

14. The П2 indicator board with the liquid-crystal indicator was destroyed due to external mechanical effect and unserviceable. There is no informative evidence that would allow determining the indications of the relative pressure altitude and selected QFE.

#### **1.16.14. Estimation of the Maximum Landing Weight**

The flight operations subcommission of the investigation team estimated the maximum landing weight in accordance with the Tu-154M FCOM (Para 3.1.6 (1) and nomogram at figure 7.7.5) for the actual approach conditions at Smolensk "Severny" airdrome on April 10, 2010: airdrome elevation about 260 m, runway length 2500 m, runway slope 0.16% down, outside air temperature  $+2^{\circ}$ , tailwind about 2 m/sec, landing with Flaps  $36^{\circ}$ . On the basis of the conducted calculations the maximum landing weight for these conditions was about 74 tons.

#### **1.16.15. Basis for Establishing Weather Minima for Smolensk "Severny" Airdrome**

The calculation of the weather minima for approaches using each approach system available at Smolensk "Severny" Airdrome was conducted in accordance with the Uniform Methods for Establishing Weather Minima for Takeoffs and Landings introduced by joint Order№ 270/ДБ-123 of the Russian Ministry of Defense and Ministry of Transportation of December 15, 1994 (hereinafter referred to as Methods).

In accordance with Para 2.1 of the Methods, airdrome minima for instrument landings shall be established for each airdrome landing systems for a certain runway direction and for each aircraft category.

In accordance with Table 2 of the Methods Tu-154 is classified as belonging to Category D aircraft.

On the basis of Para 2.1 of the Methods the landing radar + 2NDB approach system is established at airdromes equipped with radar landing systems and two NDBs. At Smolensk "Severny" Airdrome the radar+2NDB landing system for course 259° M is represented by RSP-6m2 radar landing system, PAR-10 LMM and PAR-10 LOM.

The establishing of decision height as an airdrome minima parameter is based on integrated examination of the airdrome characteristics and its navigation aids. The crucial criterion for Smolensk "Severny" airdrome is the obstacle clearance altitude. According to the obstacle data for Smolensk "Severny" airdrome, the critical stage is the final approach. The minimum safe altitude for the final approach is 72 m. This value allows establishing, in accordance with Table 4 of the Methods, the minimum decision altitude for the landing radar+2NDB system of 80 m.

The estimation of visibility as an airdrome minima parameter is based on the integrated analysis of factors determining the required visual contact with ground references and does not depend on the technical characteristics of the used radar landing system. These factors are:

- Airdrome lighting equipment:
  - a. Extension of the approach lights;
  - b. Position of approach lights;
- Established decision altitude.

The lighting equipment at Smolensk "Severny" Airdrome, course 259° M is set in accordance with SSP-1 pattern in complete form. The approach lights system is not shortened, extending for 900 m. The approach lights have central lights along the extended runway centerline. Thus the pattern and composition of lighting equipment do not affect the estimation of the minima parameters for Smolensk "Severny" Airdrome.

As the presence and location of the lighting equipment do not affect the estimation of airdrome minima, the visibility for the radar+2NDB landing system course 259° m for Category D aircraft is estimated on the basis of the minimum decision altitude of 80 m. Therefore, in accordance with Table 4 of the Methods, the visibility as an airdrome minima parameter for the landing radar+2NDB approaches with course 259° M for Category D aircraft can be established to be 1000 m.

Thus, the airdrome minima for Smolensk "Severny" airdrome landing radar+2NDB landing system with course 259° M for Category D aircraft can be established to be 80x1000 m. In compliance with Order of the Commander of Military Transport Aviation and of State

Registration and Airdrome Operation Certificate №86, Smolensk "Severny" Airdrome was authorized to accept aircraft with the landing minima of 100x1000 m.

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

### **1.17.1. Event Concerning Landing in Azerbaijan in 2008**

The circumstances of this event are related mainly on the basis of the Decision on the Refusal to Institute Criminal Case of October 1, 2010 executed by the military garrison deputy prosecutor of Vrotslav on the basis of the investigation of the non-compliance of the Tu-154 PIC with the order of a higher officer in the presence of military persons. The investigation was instituted on the basis of the appeal of the Seim member of the Republic of Poland concerning the non-compliance with the orders of the President of the Republic of Poland and the deputy Commander-in-Chief of the Polish Air Forces.

According to the provided information, on August 12, 2008 the aircraft of the President of the Republic of Poland (apart from the President on board were the Presidents of Lithuania and Ukraine as well as the Prime-Ministers of Latvia and Estonia) was performing a flight along the route Warsaw - Tallinn – Warsaw - Simpheropol - Gyanda (Azerbaijan). The PIC and the co-pilot who later conducted the accident flight on April 10, 2010 on the Tu-154M tail number 101, were included in the crew for the flight of August 12, 2008 as the co-pilot and navigator respectively. During the stay in Simpheropol the PIC of the TU-154 was officially informed via the head of the National Security Board that the President of the Republic of Poland wants to land in Tbilisi. Analyzing the possibilities of following this task the PIC of the Tu-154 concluded that due safety would not be provided in such flight, among other reasons due to the fact that they had no actual aeronautical or other information to land at a new destination airdrome of Tbilisi and for the flight in the Georgian airspace.

Further, in the course of the flight the President of the Republic of Poland who is also Commander-in-Chief of the Polish Armed Forces entered the cockpit. The President repeated his order to fly to Tbilisi. Further, the same order in written form was given by the deputy Commander-in-Chief of the Polish Air Forces. Despite that, the PIC of the Tu-154 landed at the initially planned destination airdrome at Gyandja, and the high-ranked officials had to get to Tbilisi by motor transport.

On the basis of the prosecutor inquiry, the actions of the PIC of the Tu-154 aircraft were acknowledged to be correct and consistent with the current regulations.

This event had a serious response. According to the available information the PIC who took that decision was later never included in the crews conducting flights with the President on board.

### 1.17.2. Witnesses' Interviews

This section contains a brief summary of the accident witnesses' interviews. As the investigation team has all objective information on the aircraft movement trajectory before and after the impact on the obstacles (trees) a number of witnesses were determined who gave the most precise descriptions. The main aim of the analysis of these interviews was an attempt to assess the actual weather conditions at the time of the accident.

Considering the abovementioned criterion this section contains interviews of four persons being in different places with reference to the flight path.

#### Witness №1 (at the middle marker)

According to his explanations, the witness was outside near the object, right on the approach course. Interview extract<sup>26</sup>: “*at that time the fog density in my opinion has increased, visibility was up to 50 m horizontally and not more than 10-15 m vertically.* I heard the engine humming, about 20-30 m left to the landing course the aircraft emerged from the fog at a height of about 10 m, I saw the extended landing gears and aircraft wings till the fuselage windows, the aircraft was in horizontal position.”

#### Witnesses №2 and 3 (were in a car moving from Kutuzov Str. to Gubenko Str., Smolensk)

Witness № 2: "..., turning after the fuel station I heard the increasing aircraft engine noise (*There was dense fog outside and I was surprised by that fact*). After that ahead of the car movement direction appeared a silhouette of an aircraft. It was flying low with a significant left bank and positive pitch (the bank was over 45°). *The aircraft breaking the tops of trees climbed a bit and disappeared in the fog...* I told my wife who was in the car to call the Emergency Service. I can tell you the time by her call information– 10:41.

Witness №3: "On 10.04.2010, driving from Kutuzov Str. to Gubenko Str. and passing the fuel station, I heard the increasing noise of the working aircraft engine. The noise was untypical for the approaching aircraft (very loud) which made me worried and frightened.... *It was very foggy at that time.* ... I tried to dial the Emergency Service number at 10:41.

#### Witness №4 (was at KIA Center Smolensk JSC)

Witness №4: "...I heard an unusually loud engine noise of an approaching aircraft. *I was interested to see that brave guy who dared to land in such fog, so I looked out of the window.* I saw a shape of an aircraft flying low over the trees, its left wing was almost touching the ground

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<sup>26</sup> Orthography and punctuation were corrected in all quotations.

and actually touching the trees. The landing gears were extended and were higher than the aircraft as it was falling upside down with left wing first ".

### **1.17.3. Other Persons of Interest**

#### **Deputy Chief of Military Unit 21350 (aviation base 6955) in Tver**

On April 2, 2010 the Deputy Chief of the Military Unit 21350 (aviation base 6955) in Tver who is also captain-instructor of IL-76 arrived to Smolensk "Severny" Airdrome. According to his explanations, on 1.04.2010 he received a task from the chief of Military Unit 21350 to depart to Military Unit 06755 for the purposes of organizational control and assistance to the head of this Unit (who was not an aviation specialist) with arriving VIP flights on April 7 and 10. Actually this person from April 2 to April 10 was delegated the functions of coordination and control of all airdrome services involved in accepting the arriving flights.

During the flights of 10.04.2010, according to the ATC recorder and his own explanations, this person was at the BSKP from time to time (including the time of the accident) providing general coordination of various services, informing (by phone) of different officials on the actual situations concerning the accepted flights and weather conditions as well as coordination of alternate airdromes. He was not directly involved in the air traffic control.

#### **Head of the Department for Communications and Aids to Navigation of Military Unit 06755**

According to the record on the ATC recorder and his own explanations this person was at the BSKP on 10.04.2010 from 8:00 to 10:50 for the purpose of coordination of the navigation and lighting system support for landing.

He was not directly involved in the air traffic control.

#### **Dispatcher of the Flight Dispatch Office of Military Unit 06755**

This person is part of civil personnel and is not involved directly in the air traffic control. His functional duties include:

- Receiving, filling in and timely transferring the requests for flight and transit flight;
- Monitoring their forwarding and approval in the higher ATC bodies;
- Timely requesting the higher ATC body for clearances for flights (transit flights) and use of air space, forwarding these clearances to the crews with a record in the flight sheet and to the CATC, recording flight task changes in the flight sheet;
- Forwarding to the higher ATC bodies dispatch and arrival decisions and informing the CATC on the received terms for flights or transits;

- Timely informing the higher ATC bodies and the Air Forces and Defense body on landing and departing aircraft and start (end) of flights and their delays;
- Timely informing the CATC on the received prohibitions and short-term restrictions for use of air space and changes in the air situation as well as on the readiness of alternate airdromes to accept aircraft;
- Providing and keeping the flight and transit flight plans.
- Reporting the CATC on aircraft departing for airdrome or using the airdrome as alternate one;
- Informing the interested organizations on departing and arrival of aircraft;
- Filling in flight and transit flight plans in accordance with the received requests and forwarding them for approval;

#### **1.17.4. Preparation of the Airdrome to Accept VIP-Flights on April 7 and 10**

According to the available information, a special commission made a technical flight on 16.03.2010 to Smolensk "Severny" Airdrome. The purpose of the flight was to assess if the airdrome was ready to accept Tu-154 and Tu-134. On the basis of the flight a general conclusion was made that the airdrome was ready to accept the abovementioned aircraft types considering a row of recommendations including appropriate condition of lighting and nav aids with landing course 259° M.

Flight test of the aids to navigation and communications is the most creditable form of parameter control of nav aids and aids to communication in that area of the air space where they are directly used for aircraft control.

A special flight test of the aids to navigation and communication was made on March 25, 2010 by An-12 of the Military Unit 21350, tail number 90702. Two approaches were conducted to check the operation of the navigational, lighting and radio communication means. The flight test resulted in a general conclusion: The parameters and accuracy characteristics of the RSP-6M2<sup>27</sup>, LOM PAR-10, LMM PAR-10, Lighting system "Luch-2MU", and radio stations R-854M4, R-844M2, R-862, Polet-1 comply with the established requirements and are suitable for flight service without restrictions.

On the basis of the flight test as well as other checks, the Chief of Military Unit 06755 on April 5, 2010 approved Technical Assessment of Smolensk "Severny" Airdrome for VIP flights. General conclusion: the airdrome is I Class, ready to accept VIP flights with the established

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<sup>27</sup> The results of the RSP-6M2 test flight conducted by the investigation team are shown in Section 0.

weather minima. The table of weather minima for landing course 259° M and Categories B and D of aircraft (Yak-40 and Tu-154) assumes the minima for landing radar+2NDB approach of 100x1000 meters.

#### **1.17.5. Findings of the Ballistic and Pyrotechnic Expertise**

The investigation team was provided the copies of conclusions of judicial expertise (ballistic and pyrotechnical) for criminal case №201/355051-10 in the letter from the Deputy Head of the second administration for investigation of VIP cases on crime against personal and common safety of the Main Investigation Administration of the Inquest Committee at the Main Prosecutor's Office of the Russian Federation №201/355051-10 of 14.05.2010.

Expert conclusions №897 of 13.04.2010 and №3451 of 23.04.2010 on the pyrotechnical expertise contain conclusions that no explosives (trotyl, cyclonite or octogen) were found in the wash-offs of the Tu-154M 101 aircraft parts.

The findings of the ballistic expertise confirm the presence of weapon (several hand guns) and ammunition (cartridges). It was impossible to identify the date of last shots made from those guns.

#### **1.17.6. Possibility of Abnormal Standard Pressure Setting on the Pressure Altimeter**

In the course of descent on final at 10:40:12 the MSRP-64 flight recording system started recording an on-signal evidencing the setting of standard pressure of 760 mm mercury on the PIC's main pressure electronic altimeter. The TAWS data readout revealed that this change actually took place. Upon the task of the investigation team the pressure altimeter designer and manufacturer, Aeropribor-Voskhod Ltd. conducted an analysis of the probability of abnormal (no input of the crew) setting of the standard pressure on the altimeter.

It was revealed that such situation is only possible in case the standard pressure input optocoupler failed. The probability of this failure is about  $1 \cdot 10^{-7}$  per hour, which is highly improbable. Within the entire service time of this altimeter type no in-flight failures of this type were noted.

#### **1.17.7. Applied Documentation**

On the basis of the provisions (GEN 1.2-1 Para 1.1, 1.2, 1.3; GEN 1.2-9 Para 3.9, 3.10) of the Russian AIP, and in compliance with the flight permission request (Letter PdS 10-14-2010 of March 22, 2010) submitted by the Embassy of the Republic of Poland in the Russian Federation to the Russian Ministry of Foreign Affairs of the Russian Federation, Flight PLF 101 was an international non-schedule (single) flight carrying passengers by a state aviation aircraft



of the Republic of Poland to Smolensk "Severny" airdrome that was not open for international flights. The flight was conducted on the basis of Permission № 176 CD/10 of the Russian Ministry of Foreign Affairs of April 9, 2010.

The possibility of conducting a non scheduled (single) flight on a state aviation aircraft of a foreign State to an airdrome of the Russian Federation not open for international flights is explicitly stated in the abovementioned AIP paragraphs. Due to the mentioned status of Flight PLF 101, provisions of the Russian AIP in its pertinent part are applicable to its conduct and support in compliance with GEN 1.6-1 Para 2.1.

According to Para 1 of the Federal Aviation Rules of Conducting State Aviation Flights: "The Federal Aviation Rules of Conducting State Aviation Flight (hereinafter referred to as the Rules) have been developed in compliance with the current air legislation of the Russian Federation and regulations governing the activities of the federal executive bodies and organizations that have subdivisions of state aviation, and establish the order of flight operations of the state aviation of the Russian Federation (hereinafter referred to as state aviation)». These Rules and consequently other documents based on the Rules, cannot be applicable to Flight PLF 101, as it was not a flight conducted by a subdivision of the state aviation of the Russian Federation or on an aircraft of the state aviation of the Russian Federation.

Analyzing the accident circumstances and causes the investigation team also considered the fact that a number of documents stipulating the training of aviation personnel and arrangement of VIP flights both in the Russian Federation and in the Republic of Poland are classified documents of limited access. As this Report in compliance with ICAO Annex 13 will be published in open data sources the names of these documents and quotations are not provided in this Report. The relative sections of the Final Report render extracts from the applied provisions.

#### **1.17.8. Provisions of the Russian AIP**

In compliance with Para 3.10 GEN 1-2.9 of the Russian AIP, foreign aircraft flying to airdromes not open for international flights should be escorted (led). As was mentioned in Section 1.1. the flight request supplied by the Polish Embassy in the Russian Federation contained a request for a navigator (leaderman). Further the Polish side refused the leaderman services.

## 2. Analysis<sup>28</sup>

On 10.04.2010 the crew of the special air regiment of the Polish Air Forces including the PIC, the co-pilot, the navigator and the flight engineer conducted a non-scheduled international flight PLF 101 Category "A" on Tu-154M tail number 101 carrying passengers from Warsaw (EPWA) to Smolensk "Severny" (XUBS).

Apart from the four flight crew members there were three flight attendants on board as well as 88 passengers and one security officer, 96 persons overall, all of them citizens of the Republic of Poland. Passenger tickets were not issued at the departure airport, the boarding was conducted using boarding passes without specified seat numbers. No information was provided as to the passenger insurance.

The Tu-154M t/n 101, MSN 90A837 was manufactured in June 1990. By the time of the accident the aircraft was in service for 5150 hours and about 140 hours after last overhaul. The last overhaul was done in December 2009 at Aviakor Aviation Plant. On the basis of the accident site examination as well as analysis: of the wreckage plot, wreckage layout, the instrument examination and flight recorders information, the investigation team did not detect any failures of the aircraft systems and engines. Despite the fact that the Polish side did not provide the Certificate of Airworthiness for the aircraft, ***the investigation came to a general conclusion that the accident was not connected with the aircraft technical service or maintenance.***

**Note:** *At the accident site the investigation team found an Airworthiness Certificate for the Tu-154M aircraft tail number 101 that had expired on May 20, 2009 as well as a current Airworthiness Certificate issued for another aircraft (tail number 102) that was under overhaul at the time of the accident.*

*According to the Russian AIP GEN 1.5-2 section 4 Airworthiness Certificate shall be onboard a foreign aircraft carrying out international flight.*

The aircraft was not insured. The crew members did not have insurance policies. In violation of Para 2.2 of Section GEN 1.6 of the Russian AIP the flight was conducted without compulsory insurance or other kinds of securing the responsibility of the owners of the aircraft for damage caused to third parties.

**Note:** *According to the Russian AIP GEN 1.5-2 section 4 Crew members and aircraft Insurance Certificates, Third Party Liability Insurance*

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<sup>28</sup> Information on the organization of that flight is provided in Section 1.1.

*Certificate shall be onboard a foreign aircraft carrying out international flight.*

In accordance with the submitted request for flight, another PIC was planned to operate in the accident flight who flew to Smolensk "Severny" Airdrome on April 7, 2010. According to the information provided by the Polish side, the PIC was replaced on April 2. The cause of the replacement was stated as service necessity. The crew was formed on the same day (April 2).

The analysis conducted by the investigation team revealed a number of shortcomings in the professional training of the crew members and the crew formation. While arranging their own training for Tu-154M aircraft as well as maintaining and upgrading professional skills of crews the top officials of the regiment did not use regular simulator trainings on a Tu-154M simulator.

The PIC had insignificant unsupervised experience in his position (about 530 hours). After commissioning the PIC instead of strengthening his skills of piloting and crew management during the flight preparation and completion, without having an instructor authorization and proper training regularly changed his piloting seat from left as a PIC to right as a co-pilot. Thus, on April 7, 2010 the PIC flew to Smolensk "Severny" Airdrome as a co-pilot.

The co-pilot, navigator and flight engineer had even less experience on this aircraft type (160, 26 and 240 hours respectively). The navigator had a break in flights on Tu-154M from 24.01.2010 to 10.04.2010 (2.5 months). In that time period he was flying on the Yak-40 as a co-pilot.

Besides the PIC who had made three flights to Smolensk "Severny" Airdrome (all of them as a co-pilot) neither of the crew members had flown to that airdrome before.

***Thus the investigation team came to a general conclusion that the crew formation was done without considering the actual professional level of each person and nature of the task.***

All the crew members had valid medical licenses. No deviations from the work and rest schedule were revealed. There are no indications of use of alcohol or other prohibited substances. ***The accident was not connected with the crew medical state or workability.***

There were a number of significant shortcomings in the general organization of the VIP flight. According to the information provided by the Polish side the crew conducted the preflight briefing on their own on 09.04.2010. The top officials did not take any part in the preflight briefing. Records on the briefing, questions under study, applied materials and results of the crew readiness control were not kept.

The crew did not have complete air navigation and other data on Smolensk "Severny" Airdrome when preparing for the flight. The investigation team was provided out-of-date

information on the approach charts at Smolensk "Severny" Airdrome<sup>29</sup>. The NOTAM containing information on the exclusion of some navigation aids from operation was not provided to the crew.

**Note:** *According to the information given by the Commander of the special air regiment concerning the organization of that flight, relative requests were submitted so that the Embassy of Poland in Moscow could contact the Russian side to request providing actual airdrome charts and procedures. Until the departure no information was provided to the regiment by the Embassy.*

The analysis of the air navigation information that the crew had did not reveal its date of issue (the sheets bear no title, number or date). The cover page of the mentioned fax assumes that air navigation information was issued before April 9, 2009. The airdrome data for Category D aircraft (Tu-154M) obtained by the crew stipulated only 2NDB landing system (minima 100x1500)<sup>30</sup> or an instrumental landing system (of RMS type)<sup>31</sup> which has been out of operation since October 2009 and could not have been used by the crew anyway due to the absence of relative equipment on board. The crew did not have airdrome weather minima data for other approach systems (landing radar+2NDB, landing radar) before departure<sup>32</sup>.

No technical flights to check the facilities of Smolensk "Severny" Airdrome to receive lettered flights on aircraft of the mentioned types considering the actual professional level and formation of the crew were conducted by the Polish side.

Thus, as the flight was prepared and departure decision was being taken, the executives in charge of the flight arrangement and the PIC violated the provisions of the aviation regulations of the Republic of Poland in term of the mandatory receiving by the crew of all pertinent data for the destination airdrome, airspace to be used as well as the ground equipment and navigation systems along the flight route<sup>33</sup>.

In accordance with the changed flight plan the departure from Warsaw to Smolensk was planned for 09:00 (initially it had been arranged for 08:30). Minsk-2 (UMMS) and Vitebsk (UMII) were selected as alternate airdromes. It should be noted that at the time of the accident Vitebsk airdrome was only open from Monday to Friday (excluding also state holidays of the

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<sup>29</sup> The Polish side provided the investigation team with a facsimile copy of a letter dated 9.04.2009 from the Embassy of the Republic of Poland in Moscow to the special air regiment that contained this information .

<sup>30</sup> Weather minima for Tu-154M for 2NDB approach established by the FCOM is 120 x 1800.

<sup>31</sup> Translators note: This system is not compatible with standard ILS system.

<sup>32</sup> For category B aircraft (Yak-40) this document stipulated only the instrument landing system (RMS type). The weather minima for landing radar, 2NDB or landing radar+2NDB approaches were missing.

<sup>33</sup> This regulation is mentioned in the Decision on the Refusal to Institute Criminal Case (Section 1.17.1).

Republic of Belorussia) in daytime (from 10:30 to 17:30). This was reflected in NOTAM A1643 valid from March 23 to October 30, 2010. Thus, on Saturday April 10 Vitebsk Airdrome was not open so the crew could not have used it as an alternate airdrome. Evidently the crew did not have this information when preparing for the flight.

**Note:** *According to the Commander of the special air regiment the choice of alternate airdromes was not coordinated with the visit organizers (President's Chancellery and Security Bureau). The representatives of the abovementioned bodies did not introduce their suggestions. Besides, the bodies and agencies in charge for VIP flights have never given any recommendations to the commanders of the special air regiment concerning the choice of alternate airdromes.*

In the course of the preflight briefing, at 08:10, the navigator received and signed for the weather information that included a sheet of TAF weather forecasts and METAR actual weather for the departure airdrome of Warsaw, alternate airdromes of Vitebsk and Minsk as well as for the Sheremetyevo airdrome. ***The forecast and actual weather for the destination airport, Smolensk "Severny", was not included in the received weather information. The forecast for Vitebsk had expired.***

**Note:** *According to the information given by the Commander of the special air regiment and the crew of the Yak-40 aircraft, before the flight the crews received weather briefing from the meteorologist on duty of the air squadron. The analysis of atmospheric conditions made by that expert for Smolensk "Severny" Airdrome area for April 9 did not contain any information on weather conditions that could impede the conduct of the flight.*

Request of the airdrome readiness at the time of departure and request of the clearance for arrival of the Yak-40 and Tu-154M on 10.04.2010 were not sent, information on the airdrome readiness and clearance for arrivals were not issued from Smolensk "Severny" Airdrome.

**Note:** *At 9:15 a Yak-40 of the Republic of Poland following the same route landed at Smolensk "Severny" Airdrome. That aircraft departed from Warsaw at 7:28. The analysis of communications recorded by the ATC recorder revealed that the ATC group of the Smolensk "Severny" airdrome did not have any information that this aircraft had departed and was proceeding to Smolensk "Severny" Airdrome until 8:50. The Yak-40 first contacted the Controller of Smolensk*

*"Severny" Airdrome at 8:53.*

The takeoff of the Tu-154M from Warsaw was conducted at 09:27 with a delay of 27 minutes with regard to the flight plan. The takeoff weight was about 85800 kg, the center of gravity was 25.3 % MAC, which was within the FCOM limitations.

There was no navigator-leaderman on board the aircraft. According to the available information, after submitting the initial flight permission request the Polish side refused the leaderman services explaining that the crew had sufficient mastery of Russian.

At 9:26 due to the worsening weather conditions at Smolensk "Severny" Airdrome an irregular weather observation was made: visibility 1000 m, mist, smokes, clouds 10 points, stratus at 100 m. Thus by the time of the Tu-154 departure from Warsaw the weather at the destination airdrome was already below the aircraft and PIC's minima for landing radar+2NDB approach (100x1200)<sup>34</sup>. At 09:40, after further worsening of the weather conditions the meteorologist made an additional weather measurement and noted the beginning of a hazardous weather condition – fog: visibility 800 m, clouds 10 points stratus at 80 m.

**Note:** *It should be also noted that the investigation team revealed incompliance of the PIC's weather minima (60x800). Among the provided documents there was a record of confirmation of the weather minima made during an approach in Brussels (Belgium) on 11.02.2010. The check of the actual weather conditions revealed that on 11.02.2010 at the time of the recorded approach the weather conditions: cloud base 900 m, visibility over 10 km.*

After the takeoff, at about 550 m, the autopilot was engaged in roll and pitch channels. At the transition altitude the crew set standard pressure on the altimeters (760 mm mercury) which is confirmed by the relative on/off-signal recording on the FDR.

The Tu-154M flight was passing the territory of three states: Poland, Byelorussia and Russia at FL 330 (about 10000 m). The flight path is shown on the figure below with the cockpit communications.

The FMS data analysis (Section 1.16.5) revealed that its memory contained actual lateral flight plan for route: EPWA – a row of waypoints from RW29.BAMS1G Departure – ASLUX – TOXAR – RUDKA – GOVIK – MNS (Minsk-2 VOR/DME) – BERIS – SODKO – ASKIL – DRL1 – 10XUB – DRL – XUBS. The last four waypoints were user-defined. The coordinate analysis revealed that DRL1 has coordinates of the former outer marker for approach

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<sup>34</sup> This is the lowest aircraft minima for the landing systems available at the airdrome.

with course 79° at Smolensk "Severny" Airdrome (by the day of the accident flight out of operation). 10XUB is a point 10 nm (about 18.5 km, azimuth 79°M) from the ARP in the back track direction (259°). DRL is LOM-259, XUBS is ARP. The coordinates of both outer markers and ARP were obviously taken from the air navigation charts that the crew had (in the SK-42 coordinate system, without conversion to WGS-84).

For the actual geographical position of Smolensk "Severny" Airdrome the west-to-east inaccuracy does not exceed 150 m, south-to-north inaccuracy is neglectable and the elevation inaccuracy is about 10 m. The investigation team believes that considering the actual chain of events these inaccuracies did not contribute to the accident. However, such inaccuracy in the usage of aeronautical information can depict drawbacks in the navigation support of the flight.

There was no active flight plan for vertical navigation in the FMS.





The radio communication with the Minsk Control and Moscow Control was maintained by the navigator in English.

The CVR record starts at 10:02:48. The analysis of the CVR information revealed that most probably the cockpit door was open during the entire descent and approach. From time to time there were unauthorized persons in the cockpit. The assessment of possible effect of this fact is given below.

At 10:09:22 the crew reported estimated time of descent. The Minsk Control officer cleared them for descent to 3900 m. At 10:09:50 the engines were set to idle and the crew initiated descent.

According to the FCOM of Tu-154M Para 4.4.1. (11) "Crew Actions in Cruise Flight", on the PIC's command the crew must conduct the landing briefing 10-15 minutes before the descent. The briefing was not heard in the last 7 minutes 30 seconds of the FDR record of cruise flight. It was not possible to find out if the crew discussed the approach system, the approach mode, the landing weight, the CRM (PF – PNF duties), the procedures and language of the radio communication, the go-around procedures (going to alternate airdrome) or the actions at decision altitude considering the weather conditions.

According to the conducted estimations, the maximum landing weight for the actual conditions at Smolensk "Severny" airdrome for landing with course 259° was ~74 tons. The actual flight weight at the time of the accident, according to the estimations, was about 78600 kg, i.e. it exceeded the maximum landing weight for the actual conditions. This confirms the drawbacks in the landing briefing of the crew. The landing center of gravity was 24.2 % MAC and did not exceed the limitations.

The final stage of the landing briefing has to be the Before Descent checklist. Actually, the checklist was read out by the navigator after the descent had been initiated.

**Note:** *The investigation revealed that the Operator did not have SOP for the 4-member crew of Tu-154M (further referred to as the SOP). According to the explanations of the Polish side, the flights are conducted by using directly the FCOM of the Tu-154 aircraft. It should be noted that the FCOM of Tu-154 was developed for the three-member crews and the navigator's duties and CRM are not determined there.*

The replies to the check list items assume that the crew did not consider the approach pattern (Navigator: "Procedure", PIC: "Not known yet"), although they set the landing course of



259°, the PIC decided to set the radio altimeter decision height bug at 100 m, the landing fuel was 11 tons.

**Note:**

*In accordance with the FCOM and SOP the crew must do the following procedures when setting the decision height bug. In cruise flight before the start of descent the PIC sets the decision height bug to 60 m or the actual decision height if its lower than 60 m, and the co-pilot sets his bug to the circle height. When they reach the circle height and confirm the pressure and radio altimeters readings considering the terrain, they should set the bug of the second radio altimeter to decision height or to 60 m if decision height is 60 m or higher.*

*The FDR and CVR record analysis concerning the radio altimeter warning activation as well as the findings of the examination of the instruments (Section 1.16.13) found at the accident site assume that at least at the PIC's altimeter bug was set to 60 m.<sup>35</sup>*

From 10:11:34 to 10:11:43 the CVR recorded the following crew conversation:

10:11:34,7	10:11:36,3	F/E	Can I also get pressure and temperature?	Mogę jeszcze ciśnienie i temperaturę?
10:11:36,5	10:11:37,9	Nav	How do I know (illeg)?	Skad mam wiedzieć (niezr.)?
10:11:38,5	10:11:42,7	CP	I don't know. Well, I'll tell you what the temperature is. Coool. <i>(Laughter)</i> .	Nie wiem. Nie, powiedz jaka jest temperatura. Ziiiiimno. <i>(śmiech)</i> .

The mentioned conversation confirms that the crew did not have any weather information on the destination airdrome.

The analysis of the actual weather conditions at Smolensk Severny" Airdrome at 10.04.2010 showed that in the second half of the night, after 04:00, fogs started forming in the areas of Tula, Kaluga and Smolensk Regions. According to the atmosphere sounding at 04:00 there was temperature inversion up to 400-500 m AGL which involved additional accumulation of condensation cells and formation of low-lying stratus clouds, thick mists and fogs in the

<sup>35</sup> The on/off signal as to reaching the height set by a decision height bug is recorded by the FDR from the PIC's radio altimeter (in case it is operable).

surface air layer with relative moisture content of 90-98%. The wind at altitudes was south-easterly 140-160°, and the foggy area was gradually shifting with the air mass from the south-east to the north-west.

By the time of the landing of the Yak-40 aircraft, the weather conditions at Smolensk "Severny" Airdrome started worsening abruptly, the visibility decreased to 1500 m (at 9:00 it was 4 km), mist appeared. Further, the weather was still going worse<sup>36</sup> and at the time of the accident (10:42) it was assessed as: surface wind 110-130°, 2 m/sec, visibility 300-500 m, fog, clouds 10 points stratus, cloud base 40-50 m, temperature +1 - +2°C, QFE 745 mm of mercury. Due to temperature inversion at circle altitude (500 m) the expected wind was maximum in force (about 10 m/sec, 110-130°) which is confirmed by the evidence of the PIC of the IL-76.

Thus, the weather forecast for Smolensk "Severny" Airdrome on 10.04.2010 for 06:00 to 18:00 compiled by the weather forecaster of the air base in Tver at 05:30 and amended at 09:15 did not come true as to the cloud base, visibility and significant weather (fog). At the same time, taking into account that the crew did not receive the weather forecast for the destination airdrome when they were taking the go-decision, but in the course of the flight (as will be shown below) was timely informed by the ATC and the crew of the Polish Yak-40 aircraft that the actual weather was well below the established weather minima, the investigation team made a general conclusion *that the unrealized weather forecast was not among the accident causes. The arrangement of weather observations at Smolensk "Severny" Airdrome allowed informing the crew in due time on the worsening weather conditions.*

After the weather conditions worsened, the various air traffic control bodies (Minsk Control, Moscow Control, Smolensk "Severny", Smolensk "Yuzhny") were maintaining extensive phone communications and communications with use of the by-passing aircraft. As a result, at 10:14:06, when the Tu-154M aircraft was descending and crossing flight level 7500 m, the Minsk Control officer, upon request of Kiev-1 Sector controller of the regional ATC office (Russian responsibility area) informed the crew that there was fog, visibility 400 m at the destination airdrome. The crew confirmed receiving that information, but did not request recommendations as to the alternate airdromes.

The aircraft entered the Russian airspace at about 10:22 near Bayevo (WPT ASKIL of the international air track B102). After contacting Moscow Control, the aircraft was cleared for further descent to 3600 m and instructed to contact Smolensk "Severny" Airdrome Control, callsign "Korsazh".

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<sup>36</sup> As was shown in Section 1.1 the IL-76 aircraft that reached the approach pattern almost at the same time as the Yak-40 made two approaches and proceeded to the alternate airdrome in Moscow due to weather conditions.

The PIC was maintaining radio communication in Russian. The investigation team was not provided any documents that would confirm the level of Russian proficiency of the PIC or other crew members. The assessment of the CVR record shows that the general level of the PIC's Russian could be characterized as satisfactory. At the same time it was not possible to assess the deepness of their understanding of the phraseology mandated by the FAR "Maintaining Radio Communication in the Russian Airspace".

**Note:**

*According to the available information, of all the Tu-154M crew members only the PIC spoke Russian. At the same time at the accident site the investigation team found the FCOM in Polish belonging to LOT Airline. According to the available records, the last change to that FCOM was entered in February 1994. The Tupolev Company as the aircraft manufacturer does not confirm the fact that the FCOM was officially translated into Polish.*

*The Yak-40 aircraft showed a low level of Russian proficiency and, according to the explanations of the ATC and airdrome management, as well as the IL-76 aircraft, which was also confirmed by the radio communication analysis, had significant difficulties with the understanding of instructions, especially during the taxiing after landing.*

Provided there was no information on the landing briefing, considering the standard workload distribution, if the PIC maintains radio communication, than the co-pilot is the PF. However, taking into account the difficulty of approach in the actual weather conditions, low experience of the co-pilot on Tu-154M as well as the selected control mode and the actual actions of the crew during the approach, further analysis is based on the condition that the PIC was the PF.

The crew established contact with the airdrome control at 10:23:30.

The air traffic control at Smolensk "Severnoy" Airdrome on 10.04.2010 was conducted by three ATC specialists: CATC, deputy CATC<sup>37</sup> and landing zone controller. The CATC and landing zone controller were at the BSKP with landing course 259°M, the assistant CATC was at the DSKP. The communication with all of them was at the same frequency 124.0 MHz. The working stations of the CATC and the landing zone controller are next to each other. According to the boundaries of aircraft handovers when approach is conducted using the airdrome

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<sup>37</sup> The analysis of the deputy CATC's duties and the actual communications showed that the deputy CATC told only one phrase, informing that the runway was clear after the crew reported landing configuration.

systems<sup>38</sup> the CATC controls the aircraft from the moment the aircraft enters the approach area and starts turning for the final. The landing zone controller controls air traffic on final until the crew reports: "Runway in sight." The CATC grants clearance after visual contact with the aircraft on final.

The CATC was a local specialist. He was in position of the CATC for the 06755 Military Unit and had constant experience of work at that airdrome. The landing zone controller was assigned to Smolensk "Severny" Airdrome on April 5, 2010. He was performing the duties of the landing zone controller on April 7. He has never worked at Smolensk "Severny" Airdrome before.

The working stations of the CATC and landing zone controller were equipped with the VISP-75T indicator. There were no complaints as to the operability of this equipment at the CATC's working station. As for the landing zone controller's working station, as was shown in Section 1.16.6, the glide path line was drawn with the actual slope angle of about 3°10', i.e. when the aircraft was at the top of the tolerance area (which is 30') for the nominal glide path angle of 2°40' the indication of its blip on the radar was corresponding to the "on the glide path" position.

The mentioned inaccuracy in the glide path line disposition on the screen does not affect the aircraft landing distance and does not create ground for runway overrun or early descent. The change in the glide path angle only changes the estimated vertical speed of descent and flare height. When the aircraft is following a steeper glide path (3°10' instead of 2°40') the estimated vertical speed instead of 3.5-4 m/sec increases to 4-4.5 m/sec (in case the reference flight speeds are maintained) whereas the middle marker should be passed 10 m higher than the established altitude of 70 m.

After establishing radio communication with Smolensk "Severny" Airdrome the crew did not report selected approach system.

**Note:** *According to the Russian AIP, ENR 1.5-2 Section 2.3 Entering Terminal Area Para 2.3.2: "when entering the terminal area the crew shall report :...*

*- the landing system the crew intends to use for approach if there is no ATIS or if it is different from ATIS information"*<sup>39</sup>.

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<sup>38</sup> As shown in the report below, the crew did not use the approach systems available at the airdrome, they did not request the landing radar, but conducted approach using the on board equipment.

<sup>39</sup> ATIS is not present at Smolensk "Severny" airdrome.

The controller clarified the remaining fuel (11 tons), alternate airdromes (Minsk and Vitebsk) and informed the crew twice that it was foggy at Korsazh, visibility 400 m, no conditions for landing.

At the same time the crew of the Tu-154M used the second radio station at 123.45 MHz to contact the crew of the Yak-40 who were at the airdrome. The crew of the Yak-40 emotionally explained (“You know, generally it’s absolute shit here”) that according to their assessment the weather was bad, visibility 400 m, vertical visibility less than 50 m, but they also said: “...we were lucky to land at the last moment. But frankly speaking you could try of course, there are two APS, they’ve made a gate”.

Having received and discussed the abovementioned information, the crew of the Tu-154M decided to make a "trial" approach, the PIC informing the controller at 10:25:01: “Thank you, but if it’s possible we’ll try approach, but if there’s no weather we’ll go around.”

**Note:**

*According to item c) Para 1 Section AD 1.1-1 of Russian AIP: "pilots-in-command of foreign aircraft operating in Russia, shall make a decision on the possibility of taking-off from an aerodrome, and of landing at destination aerodrome on their own, assuming full responsibility for the decision taken".*

*On March 13, 2010 Military Units 21350 and 06755 were instructed (by telegram № 134/3/11/102/2) to adhere to the abovementioned AIP item “for the purposes of high-quality arrangement and support of VIP flights” of aircraft from the Republic of Poland when providing air traffic management services. According to the provided extracts from briefing notes of the ATC group this was included in the list of major objectives and tasks for self-preparation before the flights on April 7 and 10.*

To check the remaining fuel and the possibility to proceed to the alternate airdrome after the "trial" approach, the deputy chief of Military Unit 21350<sup>40</sup>, who was present at the BSKP, contacted the crew at 10:25:11: “1-0-1, after the trial approach will you have enough fuel for alternate airdrome?” The crew replied: “We have enough.” Then as the crew requested at 10:25:22: “Request further descent please” the CATC, considering the provisions of the Russian

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<sup>40</sup> Information about that person is provided in Section 1.17.3.



AIP, Section AD 1.1-1, Para 1 c), replied: "1-0-1, heading 40 degrees<sup>41</sup>, descend 1500". Thus the controller cleared the crew for the "trial" approach.

**Note:** *The text of the abovementioned Decision on the Refusal to Institute Criminal Case (Section 1.17.1) assumes that similar provisions on the rights and responsibilities of the PIC for the final decision to take off, land or terminate the flight exist in the aviation regulations of the Republic of Poland.*

The expert conclusion drawn by a group of ATC specialists of civil and state aviation (Section 1.16.9) reveals that the fact that the crew did not report the selected approach system although they had been informed on the actual weather conditions far below the minima was interpreted by the ATC group personnel in a way that ***the crew intended to make the "trial" approach using the onboard equipment. This is confirmed by the fact that the crew did not request landing radar vectoring.*** This conclusion is confirmed by the radio communication recorded by the ATC recorder. Thus, at 09:20:50, after the landing of the Yak-40 (whose crew did not report their selected approach system either) in a telephone conversation with the Chief of military regiment 21350 (Tver) the assistant chief of the regiment who was present at the BSKP reported: "...Well, they approached all right. I guess they have equipment there, on an aircraft like that... Frankly speaking, I thought they would go around".

Having cleared, in compliance with the Russian AIP, the "trial" approach upon the crew's request in the weather conditions below minima, the ATC group personnel further kept informing the crew on the aircraft position and weather conditions within the capacity of their equipment. In the state aviation of the Russian Federation "trial" approaches in weather conditions below established minima are not allowed.

The PIC's decision was transmitted by the deputy chief of Military Unit 21350 to the aviation dispatcher of Military Unit 06755<sup>42</sup> at 10:25:59: "so he makes a trial approach, on PIC's decision, trial approach to decision height of 100 m, in case of missed approach let them request if Minsk and Vitebsk are ready."

Analyzing the possible motivation of the crew and the PIC in the first place that could influence the decision to make a "trial" approach (instead of going to alternate airdrome) which actually was the beginning of the chain of events, the investigation team marks several issues that probably affected that decision.

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<sup>41</sup> The FMS data analysis revealed that the crew used the CMD HDG mode to proceed with headings 40° and further 79°.

<sup>42</sup> Information about this person is provided in Section 1.17.3

As was mentioned in Section 1.17.1 in August 2008, upon decision of the PIC of that flight and despite the orders of the President of the Republic of Poland and the Deputy Commander-in-Chief of the Polish Air Forces to fly to Tbilisi (Georgia), the aircraft in accordance with the flight plan landed at Gyandja airport (Azerbaijan) due to impossibility (on the Captains's assessment) to provide safety of flight to the new destination airdrome. This case had a wide response, high-ranked officials had to go to Tbilisi by cars. The Captain who took that decision was later never included into crews making flights with the President on board. According to the available information, the PIC and the co-pilot of the accident flight on April 10, 2010 were co-pilot and navigator respectively in that flight. Most probably, after they were informed on the weather conditions below minima the PIC recalled that story, which is confirmed by his phrase at 10:16:48: "I'm not sure, but if we don't land here, he'll give me trouble".

As for the accident flight, having received information on the unfavorable weather from the Minsk and Smolensk controllers as well as the Yak-40 crew, the crew of the Tu-154M aircraft discussed several times and for a long time the worsening weather conditions and the possible further actions among themselves and with the third persons present in the cockpit<sup>43</sup>. The discussion ended with the following conversation:

10:25:55,1	10:25:57,9	F/O	As they see it, visibility about 400m, cloud base 50 m.	Na ich oko jakieś 400 widać, 50 metrów podstawy.
10:25:57,6	10:25:58,3	PIC	How much?	Ile?
10:25:59,0	10:26:02,6	F/O	400 m visibility, 50 m cloud base (illeg.).	400 metrów widać, 50 metrów podstawy (niezr.).
10:26:04,5	10:26:05,8	A	(illeg.).	(niezr.).
10:26:05,2	10:26:06,9	F/O	No, but they managed.	Nie, im się udało.
10:26:07,9	10:26:11,1	F/O	He says also there's fog (illeg.).	Mówi też, że mgła (niezr.).
10:26:11,1	10:26:12,6	A	(illeg.).	(niezr.).

<sup>43</sup> The identification of the voices recorded on the CVR shows that this question was discussed with the Protocol Director.

10:26:17,1	10:26:34,3	PIC	Pan Director, fog has appeared. Now, in the present conditions we cannot land. Let's try to approach but most probably this will not succeed. So please ask (the chief) what we should do.	Panie dyrektorze, wyszła mgła... W tej chwili, w tych warunkach, które są obecnie, nie damy rady usiąść. Spróbujemy podejść, zrobimy jedno zajście, ale prawdopodobnie nic z tego nie będzie. Tak, że proszę zapytać (szefa), co będziemy robili.
10:26:35,6	10:26:36,8	A	Shall we try? <i>{Director Kazana }</i>	Będziemy próbowali? <i>{dyrektor Kazana }</i>
10:26:38,1	10:26:40,2	PIC	We don't have that much fuel to wait for ages.	Paliwa nam tak dużo nie starczy, żeby do skutku.
10:26:43,6	10:26:44,8	A	So we have a problem. <i>{Director Kazana }</i>	No, to mamy problem... <i>{dyrektor Kazana }</i>
10:26:44,8	10:26:47,3	PIC	We can hold for half an hour and proceed for the alternate.	Możemy pół godziny powiesić i odlecieć na zapasowe.
10:26:47,7	10:26:49,0	A	Which alternate? <i>{Director Kazana }</i>	Jakie zapasowe? <i>{dyrektor Kazana }</i>
10:26:48,8	10:26:50,2	PIC	Minsk or Vitebsk.	Mińsk albo Witebsk.
10:26:51,0	10:26:52,7	A	Minsk or Vitebsk... <i>{Director Kazana }</i>	Mińsk albo Witebsk... <i>{dyrektor Kazana }</i>

*Thus, the violation of the "sterile cockpit" principle and presence of too many VIP passengers aboard most probably affected the crew's decision to make a "trial" approach.*

Another factor probably contributing to the taken decision was the aim of the flight – participation in the celebrations in the Katyn Memorial Complex. The flight departure was delayed, and the aircraft that had departed earlier with the mass media group had already landed. Thus, the PIC realized the importance of landing exactly at the destination airdrome.

Considering the fact that the PIC had not performed approaches in complicated weather conditions (corresponding to his weather minima 60x800) for a long time (over 5 months) and after authorization for flights on Tu-154 had made only 6 NDB approaches (all of them in simple meteorological conditions) the ambiguity of the situation connected with the weather conditions growing worse required mobilization of psychological reserves. Most probably from that moment the PIC and the crew were in the state of high emotional stress.

**Примечание:**

*In the course of the investigation, upon request of the commanders of the special air regiment, a member of the investigation team, an honoured test pilot, conducted training for the instructors of the air regiment according to the specially agreed program. The program included, among other things, training of precision and non-precision approaches (including 2NDB) at day and night times, in visual and instrumental flight conditions. Additional training was conducted in accordance with the Flight Training Program for Instructors concerning emergency situations developed by the State Research Institute of Civil Aviation.*

Analyzing the internal communications at the BSKP for that period of time the investigation team comes to the conclusion that the CATC and the chiefs were sure that the aircraft would go to the alternate airdrome. For example, at 10:26:17 the deputy chief of Military Unit 21350: “Allowing them till 100 m only, 100 m no questions.” This assuredness was based on the fact that the weather was not expected to improve in the nearest time while the remaining fuel on board did not allow staying long in the holding pattern.

At 10:27 the crew of the Tu-154M aircraft contacted the pilots of the Yak-40 again and was informed that the layer of clouds near the ground is 400-500 m and also that a Russian aircraft after two unsuccessful approaches left to alternate airdrome (IL-76, 78817).

**Note:**

*It should be mentioned that the PIC of the IL-76 had earlier passes military service at Smolensk and was perfectly aware of the airdrome features as well as the radio and lighting facilities. However, based namely on the weather conditions the PIC took the wise decision to proceed to alternate airdrome.*

At the altitude of about 2000 m at 10:28:45 the crew set the airdrome pressure at the altimeters which was confirmed by the off-signal of setting 1013 hPa at the left pressure altimeter recorded by the FDR. The crew communication and altimeter examination analysis (Section 1.16.13), the accuracy of maintaining the circle altitude (500 m) as well the FMS data analysis reveal that the crew correctly set the QFE to 745 mm mercury (993 hPa) and that the approach was planned to be performed using QFE.

**Note:**

*According to Para 8.17.8a2. c) of the Supplement to Tu-154M FCOM, for aircraft equipped with TAWS, in order to prevent false firing of the system, before setting QFE at the altimeter the crew should have engaged TAWS QFE mode (press QFE). However, in*

*that flight engaging this mode was impossible as Smolensk "Severny" airdrome was not present in the system's database.*

After setting the pressure the crew went through the After Transition to Airdrome Pressure Checklist. The checklist analysis reveals that the crew set up the frequencies of the outer and middle NDBs with markers as well as the PN-5 and PN-6 and autothrottle control panels. The navigator expressed pity that there was no ILS system at the airdrome. Thus, at that flight stage the crew was aware of the difficulties connected with further approach.

**Note:** *According to the cockpit communications transcript the crew set the correct frequencies of the outer and middle NDBs with markers at 310 and 640 kHz respectively. At the same time, the findings of the examination of one of the ARK-15M control panels (the second panel was not found at the accident site) did not confirm that the frequencies were set correctly. It should be also mentioned that the SOP (in respect to information to which NDB each ADF is tuned) was not followed by the crew.*

After the checklist was done the crew reported to the controller that they were maintaining 1500 m but did not report setting QFE. Without receiving the crew report on setting the QFE, the controller at 10:30:15 cleared further descent to 500 m and instructed them to proceed heading 79° to the base turn. The crew confirmed both instructions.

At that flight stage the CVR recorded a phrase told by Director of Protocol: "So far there's no President's decision what to do next". The crew replied that they had been cleared to descend to circle altitude (500 m). Considering the PIC's high level of conformity<sup>44</sup>, only the fact of such issue formulated by the Main Passenger exposed psychological pressure on the PIC and caused a state of ambiguity which was reflected in the clash of motives: either to go to an alternate airdrome or to try and complete the landing. Such situation inevitably leads to increasing of psycho-emotional stress and exhausts the nervous system.

At 10:32:56 while approaching the base turn the PIC took the following decision: "We'll make an approach. In case of failure we'll go around in autoflight mode". In compliance with that decision at 10:34:20 after establishing on the circle altitude of 500 m the crew engaged the autothrottle. By taking this decision the crew demonstrated low knowledge of the aircraft equipment. In fact Tu-154M does allow going around in the autoflight mode. The appropriate procedures are written in Section 8.8.2 (4) (d) of the FCOM. The PIC must make sure that:

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<sup>44</sup> See section 1.16.10 for more details.

- the ROLL and PITCH switches (Panel 46) are on;
- the GLIDE SLOPE light on autopilot control panel is on,

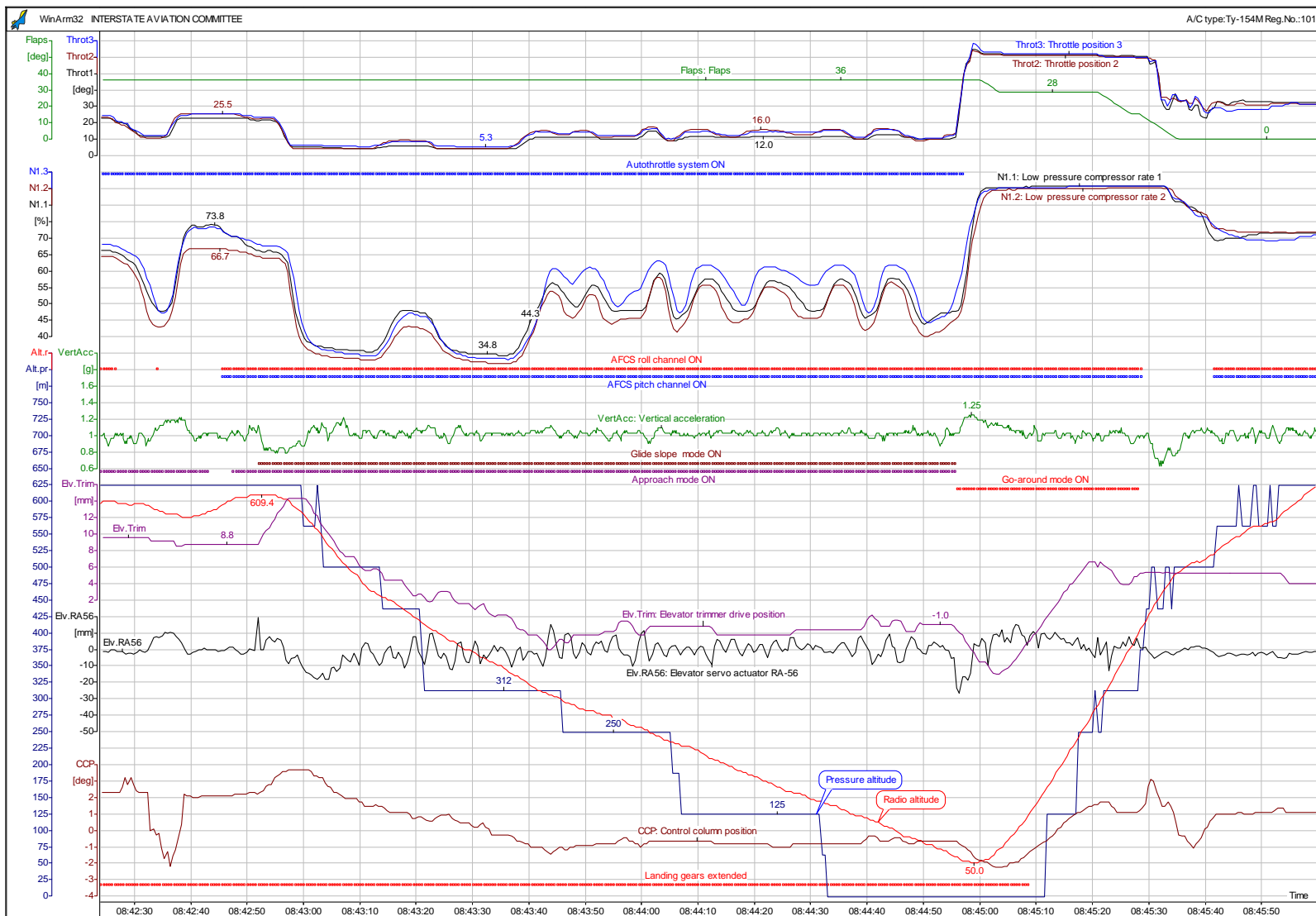
and then press the GO AROUND button. The mentioned procedure assumes that a mandatory condition for arming the autoflight go-around is active Glide slope mode used for autoflight or flight director approach in combination with Approach mode. It was not possible to use this mode when landing at Smolensk "Severny" Airdrome due to the absence of appropriate ground based nav aids (ILS).

In compliance with Section 8.8.2 (4) of the FCOM "Check of engagement and disengagement of the Go-around mode" the crew could arm the Go-Around mode by pressing the APPROACH and GLIDE SLOPE buttons on autopilot control panel. It should be noted that these actions are only prescribed to be performed *on the ground during the preflight inspection* of the autopilot and cannot be performed in flight according to the FCOM. Without meeting this condition automatic go-around was impossible. However, the APPROACH and GLIDE SLOPE buttons as well as the GO-AROUND button were not used by the crew in the accident flight. The flight recorders did not record relative callouts or data.

**Note:** *On April 6, 2010<sup>45</sup> during an ILS approach at Warsaw airport this aircraft made an automatic go-around. The FDR recorded the relative on/off-signals (autoflight modes): Approach, Glide slope, and Go-around (Figure 44).*

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<sup>45</sup> In accordance with the available information, on April 6 a test flight of the aircraft was made before the VIP flights of April 7 and 10. The PIC duties were performed by a pilot who flew to Smolensk on April 7 (and assigned as the PIC in the preliminary request for April 10). The PIC of the accident flight was a co-pilot in the test flight.



Aircraft TU-154M TailNo 101 (Republic of Poland) flight parameters during automatic go-around on April 06, 2010

Figure 44



As was mentioned above, the flight was conducted with AP on in roll and pitch channels and with the autothrottle engaged. Before a base turn most probably altitude hold mode was engaged in the pitch channel, and FMS control in the roll channel (CMD HDG and LNAV modes)<sup>46</sup>. Autothrottle was used to set and maintain flight speed. Thus, after reaching 500 m the IAS was decreased to 370-380 km/h and at 10:34:57 the landing gears were extended. Almost at the same time the flaps were extended to 15°, slats were extended and stabilizer moved to 1.5° pitch up. After the flaps were extended the IAS was decreased to 330-340 km/h.

When reaching the base turn, in order to inform the crew about the additional lighting equipment on the airdrome (projector stations), the controller checked if the crew had landed at a military airdrome before (which was confirmed by the crew) and informed them that the projectors were on in daytime mode. Then the controller cleared the crew for the base turn and warned them to be ready to go around from the altitude of 100 m. The crew replied with: “Yes, sir!”

At 10:20:57 a cabin attendant asked the PIC if it was time to fasten seat belts (the PIC confirmed it was). At 10:35:12 the cabin attendant reported to the PIC that they were ready for landing. The medical tracing analysis (Section 1.16.8) revealed that part of the passengers who were mainly in the forward part of the cabin was not fastened.

The crew initiated the base turn at 10:35:20. The turn was made with a roll of about 20°. After the base turn, at 10:36:36, the crew started to extend flaps to 28°.

**Note:** *The crew did not perform the Before Base Turn or at 25-20 km Distance Checklist and did not report the landing gear extension. Further there were no reports in compliance with the SOP from the crew on flap and slat extension and relative trim of the stabilizer. There are only broken phrases on the CVR. The investigation team considers that these shortcomings are connected with the overall low level of the crew professional training and also with the low level of operational management in the air regiment including the abovementioned lack of the SOP for 4-member crews.*

At 10:37:01 the crew of the Yak-40 aircraft contacted the Tu-154M and informed the crew that according to their assessment the visibility was 200 m.

As was mentioned before, the actual weather at the time of the accident was estimated by the investigation team as follows: visibility 300-500 m, fog, clouds 10 points, stratus, cloud base

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<sup>46</sup> FDR only records if autopilot in pitch and/or roll channels is engaged or disengaged. The particular mode that is engaged is not registered except APPROACP, GLIDE SLOPE and GO-AROUND modes.

40-50 m. Also, considering the observations of an eye-witness who was at the middle marker (see Section 1.17.2) as well as the video records made directly after the accident, there was possible decrease in visibility in the low-lying areas (middle marker area) due to fog down to 50-100 m with minimal vertical visibility (10-15 m).

Despite one more warning from the Yak-40 aircraft, the Tu-154M crew continued approach and at 10:37:23 requested final turn. The clearance was received from the landing zone controller.

The final turn most probably was performed with autopilot TURN (HEADING) knob and was finished at 10:38:25 by joining heading  $\sim 245^\circ$  at a distance of about 14 km from the runway threshold. Further the heading was corrected smoothly to the right (about  $10^\circ$  in about 1 minute). It should be mentioned that tailwind of 30-40 km/h at circle altitude could have led to time deficiency when starting glide path descent.

At 10:39:05 (10.5 km from Runway 26 threshold) the crew finished extending flaps to  $36^\circ$  (the stabilizer moved to  $3^\circ$  pitch up) setting the aircraft to the landing configuration. After extending the flaps the IAS was decreased to 300 km/h. At that time the aircraft was almost at the glide path entrance point (FAP) (10.41 km from Runway 26 threshold according to the approach pattern). In accordance with the Tu-154M FCOM (table 3.1.8.4), the approach speed for the actual landing weight (78.6 tons) and Flaps  $36$  is 265 km/h. Thus, the crew was maintaining speed 35 km/h higher than recommended by the FCOM.

At 10:39:10 the controller informed the crew that they were 10 km from the runway threshold and had reached the glide path entrance point. The crew did not give a relative read back. When passing the glide path entrance point no relative report: "Glide path intercepted, descending ... m/sec" was made by the navigator (in accordance with the typical SOP for 4-member crews) or the co-pilot (SOP for 3-member crews).

**Note:**

*It should be also noted that here and after during the glide path descent the crew members did not perform their duties concerning informing the PIC on various deviations: in IAS ( $\pm 10$  km/h from the estimated), in position with regard to the glide path, in vertical speed above 5 m/sec. During the non-precision approach none of the crew members monitored the aircraft position with reference to the glide path by distance to the runway and actual flight altitudes (there were no reports).*

The crew continued flight at 500 m going through the Before Outer Marker Checklist. The checklist was finished at 10:39:30. Almost at the same time the controller information followed: “8 km on course and glide path”<sup>47</sup>.

**Note:** *On the background of the checklist items called out the CVR recorded a voice identified by the Polish experts as belonging to the Commander-in-Chief of the Polish Air Forces. The findings of the medical tracing examinations (Section 1.16.8) are consistent with the presence of this high-ranked official in the cockpit until the moment of the accident. The content of the phrase (explanation of the high-lift devices function) allows assuming that at that moment at least two unauthorized persons were present in the cockpit.*

The actual descent path of the aircraft is shown in Figure 45 and Figure 46.

As follows from the analysis of the navaid test fly-around (Section 1.16.6), the graphical glide path line on the landing radar screen referred to the glide path angle of  $\sim 3^{\circ}10'$ . It means that the actual aircraft position was higher than that shown on the graphical lines by about 30' ( $0.5^{\circ}$ ), i.e. when the aircraft was on top of the tolerance (for glide path angle of  $2^{\circ}40'$ ) the actual indication of its blip on the radar corresponded to the “on glide path” position on the radar screen.

At a distance of 8 km the aircraft was 100 m higher than the glide path (glide path angle  $2^{\circ}40'$ ), at 6 km (outer marker area) – 120 m higher than the glide path (glide path angle  $2^{\circ}40'$ ), at 4 km – 60 m higher than the glide path (glide path angle  $2^{\circ}40'$ ) and at 3 km – 15 m higher than the glide path (glide path angle  $2^{\circ}40'$ ).

At the distances of 8, 6, 4 km the landing zone controller informed the crew that the aircraft was on glide path although the actual aircraft position was higher than the glide path but within the tolerance range on the radar screen (glide path angle about  $3^{\circ}10'$ ). At a distance of 3 km the aircraft was almost at the depicted glide path (glide path angle about  $3^{\circ}10'$ ).

The test fly-around revealed that the established landing zone controller practice was such as to inform the crews that they were on glide path in case the aircraft was anywhere within the glide path tolerance area. At 10:39:34 the PIC informed the controller on the extended flaps and landing gears: “Landing gears, flaps extended, Polish 101”. The deputy CATC informed that

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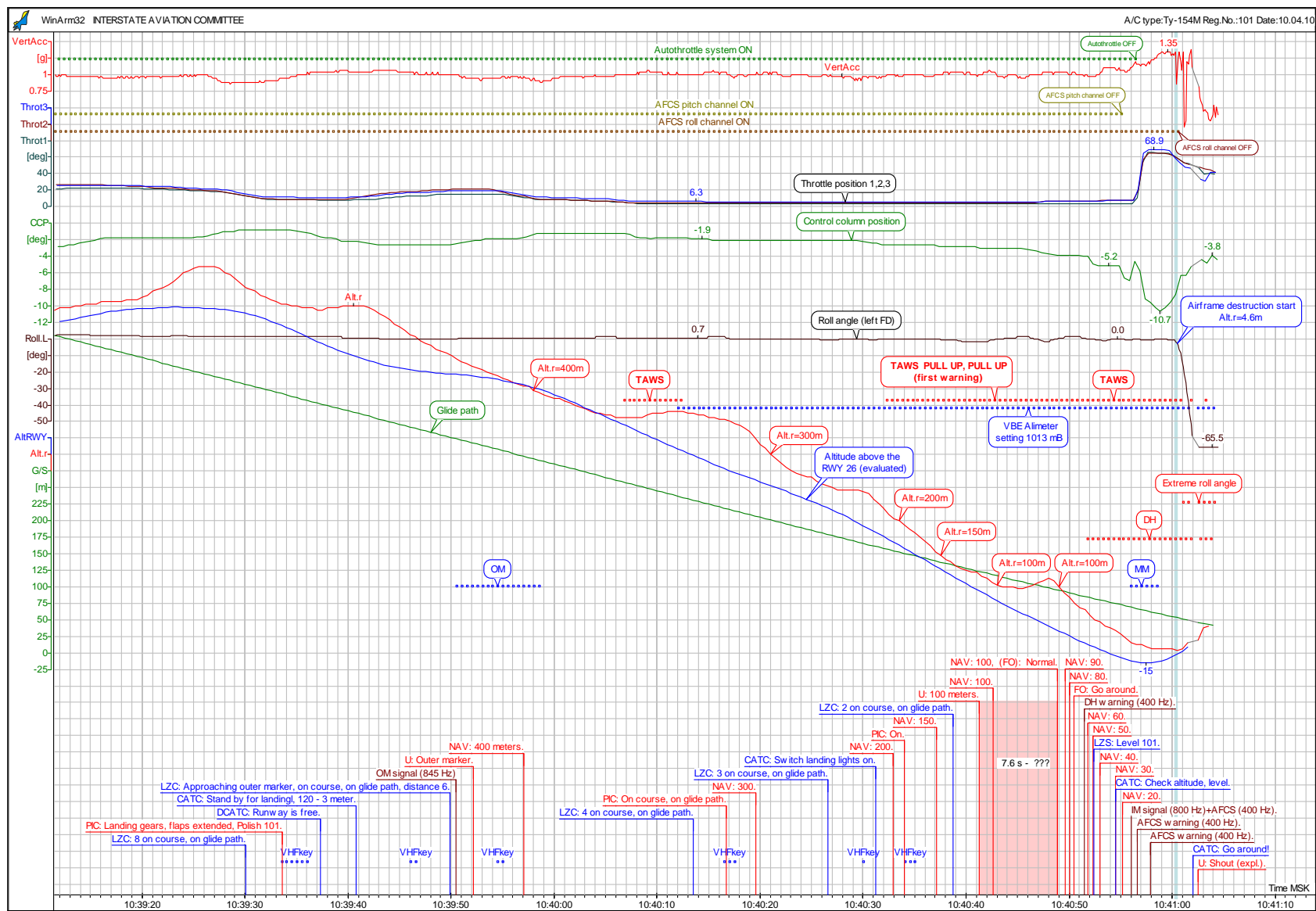
<sup>47</sup> Estimations revealed that the information about distance to runway threshold (8, 6, 4, 3 and 2 km) was given by the controller to the crew about 500 m earlier in the average. The test fly-around (Section 1.16.6) revealed that the aircraft blip indication inaccuracy on the radar made it appear 90-150 m closer to Runway 26 threshold.

the runway was clear and right after that, at 10:39:41 the CATC informed the crew: "Stand by for landing....", and indicated the actual wind "... 120-3 meters".

**Note:**

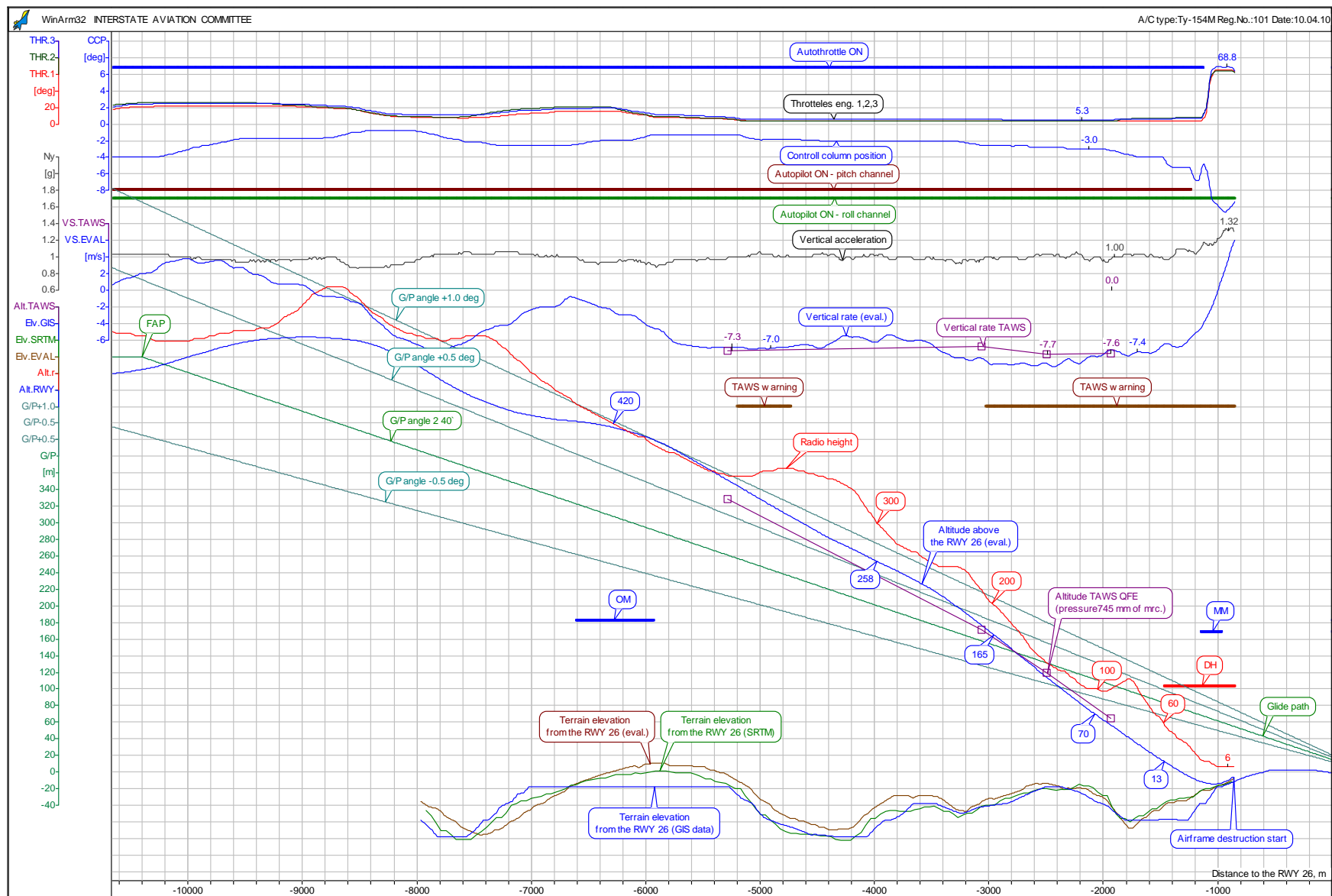
*According to the Russian AIP ENR 1.5-4 Para 2.3.10 ATC controller shall timely inform the crew about exceeding the maximum permissible deviations from the heading and (or) glide path on final between LOM and LMM;*

*During the approach of the Yak-40 that was on glide path until the distance of 1 km in accordance with the LZC's information, its actual position with reference to the runway threshold was above the target one which confirms the data above. The CATC instructed the crew to go around. However, the Yak-40 crew did not follow this instruction but landed.*



Aircraft TU-154M TailNo 101 (Republic of Poland) flight parameters during the accident happened on April 10, 2010 near the aerodrome Smolensk "Severyn"

Figure 45



Aircraft TU-154M TailNo 101 (Republic of Poland) flight parameters during the accident happened on April 10, 2010 near the aerodrome Smolensk "Severyn"

Figure 46

Depending on the situation (e.g. occupied runway or worsening weather conditions) the CATC informs the crew about that and reports: “Stand by for landing”. This phrase means that the landing is not cleared. In this case if the crew takes and informs on their decision to land upon their own responsibility before passing the decision altitude but in any case not later than passing 1000 m from the runway threshold, the controller can clear them for landing but this clearance will only mean that the airspace ahead and the runway are clear (FAR "Maintaining Radio Communication in the Russian Airspace" and Russian AIP, ENR 1.5-3 Para 2.3.8, 2.3.10).

**Note:** *According to the Russian AIP the controller must prohibit landing of an aircraft and instruct the crew to go around if:*

- *there are any obstacles along the aircraft descent path or on the runway jeopardizing flight safety;*
- *there appeared a threat to flight safe aircraft separation on final.*

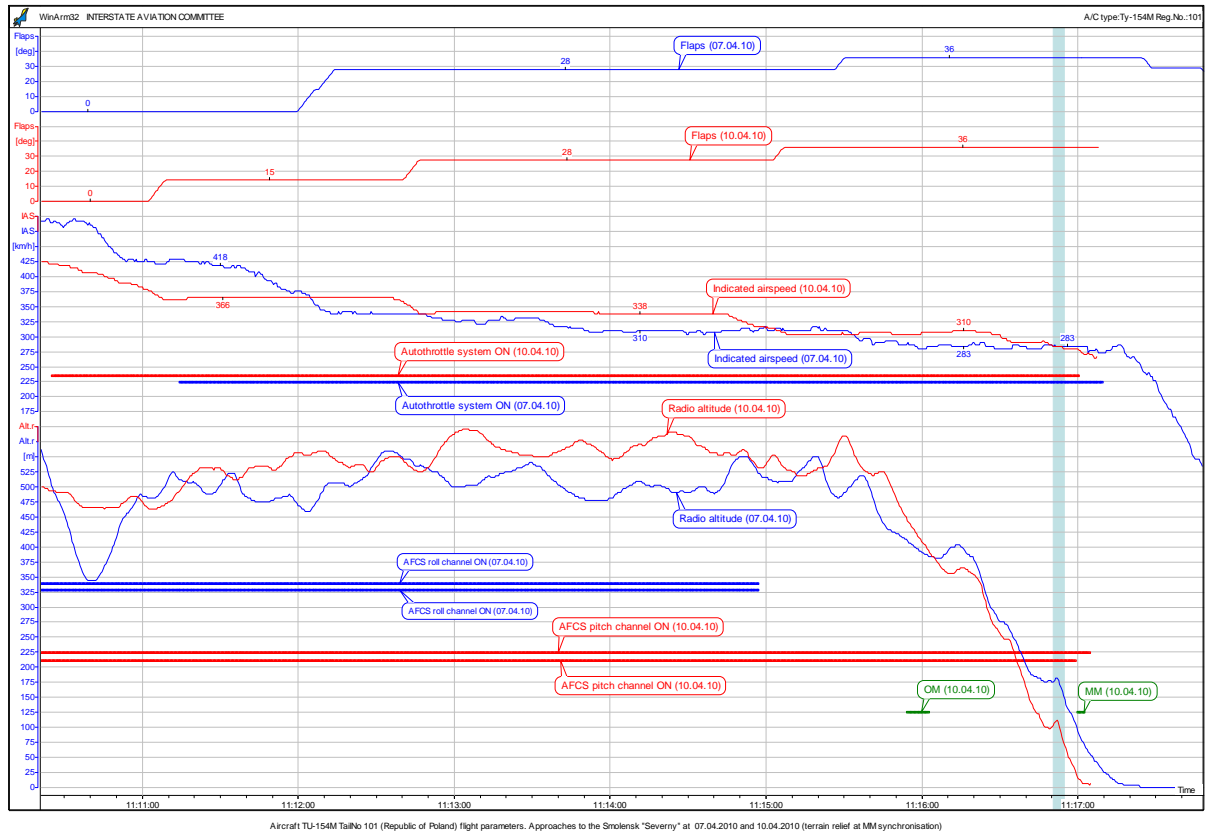
The crew initiated descent on the glide path from the distance of 9 km from the runway threshold switching to autopilot control in pitch channel by the DESCENT-CLIMB wheel. First the crew did not manage to achieve stable descent. The vertical speed increased to almost 8 m/sec by the distance of 8 km from the runway threshold and then by 7 km distance decreased almost to zero.

Controlling vertical speed with required accuracy with the wheel requires definite skills from the pilot. Usually pilots use this wheel in climb and descent modes that do not require high accuracy in vertical speed control while the time needed to select the appropriate pitch to maintain constant speed is not that important. In the approach modes when required vertical speed must be set in short time and with high accuracy using the DESCENT-CLIMB wheel is not appropriate as it requires significant time to set vertical speed which usually requires readjusting. This is explained first of all by the VSI lagging (especially the TCAS VSI) and the long feedback chain: pilot – DESCENT-CLIMB wheel – autopilot – aircraft - VSI – pilot. This is why using the DESCENT-CLIMB wheel to control the vertical speed of descent during approach is complicated and impracticable, requires increased time and attention, distracts from monitoring other flight parameter and increases the workload on the pilots. Usually the Tu-154 crews use manual control column steering during non-precision approaches.

**Note:** *The analysis of the flight made to Smolensk "Severny" Airdrome on this aircraft on April 7, 2010 reveals that the crew switched to manual control column steering before starting the glide path descent (Figure 47).*



The use of autopilot by the PIC which was not stipulated by the FCOM at an airdrome with no precision instrument landing systems confirms the uncertainty of the PIC that he could maintain the selected descent parameters controlling the aircraft manually as well as his psychological stress due to the incompliance of the actual weather conditions with his training level provided he had had breaks in approaches in the established weather minima.



**Figure 47**

Such aircraft control led to the situation that by the time of passing the outer marker which the crew identified by the relative aural warning, the aircraft was about 120 m above the glide path.

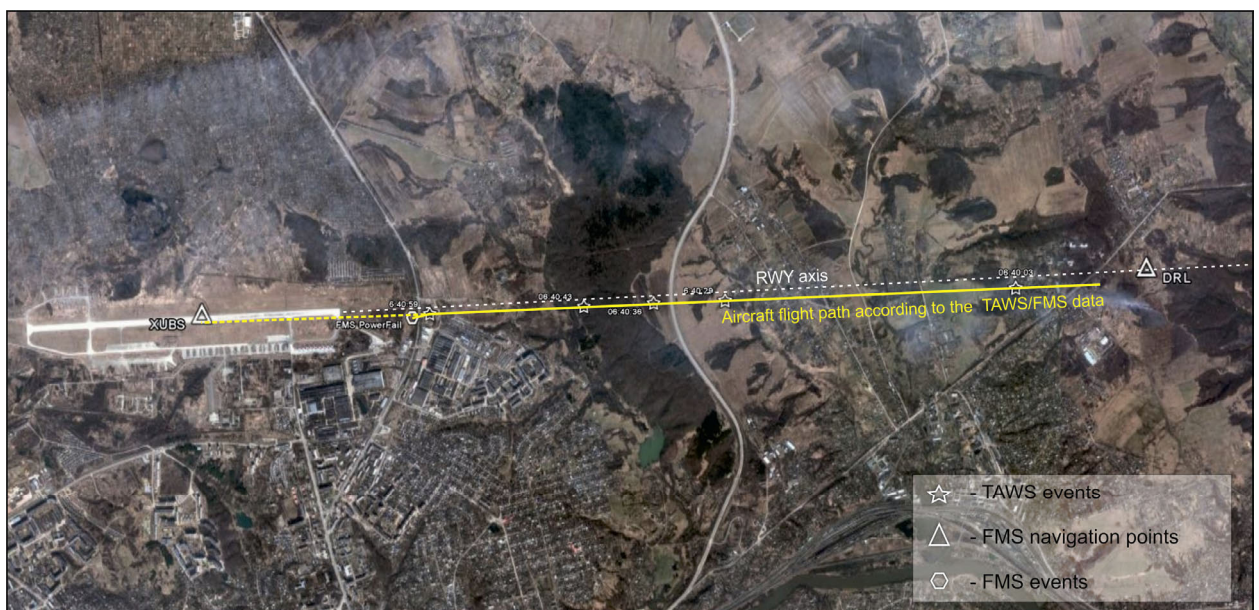
At the same time as the aural warning was triggered the landing zone controller informed the crew: “Approaching to outer, on course, on glide path, distance 6”.

At 6 km the aircraft was actually higher than the glide path (considering the indication inaccuracy the aircraft blip was on the top boundary of the glide path tolerance area for glide path angle of  $\sim 3^{\circ}10'$ ). Meanwhile, judging by the cockpit internal communications (unidentified voice saying “Outer” and navigator replying “400”) the crew realized that they were over the glide path as the outer marker must be passed at 300 m. Further crew actions to bring the aircraft to stable descent with vertical speed of 7-8.5 m/sec (instead of the standard 3.5 – 4 m/sec) confirm this assumption and mean that the crew was trying to catch up with the glide path. Such average vertical speed of descent was maintained by the crew until they initiated the obstacle

avoidance actions, but none of the crew members called out “steep descent” as mandated by Para 4.6.3 of the FCOM.

The FMS data analysis shows that at the time of the accident the FMS was in the LNAV mode. The flight was conducted in accordance with the entered flight plan from DRL to XUBS waypoints. The coordinates of the middle marker and Runway 26 threshold were not entered into the FMS.

From the outer marker to XUBS (the last waypoint in the active flight plan), the flight path calculations (Figure 48) suggested two possible methods as to how the flight crew was controlling the airplane - either by the FMS, or by the use of the TURN (HEADING) knob. The flight path calculations revealed that, after passing the outer marker, the airplane was to the left of the extended runway centerline (within the course tolerance area) heading directly to the XUBS waypoint. It is possible the FMS could have provided the course adjustment for the airplane to track directly to XUBS and, therefore, converge on the line between the waypoints. In addition, the flight crew could have used the autopilot TURN (HEADING) knob to adjust the airplane's track.



**Figure 48**

After passing the outer marker the crew set selected speed to 280 km/h. The autothrottle set all engines to idle but due to the high angle of descent this speed was only reached after 40-45 seconds.

At 10:40:06 the first TAWS "TERRAIN AHEAD" warning was activated which was accompanied with a record of the relative artificial voice. The TAWS readout analysis (Section 1.16.5) showed that despite the lack of Smolensk "Severny" airdrome in the system database, the TERR INHIBIT function was not activated despite the limitations of the Supplement to the

Tu-154M FCOM. The flight pressure altitude recorded by the TAWS by that time was 1080 ft (about 330 m) which complies with the calculated altitude pretty well.

The crew did not comment on or react to the triggering of this warning. The alert was active for 6 seconds. The TAWS alert stopped simultaneously with the record of the on-signal confirming the standard pressure (760 mm mercury) on the PIC's altimeter. The analysis of further parameters recorded by TAWS confirms that the standard pressure was set on the PIC's altimeter that provides data to the TAWS system. Thus, all pressure altitude readings recorded by TAWS during further warning activations show good compliance with the calculated values if 165-170 m which corresponds to the change in pressure settings of 15 mm mercury are subtracted.

The analysis of the FMS data revealed that the split in the barocorrected readings of the PIC's and the co-pilot's main electronic altimeters at the time of the power loss was about 170 m, which corresponds to a difference in pressure of about 15 mm of mercury and confirms that the co-pilot's main altimeter was set to 745 mm of mercury.

**Note:**

*The conducted examination of the pressure altimeters VM-15PB, fitted in the right lower corner of the co-pilot's control panel , and UVO-15M1B, fitted on the PICs control panel, to the right of the main electronic altimeter, also confirm that they were set to 745 mm of mercury.*

Analyzing the available information it was not possible to determine precisely who set the standard pressure at the PIC's altimeter and for what reason<sup>48</sup>. The reset of the pressure led to abrupt change in the PIC's altimeter indications increasing by about 165 m. This could have misinformed the PIC in case he was monitoring the altitude. However, if the PIC was monitoring the altimeter indications<sup>49</sup> he could not have missed the abrupt erratic change in its indications. The experience of air accident investigation reveals that such situations happen when the PF (PIC) distracts his attention from the instruments "turning his eyes and attention to the space outside the cockpit" in order to search for the runway or ground references.

The results of the examinations conducted by the State Research Institute of Military Medicine of the Russian Ministry of Defense reveal that a characteristic feature of the pilot's actions during the approach in the weather conditions below his minima is distraction from

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<sup>48</sup> Physically this operation could only be done by the PIC or the navigator. One of the possible explanations is given in the flight operations assessment (Section 1.16.3). The analysis of the possibility of non-crew-induced setting of standard pressure (Section 1.17.6) revealed that this is highly improbable and has never been noted within the entire operation of this altimeter type.

<sup>49</sup> The mechanical altimeter UVO-15M1B (Figure 4) on which the QFE of 745 mm of mercury was set, is located near the PIC's pressure electronic altimeter.

monitoring the instruments in order to find outside references and the runway. Researches show that in such conditions the pilot experiences a special psychological condition of expecting to leave the clouds which leads to inadvertent (sometimes subconscious) distraction from the instruments and subconscious transfer of attention outside the cockpit.

Regular flights in complicated meteorological conditions develop skills of alternating monitoring that allow being distracted from monitoring the instrument indications to search for the runway for not longer than 0,5-0,8 seconds. If the training level is insufficient or if there were breaks in flights in complicated meteorological conditions for over two months the mentioned skills get weaker, which leads to redistribution of attention between monitoring the instruments and searching the runway with a significant increase of time spent on the latter up to complete disregard of the instrument indications.

In this certain case when the PIC had a break in flights in complicated meteorological conditions (corresponding to his weather minima 60x800) was over 5 months, it can be concluded that his doubt of a safe landing increased his psycho-emotional stress and led to abrupt narrowing of attention to separate flight parameters to the prejudice of the complete image of the flight.

Experimental research on the effect of breaks in flight on the quality of flight actions revealed a logical increase in the number of erroneous actions, especially when flying on final in clouds, which are reflected in deviations from the target descent parameters and late go around decision.

**Note:**

*The FMS data analysis showed that at the time of the accident there was a split of about 170 m in the PIC and co-pilot's pressure altimeter indications. In accordance with the Supplement to Tu-154M FCOM for aircraft equipped with the air data reference system, in case of a split in the PIC's and co-pilot's altimeter indications of over 60 m, a SPRAWOZ WYSOK (CHECK H) amber light must have activated on the central control panel. No comments of the crew concerning this issue were recorded (the required crew actions are described in the Supplement to the FCOM, Section 8.17.12.3 (1)).*

At 10:40:13 the landing zone controller informed the crew: "4, on course, on glide path". Actually at a distance of 4 km the aircraft was at a height of 260 m (for this distance: on glide path with angle 2°40' – 200 m, glide path tolerance area – 35 m) while the aircraft blip on the

radar considering the abovementioned inaccuracies, did not go beyond the top boundary of the glide path tolerance area. The crew gave a relative read back.

At 10:40:20 the navigator reported the height: “300”. The comparison of this and further navigator’s reports on the flight height (250 m, 200 m, 150 m, 100 m) with the actual pressure altitude and radio height especially in the time interval from 10:40:41 – 10:40:49 indicated in color on Figure 45 reveals that at least from that moment the altitude was monitored by the radio altimeter<sup>50</sup>. It should be noted that the navigator had not conducted flights on Tu-154M flying as a co-pilot of Yak-40 for the last 2.5 months. The interview of the Yak-40 PIC who was flying to Smolensk "Severny" Airdrome on April 7 and 10 showed that for the crews of Yak-40 in the regiment “there is a procedure of monitoring altitude by the radio altimeter from the height of 250 m”. The actual terrain along the flight path is shown on Figure 46. It is clear from the picture that after the outer marker the terrain level was much lower than RWY 26 threshold (up to 80 m).

At 10:40:27 the landing zone controller informed the crew: “3, on course, on glide path”. The crew did not confirm this. The aircraft was at a distance of about 3500 m from the runway and was on the ~3°10' glide path (on the upper boundary of the glide path tolerance area of the 2°40' glide path). Thus, the landing zone controller was watching the aircraft on the radar as being exactly on glide path.

At 10:40:29 the aircraft passed the altitude of 200 m with reference to RWY 26 threshold. The standard SOP contains a warning that if at 200 m the required engine mode is higher than the nominal or lower than 75% (N2) it is necessary to go around. If the actual required N2 is lower than 75% the physical sense of this warning is that either the aircraft is not in landing configuration or the descent is conducted with vertical speeds much higher than the required speeds for flight on the standard glide path.

For the actual flight conditions N2 75% refers to N1 51-52% which is evidently higher than the recorded values (32-33%). Thus, at that stage the crew already should have initiated the go around.

At 10:40:31 the CATC, aiming to find the aircraft visually, asked the crew to turn on the forward lights which was replied by the PIC: “On”. The analysis of the CVR and FDR records (click of the switch recorded by the CVR and voltage jump record on the FDR) reveal that most probably the lights were turned on at that very moment. However, about a minute ago, responding to the checklist items the PIC confirmed the lights were down and on. This fact

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<sup>50</sup> In accordance with the standard SOP the altitude monitoring shall be done every 100 m by pressure altimeter and starting from the height of 60 m – every 10 m by the radio altimeter.

confirms again that the PIC was not in the optimal working condition and his ability to perceive information was fragmentary.

At 10:40:32 the second TAWS warning "TERRAIN AHEAD" was fired. The aircraft was at a height of about 180 m with reference to RWY 26 threshold.

At 10:40:37 the aircraft reached the visual assessment altitude of 130 m (DA + 30 m). At that stage the navigator (or co-pilot) should have called out: "Decision", after which the PIC starts establishing visual contact with the ground references. At that time the co-pilot had to control the aircraft and monitor the flight instruments. No crew member called out "Decision".

At 10:40:39 the landing zone controller informed the crew: "2, on course, on glide path". At that time the aircraft was at a height of about 115 m with reference to RWY 26 threshold, which was almost corresponding to the missed approach height. Considering the indication inaccuracies the aircraft blip on the radar was almost at the lower boundary of the glide path tolerance area<sup>51</sup>.

At 10:40:41 the aircraft passed the decision altitude of 100 m. After the previous controller information "stand by for landing" the crew did not report establishing visual contact with the runway, the controller did not issue clearance for landing and the crew did not report their intention to go around. Before the DA there was no command "Landing" from the PIC, therefore, according to the SOP and Para 4.6.10 (7) of the FCOM the co-pilot should have immediately initiated the go-around.

**Note:** *According to the Russian AIP 1.5-3 Para 2.3.8 landing of aircraft shall be cleared by the controller.*

In a second the TAWS PULL UP artificial voice warning was activated. When PULL UP warning is activated the crew must immediately start climbing until the warning stops. However, no crew actions or comments followed and the aircraft continued descent with the same vertical speed and with AP on in pitch and roll channels and with the autothrottle engaged. The alert was active until the impact.

From 10:40:41 to 10:40:49 the crew pronounced the same altitude value of 100 m (same as decision altitude) for three times, but there was no callout to go around. The actual change of altitude during that time was 60-70 m while the radio altimeter indications used for callouts were affected by the terrain undulations. After the third report most probably it was the co-pilot who reported: "normal" which reveals that the crew was not monitoring the descent parameters

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<sup>51</sup> At a distance of 2 km the line value of the tolerance area is  $\pm 17$  m.

(vertical speed, distance to the runway threshold, altitude, aircraft position with reference to the middle marker). Further the navigator continued altitude callouts every 10 m.

At 10:40:51, before passing the middle marker, simultaneously with the warning on reaching the target altitude set on the radio altimeter at a height of 60 m, the co-pilot called out: “Go around”. At that moment the aircraft altitude was of 10-15 m with reference to RWY 26 threshold. The analysis revealed that simultaneously with the co-pilot’s phrase the FDR recorded the control column pull-up deflection which corresponds with the delta elevator deflection about 5° pitch up (Figure 49). The elevator deflection led to the increase of pitch and angle of attack angles and increase of vertical acceleration by 0.15g. However, this deflection was not enough to overpower the autopilot in the pitch channel (it requires the control column deflection of 50 mm from the trimmed position) which led to the AP moving the elevator pitch down to the previous position to maintain the target pitch angle.

Considering the coincidence of the “Go around” callout and the control column pulling up, the investigation team believes that the co-pilot tried to initiate the go around procedure but did not complete it.

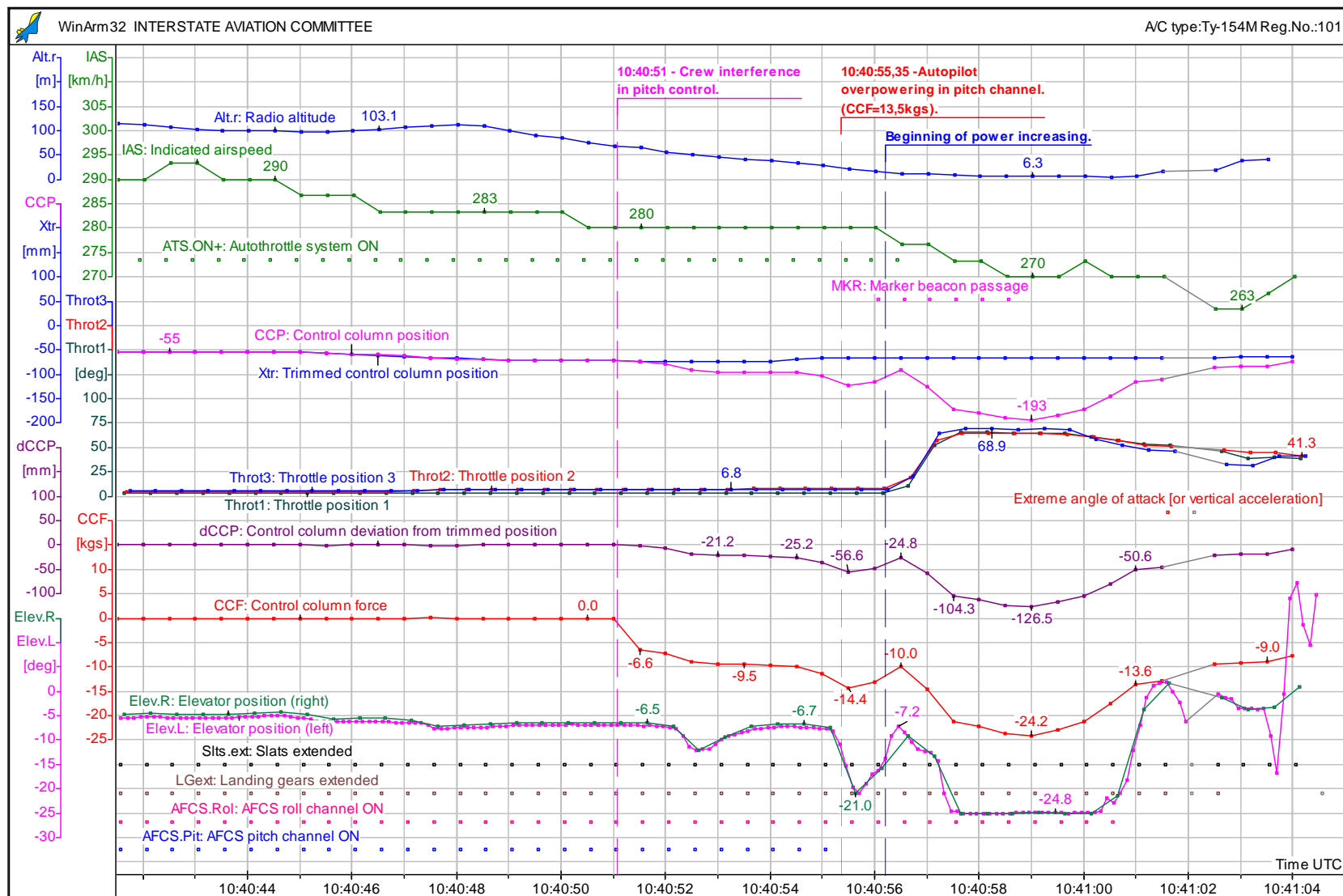
**Note:** *The correct crew actions during a go around with Flaps 36 include (Section 4.6.10 of the FCOM):*

- *Increasing thrust to takeoff mode and calling out “Takeoff mode, going around”;*
- *Switching from descent to climb with flaps retracting to 28°;*
- *Retracting landing gear after vertical speed becomes positive.*

The navigator continued calling out heights: 60, 50. At that time, having not obtained the crew report on going around, the landing zone controller instructed: “Level, 101”. No crew actions followed to terminate descent, the aircraft continued descent and the navigator continued the height callouts: 40, 30, 20.

At 10:40:55 at a height of about 30 m the CATC instructed: “Check altitude, level” and simultaneously the control column was abruptly pulled up (moving the elevator to 20° pitch up, load forces up to 15 kg) which led to autopilot being overpowered in the pitch channel. In a second throttles of all engines were set to takeoff mode (with a rate of one second) which led to the disengagement of the autothrottle. Usually when the missed approach is made in control column steering mode the autopilot is disengaged by pressing the quick switch-off button on the pilot’s control wheel.





Calculated forces on the control column.

Figure 49

**Note:** *On the basis of the conducted operational assessment (Section 1.16.3) and the findings of the medical tracing examination of the crew members (Section 1.13.1), the investigation team assumes that these actions were done by the PIC.*

The tempo and amount of control column input were much higher than during a normal go-around. Evidently the PIC could be only motivated by the following – at that very moment he could see the ground and obstacles (trees), assess the height visually and realize the critical character of the situation. In this situation the PIC's actions were instinctive.

This was followed by an instant push back of the control column (the elevator moved back to the almost trimmed position) and in 1.5 seconds the control column was completely pulled up till the elevator max stop of 25° (load forces about 25 kg) which was retained until the start of aircraft destruction.

The analysis of this part of the FDR record conducted by experienced pilots revealed that such action done with the control column are most probably induced by the fact that the PIC did not have experience of overpowering the autopilot. At the moment when significant forces are applied to the control column it sinks in the pull up direction which leads to reflectory push down and only after that as the pilot realizes the situation it is pulled up again.

The analysis of the simulator experiment findings and the terrain and obstacle characteristics revealed that in case the co-pilot had taken active measures to go around (vertical acceleration of about 1.4g and setting engines to takeoff mode) initiated at 10:40:51 it could have most probably allowed avoiding the accident although possibly exceeding the operational AOA limitations (SPS warning activated).

The comparison of the crew actions and the wreckage plot reveals that active control measures were taken almost at the moment of the first collision of the aircraft with an obstacle at a height of 10 m (over 10 m below the elevation of RWY 26 threshold). This confirms the words of the eye witness who was at the middle marker saying that the actual visibility at that place was 50-100 m and vertical visibility was 10-15 m.

Considering the analysis of visibility conditions of the lighting system elements (Section 1.16.7), the investigation team comes to a general conclusion that in the actual weather the conditions of Group I, II and III approach lights (900, 800 and 700 m from RWY 26 threshold) (Section 1.8) could not have contributed to the accident.

The abovementioned crew actions led to increasing vertical acceleration and climb. However, due to elevating terrain along the flight path, at 10:41:00 about 245 m after the first

impact and about 60 m left from the extended runway centerline the aircraft hit a birch (its trunk being 30-40 cm wide) with its left wing which led to a significant part of the detachable part of the left wing (about 6.5 m) being ripped off. At the moment of the impact with the birch the autopilot was still engaged in the roll channel.

The ripped off left wing led to intensive left roll and in 5-6 seconds the aircraft hit the ground inverted and was totally destroyed. The emerging insignificant ground fire was extinguished 18 minutes after the accident by the arriving fire fighters.

The medical tracing examination revealed that at the time of the aircraft destruction, inverted, the passengers and crew members were exposed to acceleration of over 100g. According to the medical expertise, death of all persons on board occurred instantaneously at the time of the collision due to numerous mechanical injuries incompatible with life obtained due to traumatic effect of the outrageous impact deceleration forces and destructed parts of the aircraft.

About 13 minutes after the accident the police of Smolensk Region and Federal Security Service officers cordoned off the accident site in the radius of 500 m. The emerging insignificant cell of ground fire at the accident site was extinguished by the arriving fire fighter brigades 18 minutes after the accident. The actions of all search and rescue services were appropriate and timely, which allowed preventing the expansion of the ground fire and providing custody to the flight recorders, aircraft elements and bodies of the persons on board.

Thus, the investigation team notes a combination of causes and contributing factors that led to the accident:

In the first place, this is significant shortcomings in the organization of flight operations and crew training in the special air regiment, including the arrangement of this VIP flight. The insufficient level of the crew professional training and errors in crew formation, as well as unsatisfactory CRM during the descent and approach, incorrect duty distribution and lack of SOP did not allow the crew and first and foremost the PIC to make a timely (before reaching the decision altitude) assessment of the descent parameters and aircraft position with regard to the glide path and initiate the go around.

Despite being regularly informed on the bad weather conditions, after discussing this information with the crew and high-ranked officials present in the cockpit and understanding the importance of landing at Smolensk "Severny" airdrome the PIC decided to make a "trial" approach. This decision could only be justified in case the main rule is strictly complied with – namely not descending lower than the established weather minima (100 m). Probably at the moment of taking this decision the PIC intended to do so, which is confirmed by the fact that he informed the crew about the go around in case of approach failure and by his brief military reply to the controller's instruction to go around from 100 m.

However, constant presence of unauthorized persons in the cockpit during the approach evidently increased the stress and distracted the crew from their duties. The phrases recorded by the CVR (at 10:30:33 Director of Protocol: “There’s no President’s decision what to do next yet” and at 10:38:00 navigator: “He’ll go crazy ...” confirm that that the PIC was in complicated psychological condition. It was clear that in case of missed approach and proceeding to alternate airdrome the PIC would have to face negative reaction of the Main Passenger.

As was noted before (Section 1.16.10), according to the Polish and Russian expert psychologists the PIC featured a high level of conformity. This personality trait in extreme situation can lead to hesitation, uncertainty, pliability, dependence on the reference (meaningful) group or person. During the flight and final descent until the collision the Commander-in-Chief of the Polish Air Forces was present in the cockpit and though he was aware of the weather information he did not take any measures to terminate the approach as the top military aviation official. Expert psychologists concluded (Section 1.16.10) that the indifference of the Commander-in-Chief of the Polish Air Forces to solving the emerging extremely hazardous situation affected the PIC’s decision to continue approach and descend below decision altitude without establishing visual contact with the ground references.

Thus, the PIC obviously changed his previous decision and took the risk of descending lower than the decision altitude hoping to finally establish visual contact with the runway and land. The change of decision requires a change in the action plan: setting an internal task, a “barrier” i.e. a reasonably safe height from which go around should be initiated and informing the crew about it. However, due to time deficiency (the aircraft was on final) and growing stress the PIC could not implement that.

As the information on the landing system was not discussed between the crew and the controller, the landing radar was not requested by the crew, the crew did not read back in most cases the controller’s information and the altitude information was not reported to the controller during the descent on final, the investigation team assumes that actually the crew did not conduct the landing radar+2NDB approach<sup>52</sup>. The crew made the "trial" approach using their own instruments, autopilot and autothrottle. This type of approach is not described in the FCOM so the weather minima and SOP are not determined.

The PIC did not reply to the co-pilot’s challenge at 10:21:18: “Monitor the direction... shall I read the altitude by distance?”. None of the crew members report the distance to runway. After passing the outer marker and understanding that the aircraft was above the glide path the

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<sup>52</sup> This is also confirmed by the interview of the Yak-40 crew who stated they were preparing to land using the markers with GPS monitoring.

PIC used the DESCENT-CLIMB wheel to set the selected pitch which corresponded to vertical speed of 7-8.5 m/sec (depending on the actual ground speed).

Besides, as was mentioned above, the PIC was in a complicated situation psychologically. On the one hand, he clearly understood that landing in such conditions was not safe (this was confirmed by his initial decision to go around from the altitude of 100 m), on the other hand there was strong motivation to land at that very airdrome. Speaking in terms of aviation psychology, this situation is called clash of motives. In such condition the range of attention gets narrower and the possibility of taking inadequate decisions increases. These two factors (lack of new clear plan of actions and clash of motives) as well as a long break in flights in complicated weather conditions (corresponding to his weather minima 60x800) explain the PIC's passivity during the final stage of approach.

Abrupt PIC's actions taken at the last moment did not result from his well-formed decision to go around and were not his conscious reaction to:

- the high vertical speed of descent (~8 m/sec);
- recurrent activation of the TAWS "PULL UP, PULL UP" alert;
- the descent lower than the decision altitude (100 m);
- the activation of the Decision Height Alert when reaching the radio altimeter height of 60 m;
- the co-pilot's callout "Go around!";
- the controller's instruction to terminate descent: "Level, 101".

This can mean that there was an attempt to initiate visual flight before passing the middle marker in order to land visually. In the course of approach the PIC requested and received information from the crew of the Yak-40 on the cloudbase that was lower than 50 m. In the actual weather conditions transition to visual flight was impossible.

As was mentioned before, the abrupt actions taken by the PIC can have only one explanation – at that moment the PIC could see obstacles and/or ground, visually determine the height and assess the critical nature of the situation. In this situation the PIC's actions were instinctive.

The obstacle avoidance maneuver was so abrupt that by the moment of collision with the tree, that initiated the destruction, the aircraft's angles of attack significantly exceeded the operational ones and almost corresponded to stall AOA. Most probably, if not for the collision, in a few seconds the aircraft would have entered a stall followed by a crash.

### 3 Conclusions

The investigation of the fatal accident involving the Tu-154M aircraft of the State aviation of the Republic of Poland, performing a non scheduled international flight carrying passengers to Smolensk "Severny" airdrome belonging to the State aviation of the Russian Federation, was conducted upon decision of the Governments of the Russian Federation and the Republic of Poland in compliance with the Standards and Recommended Practices of ICAO Annex 13.

ICAO Annex 13 is the only international document that defines the order of institution, arrangement and conducting of an investigation of aircraft accident involving two or more States. The provisions of Annex 13 regulate the rights and responsibilities of the States involved in the investigation as well as the order of completing and releasing the Final Report.

The investigation was conducted by the technical Commission of the Interstate (International) Aviation Committee. The Accredited Representative of the Republic of Poland, his Advisors and a large group of civil and military experts participated in all major aspects of the investigation provided by ICAO Annex 13. The Polish representatives were provided with materials pertinent to the investigation and were given an opportunity to get acquainted with extracts from classified documents of restricted access. The investigation was also participated by experts of research institutes and industry of the Russian Federation, the Republic of Poland and the USA.

According to the provisions of the Aeronautical Information Publication of the Russian Federation and countries of the Commonwealth of Independent States (Russian AIP) that regulates the air traffic management and international flights for all types of aviation on the territory of the Russian Federation, and according to the flight permission request sent by the Embassy of the Republic of Poland in the Russian Federation to the Ministry of Foreign Affairs of the Russian Federation, Flight PLF 101 was an international non scheduled (single) flight carrying passengers.

The possibility to carry out a non scheduled (single) flight on a state aviation aircraft of a foreign State to a Russian airdrome not open for international flights is explicitly stated in the Russian AIP. Based on the mentioned status of Flight PLF 101, the AIP provisions in parts applicable are to be considered as regulating documents for conduct and organization of this flight.

The provisions of the Federal Aviation Rules for State Aviation of the Russian Federation as well as other documents based on these Rules are only applicable to state aviation organizations of the Russian Federation and state aircraft of the Russian Federation and therefore

cannot be applied to Flight PLF 101 as it was not conducted by a state aviation organization of the Russian Federation or on a state aviation aircraft of the Russian Federation.

### 3.1 Findings

The analysis of the revealed facts and circumstances of the flight, the results of the field investigation, including the aerial photography and wreckage plot drawing as well as aircraft natural scale layout, the flight recorder readout data, the mathematical and semi-natural simulation, analysis of the air navigation and weather service, materials of the test fly-around of the aerodrome nav aids and lighting equipment, the findings of the examination of the remaining aircraft fragments and equipment, the results of the experiment on a Tu-154 flight simulator, the provided data on the flight crew and ATC group training, as well as maintenance documentation, operational and ATC assessments of the crew and controllers' actions conducted by international expert groups of pilots, air traffic controllers and aviation psychologists **revealed that:**

- 3.1.1 The Tu-154M aircraft tail number 101 was serviceable before the departure from Warsaw.
- 3.1.2 The aircraft had enough fuel onboard for the selected route considering the selected alternate airdromes. There was nothing wrong about the physical and chemical parameters of the fuel and oil.
- 3.1.3 The takeoff and landing weight as well as the center of gravity were within the limitations established by Section 2 of the AFM. However, the landing weight was about 4.6 tons higher than the limitations for the actual landing conditions at Smolensk "Severny" Airdrome. The stability and controllability characteristics complied with characteristics of the aircraft type.
- 3.1.4 The aircraft was equipped with the TAWS and FMS UNS-1D. Both systems were on and serviceable.
- 3.1.5 No evidence of aircraft, engine or system failures before the collision with obstacles was revealed. There was no fire, explosion or in-flight destruction before the collision with obstacles.
- 3.1.6 All destructions were caused by the impact forces during the obstacle and ground collisions.
- 3.1.7 Although the Tu-154M tail number 101 did not have a valid Airworthiness Certificate, the accident was not caused by the aircraft technical operation, maintenance or overhaul.



- 3.1.8 By the time of the departure from Warsaw the actual weather at the Smolensk "Severny" airdrome was lower than the established aircraft and PIC minima for approach using the available approach systems.
- 3.1.9 Before the departure the crew received the weather information for the departure airdrome, the alternate airdromes as well as for the flight route. The crew did not have the actual and forecast weather for the Smolensk "Severny" destination airdrome. The weather forecast for the alternate airdrome of Vitebsk was expired. The meteorological support for the VIP flight at departure from Warsaw was unsatisfactory.
- 3.1.10 The actual weather at the airdrome at the time of the accident was: visibility 300 – 500 m, vertical visibility 40-50 m, fog.
- 3.1.11 The actual visibility at the accident site (near the middle marker) was lower than at the airdrome due to the terrain peculiarity (lowland). The vertical visibility near the middle marker did not exceed 20 m.
- 3.1.12 During descent and approach the crew of the Tu-154 M aircraft was not once warned by the ATC and the crew of the Polish Yak-40 aircraft that had landed before at the Smolensk "Severny" Airdrome on the absence of required meteorological conditions for landing. The decision to proceed to the alternate airdrome was not taken, which can be considered as the beginning of the chain of events which led to the accident.
- 3.1.13 The weather observation arrangements at the Smolensk "Severny" Airdrome allowed informing the crew in due time on the worsening weather conditions. The accident was not caused by the deficiencies in meteorological support of the flight.
- 3.1.14 The Smolensk "Severny" Airdrome is suitable for various types of aircraft including Tu-154M under the established weather minima for the selected approach system.
- 3.1.15 The airdrome was not approved for international flights. The categorization in compliance with ICAO standards was not conducted. The airdrome does not have ground aids for automatic or flight director approach.
- 3.1.16 Considering the obstacles in the visual segment of approach, the glide path angle of 2°40'- 3°30' is acceptable for international flights.
- 3.1.17 The Polish side did not conduct technical (check) flights to the Smolensk "Severny" airdrome to try airdrome equipment and capabilities to accept VIP

flights considering the actual level of training of the crew members. The Polish side refused the leaderman (navigator) services.

- 3.1.18 All the airdrome navaids for the approach with the course of  $259^\circ$ , including two NDBs with markers and the landing radar system at the moment of the accident were on and serviceable. There were no breaks in the power supply. The equipment used on April 7 and 10 was the same.
- 3.1.19 The graphical glide path line on the landing radar screen of the landing zone controller was depicted with an actual angle of  $\sim 3^\circ 10'$  instead of the established  $2^\circ 40'$ , which means that the actual aircraft position in the accident flight was higher than the depicted one (with reference to the graphical glide path line) by about  $0.5^\circ$ .
- 3.1.20 The inaccuracy in the glide path line depicting does not affect the landing distance parameters and does not lead to early descent. When following a steeper glide path of  $3^\circ 10'$  instead of  $2^\circ 40'$ , the estimated vertical speed of 3.5 – 4 m/sec increases to 4 – 4.5 m/sec, and the middle marker should be passed 10 m higher than the established altitude of 70 m.
- 3.1.21 The communication aids were operating normally. The stable two-way radio communication was provided during the whole approach.
- 3.1.22 The lighting equipment of the airdrome before the flights on April 10 was serviceable. There were no complaints about the lighting received by the Safety Investigation Team from the crews of aircraft arriving at the airdrome on April 10 and at night from April 10 to April 11.
- 3.1.23 The inspection of the lighting equipment at 9:00 on 11.04.2010 revealed mechanical damage (lamps are partly broken, torn power cable) of Group I, II and III lights (at a distance of 900, 800 and 700 m from RWY 26 threshold respectively) that were located beyond the airdrome in the city.
- 3.1.24 In the actual weather conditions at the time of the accident it was impossible for the crew to establish visual contact with the lighting elements from the established minimum descent altitude of 100 m considering the aircraft position on the glide path.
- 3.1.25 According to the provided documents the training and qualification of the ATC group personnel complied with the established state aviation regulations of the Russian Federation. The ATC group personnel were the same on April 7 and 10.

- 3.1.26 The crew did not pass recurrent training on a Tu-154 simulator to train CRM skills including the emergency situations in flight and during approaches using various landing systems and on-board equipment.
- 3.1.27 The special air regiment of the Polish Air Forces had no SOP for the four-member crew of the Tu-154M.
- 3.1.28 The crew for the flight was formed on April 2. The PIC had previously conducted 3 flights to the Smolensk "Severny" Airdrome (all as a Co-pilot), while the other crew members had never flown to that airdrome before.
- 3.1.29 The crew for the VIP flight was formed without considering the actual level of training of each crew member. The PIC had a break of over 5 months in approaches on Tu-154M in complicated meteorological conditions corresponding to his weather minima 60x800. The PIC's flight log contains records only about 6 NDB approaches within his experience as a PIC of Tu-154M, last conducted in December 2009 (all in simple meteorological conditions). The navigator did not fly Tu-154M for the last 2.5 months permanently conducting flights as a co-pilot of Yak-40.
- 3.1.30 The crew members had valid medical licenses. No violations of the work and rest balance were detected. No evidence of alcohol or other prohibited substances was revealed by the coronary examination. The accident was not caused by the health or capacity of the crew members.
- 3.1.31 The chiefs of the air regiment did not monitor the preparation for the VIP flight.
- 3.1.32 The selection of the alternate airdromes was not coordinated with the visit managers: The President's Chancellery and the Security Board.
- 3.1.33 Before the flight the crew did not have the actual aeronautical data for the Smolensk "Severny" destination airdrome and the Vitebsk alternate airdrome including the current NOTAMs. The Vitebsk airdrome could not have been chosen as an alternate airdrome as according to its working schedule it was closed on weekends.
- 3.1.34 The available aeronautical data for the Smolensk "Severny" airdrome provided only 2 NDBs approach for the Tu-154M. The crew did not have data on the weather minima for the other landing systems (landing radar+2NDB, landing radar) before the flight.
- 3.1.35 The aircraft departed from Warsaw at 9:27, with a 27-minute delay with regard to the changed departure time (9:00). Initially the flight had been planned for 08:30.

- 3.1.36 The radio communication with the Minsk Control and the Moscow Control was maintained by the navigator in English. The radio communication with the ATC group of Smolensk "Severny" airdrome was maintained by the PIC in Russian. The radio communication with the Yak-40 crew was conducted in Polish. The general level of the PIC's Russian was satisfactory. Most probably the other crew members did not speak sufficient Russian.
- 3.1.37 The CVR record did not contain the landing briefing. Therefore it was impossible to define if the crew discussed the approach system, the approach mode, the duty distribution, the piloting procedures and the missed approach (proceeding to the alternate airdrome) considering the actual weather conditions.
- 3.1.38 According to the CVR record and voice identification conducted by the Polish experts there were unauthorized persons present in the cockpit during the descent and approach including the Protocol Director and the Commander-in-Chief of the Polish Air Forces, who was in the cockpit during the final descent until the ground collision.
- 3.1.39 The presence of unauthorized persons in the cockpit who discussed with the crew the possible variants of continuing flight and the reaction of the Main Passenger induced psychological pressure on the crew and on the PIC in the first place and increased his emotional stress.
- 3.1.40 Considering the absence of weather conditions to approach using the available landing systems on the destination aerodrome the PIC decided to make a "trial" approach. It was an international flight conducted in accordance with the Russian AIP. In compliance with the Russian AIP<sup>53</sup> the controller permitted the "trial" approach but further warned the crew to be ready for go around from 100 m. The crew explicitly confirmed that instruction.
- 3.1.41 When requesting the trial approach the crew did not specify the approach system and they did not request landing radar. Most likely, the crew did not use the LOM and the LMM for navigation and they approached by use of the onboard means.

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<sup>53</sup> Russian AIP. AD 1.1-1 Para.1 c) pilots-in-command of foreign aircraft operating in Russia, shall make a decision on the possibility of taking-off from an aerodrome, and of landing at destination aerodrome on their own, assuming full responsibility for the decision taken;

As follows from the Decree on Denial to Initiate a Criminal Case dated October 1, 2008 executed by the Deputy of the Military Garrison Prosecutor of Vroclav (Section 1.17.1) similar provisions as to the rights and responsibilities of the PIC concerning the final decision to take off, land or terminate flight exist in the aviation regulations of the Republic of Poland.

- 3.1.42 After clearing the crew for the "trial" approach in the weather conditions below the airdrome minima in accordance with the Russian AIP, the ATC group personnel further informed the crew on the aircraft position and the weather conditions within the capabilities of their equipment.
- 3.1.43 At the transition level the crew set the QFE of 745 mm of mercury on the barometric altimeters which had been transmitted by the controller earlier.
- 3.1.44 Descent on final was made with the AP engaged in the pitch and roll channels and with the autothrottle engaged. The crew controlled the aircraft pitch using AP "CLIMB-DESCENT" control wheel. This type of approach was not provided by the aircraft FCOM, and the weather minima and SOP were not determined.
- 3.1.45 The final descent was initiated with a delay despite the timely controller's input on reaching the glide path entrance point. None of the crew members reported reaching the glide path entrance point and estimated vertical speed on the glide path.
- 3.1.46 Before initiating descent on final the aircraft was set to landing configuration: flaps 36°, landing gears down.
- 3.1.47 The crew initiated final descent from the distance of about 9 km from RWY 26 threshold. Before the distance of 6 km they could not achieve descent with constant vertical speed. The descent was conducted at increased speed of about 300 km/h (the estimated speed being 265 km/h) with variable vertical speed.
- 3.1.48 At a distance of about 8 km the crew reported extended landing gear and flaps. Considering the actual weather conditions below the minima the ATC instructed: "standby for landing" which means that landing was not cleared. Further the crew did not report establishing visual contact with the runway, the controller did not clear the aircraft for landing, and the crew did not report initiating the go around on reaching the established minimum descent altitude of 100 m.
- 3.1.49 After passing the outer marker, the next point in the active FMS flight plan was the ARP which is 1250 m down RWY 26 threshold. The coordinates of the LMM and RWY 26 threshold were not entered into the FMS by the crew.
- 3.1.50 At a distance of 8, 6, 4 km from the threshold as the aircraft was within the glide path tolerance area (above the glide path) with reference to the depicted glide path line on the landing radar screen (glide path angle of  $\sim 3^{\circ}10'$ ), the landing zone controller informed the crew that they were on the glide path. At a distance of 3 km the aircraft was almost on the glide path (glide path angle of  $\sim 3^{\circ}10'$ ).

- 3.1.51 After passing the outer marker the crew selected the pitch angle with AP "CLIMB-DESCENT" control wheel which resulted in vertical rate of descent of 7–8.5 m/sec, which was two times higher than the estimated rate.
- 3.1.52 Considering the actual difference of the indicated air speed and the vertical speed from the estimated values, none of the crew members reported the deviations. The crew also did not monitor the flight altitude by the distance from the runway threshold while conducting the non-precision approach.
- 3.1.53 From the height of 300 m the navigator called out the flight altitude using the radio altimeter readings, which did not comply with the SOP and misinformed the crew on the flight altitude over uneven terrain.
- 3.1.54 The first TAWS TERRAIN AHEAD alert was triggered at a distance of 4 km from the point of first impact at an altitude of about 340 m. The crew did not react to this warning.
- 3.1.55 At a distance of 4700 m from RWY 26 threshold and at an altitude of about 300 m the standard pressure of 760 mm of mercury was set on the PIC's main pressure altimeter, which led to the increased altimeter indications by about 165 m and stopped the TAWS alert. The second PIC's altimeter UVO-15M1B and co-pilot's main pressure altimeter retained the QFE setting (745 mm of mercury).
- 3.1.56 The second triggering of the TAWS TERRAIN AHEAD alert was at the distance of 2 km from the point of first impact at an altitude of about 180 m. The crew did not react to that warning either.
- 3.1.57 At a distance of 2800 m from RWY 26 threshold the aircraft crossed the nominal glide path (glide path angle 2°40') and in 3 seconds the landing zone controller informed the crew of aircraft position being on the course and glideslope. The flight altitude was 115 m which almost matched the missed approach altitude.
- 3.1.58 At a distance of about 2400 m from RWY 26 threshold the aircraft passed the established minimum descent altitude of 100 m. Deviating from the FCOM the "Decision" request to the PIC (from co-pilot or navigator) and his decision to go around did not follow. In a second the TAWS PULL UP alert fired, which was active until the aircraft was destroyed. The flight recorders did not record any crew actions to terminate descent and initiate climb after the alert.
- 3.1.59 At a distance of 1200-600 m from the point of first impact during the actual descent with the vertical speed of about 8 m/sec, the CVR recorded three reports within 8 seconds about the height of 100 m, equal to the established minimum descent altitude. At that stage of the flight path there exists lowering terrain down

to minus 60 m with reference to RWY 26 threshold. The PIC's decision to go around did not follow.

- 3.1.60 The firing of the radio altimeter decision height alert set to 60 m, as well as the co-pilot's callout "Go around!" occurred before passing the middle marker at a distance of 400 m before the point of first impact at an altitude of 15-20 m with reference to RWY 26 threshold. If the crew had taken active measures to go around at that moment most probably they could have prevented the accident.
- 3.1.61 The landing zone controller not having received the crew report on going around instructed them: "Level, 101". The crew actions to terminate descent did not follow and the aircraft continued descent.
- 3.1.62 The lack of crew actions on passing the established minimum descent altitude of 100 m, no reaction to the TAWS alerts and decision height alert as well as to the landing controller's instruction to terminate descent can evidence the crew's attempt to establish visual flight before passing the middle marker to make a visual landing.
- 3.1.63 The presence of unauthorized persons in the cockpit during the approach increased the stress and distracted the crew from their duties. The communication analysis reveals that in case of missed approach and proceeding to alternate airdrome the PIC expected negative reaction of the Main Passenger.
- 3.1.64 On final the PIC was experienced psychological clash of motives: on the one hand he understood that the landing in the actual conditions was unsafe and on the other hand there was strong motivation to land exactly at the destination airdrome. The presence of the Commander-in-Chief of the Polish Air Forces until the collision affected the PIC's decision to continue approach and descend lower than the minimum descent altitude without establishing visual contact with the ground references.
- 3.1.65 The first collision with an obstacle without structural destruction occurred before the middle marker at a distance of about 1100 m from the runway threshold, 35 m left from the extended RWY centerline at a height of about 10 m above terrain. The altitude of the aircraft with reference to the runway threshold elevation considering the terrain peculiarities (lowland) and the tree height was about minus 15 m.
- 3.1.66 The crew instinctive actions: pulling up the control wheel which led to disengaging the autopilot in the pitch channel by overpowering and setting the throttles to takeoff position with disengaging the autothrottle occurred almost at



the moment of the first impact with the obstacle which confirms the extremely low visibility and vertical visibility near the middle marker as well as the failure of the crew to take the go-around decision.

- 3.1.67 The medical tracing investigation revealed that these actions were taken by the PIC who was at his working seat fastened by seat belts. The other crew members were also at their working seats and fastened.
- 3.1.68 Results of the medical tracing investigation of the injuries sustained by the Commander-in-Chief of the Polish Air Forces correspond to his presence in the cockpit at the time of the impact with the ground. The coronary examination conducted at the Department for Coronary Expertise of the State Health Enterprise of Moscow “Bureau of Coronary Expertise of the Moscow Health Department” revealed 0.6‰ of ethanol in the blood of the Commander-in-Chief of the Polish Air Forces.
- 3.1.69 In 4-5 seconds after the first collision with the obstacle the aircraft collided with the birch with a trunk diameter of 30-40 cm, which led to the left outer wing portion of about 6.5 m ripped off and intensive left bank.
- 3.1.70 In 5-6 more seconds, inverted, the aircraft collided with the ground and was destroyed.
- 3.1.71 As the aircraft was destroyed, the passengers and crew members on board were exposed to acceleration forces more than 100 g. The coronary expertise revealed that deaths of all persons on board occurred immediately at the moment of the crash due to multiple injuries incompatible with life sustained as a result of traumatic effect of excessive deceleration and breaking aircraft parts.
- 3.1.72 Actions of all rescue services were correct and timely, which allowed preventing the development of ground fire and secure the flight recorders, aircraft structural parts and remains of the persons of board.

### 3.2 Causes

#### Considering that:

- The Tu-154M aircraft was serviceable before the departure from Warsaw. No evidence of aircraft, engine or system failures before the collision was revealed. There was no fire, explosion or in-flight destruction before the collision;
- There were serious shortcomings in the arranging of the VIP flight concerning the crew training, composition, monitoring of its preparation and selection of alternate airdromes;
- The departure was conducted without available actual and forecast weather and the actual aeronautical information for the destination aerodrome. According to available information the Polish side refused the leaderman (navigator) services;
- In the course of the flight the crew of the Tu-154M not once was informed by the ATC of the Republic of Byelorussia and the Smolensk "Severny" airdrome as well as the crew of the Polish Yak-40 aircraft that had already landed on Smolensk "Severny" airdrome on the incompliance of the actual weather conditions at the destination airdrome to the established minima. Despite that, the crew did not take a decision to proceed to the alternate airdrome which can be considered as the beginning of the chain of events which led to the accident;
- On contacting the ATC group of Smolensk "Severny" airdrome the crew did not report the selected approach system to them which deviated from the Russian AIP requirements. Further the crew continued approach using the on-board equipment without utilizing ground navigation aids;
- The crew requested conducting a "trial" approach in the actual weather conditions below the established minima for landing. In compliance with the Russian AIP (Russian AIP AD 1.1-1 Para.1 c) Pilots-in-command of foreign aircraft operating in Russia, shall make a decision on the possibility of taking-off from an aerodrome, and of landing at destination aerodrome on their own, assuming full responsibility for the decision taken) the controller cleared the crew for the "trial" approach provided they should descend not lower than 100 m and go around from that altitude. The crew confirmed they received that instruction;
- Before the final turn the crew of the Yak-40 warned the crew of the Tu-154M that the visibility was 200 m. This warning did not affect the decision of the Tu-154 crew who continued the approach;
- The PIC had a break of over 5 months in approaches in complicated meteorological conditions (corresponding to his weather minima 60x800) on Tu-154M. The PIC had not

had enough training on approaches in manual steering mode using non precision type of approaches.

- The approach was made using the autopilot in pitch and roll channels as well as the autothrottle. This type of approach is not provided by the Tu-154M FCOM and the weather minima and SOP for this type of approach are not described there;
- The crew did not receive the clearance to land from CATC;
- The crew interaction and the PIC's CRM were unsatisfactory;
- Despite the established procedure, from 300 m the navigator started altitude callouts on the basis of the radio altimeter indications;
- The crew did not terminate descent at the established minimum descent altitude of 100 m, but continued descent with a vertical speed two times higher than the estimated without establishing visual contact with the ground references;
- Despite the numerous TAWS (TERRAIN AHEAD and PULL UP) alerts, the triggering of the radio altimeter decision height alert at 60 m and the ATC instruction, the crew continued descent which can be an evidence of their attempt to establish visual flight before passing the middle marker in order to conduct a visual landing;
- The operation of the ground based navigation and lighting equipment did not affect the accident;
- The presence of high-ranked persons in the cockpit including the Commander-in-Chief of the Polish Air Forces and the Protocol Director, and negative reaction of the Main Passenger expected by the PIC exposed psychological pressure on the crew members and influenced the decision to continue approach in the conditions of unjustified risk.

**The investigation team concludes that:**

**The immediate cause** of the accident was the failure of the crew to take a timely decision to proceed to an alternate airdrome although they were not once timely informed on the actual weather conditions at Smolensk "Severny" Airdrome that were significantly lower than the established airdrome minima; descent without visual contact with ground references to an altitude much lower than minimum descent altitude for go around (100 m) in order to establish visual flight as well as no reaction to the numerous TAWS warnings which led to controlled flight into terrain, aircraft destruction and death of the crew and passengers.

According to the conclusion made by the pilot-experts and aviation psychologists, the presence of the Commander-in-Chief of the Polish Air Forces<sup>54</sup> in the cockpit until the collision exposed psychological pressure on the PIC's decision to continue descent in the conditions of unjustified risk with a dominating aim of landing at any means.

**Contributing factors to the accident were:**

- long discussion of the Tu-154M crew with the Protocol Director and crew of the Polish Yak-40 concerning the information on the actual weather that was lower than the established minima and impossibility (according to the Tu-154M crew opinion) to land at the destination airdrome which increased the psychological stress of the crew and made the PIC experience psychological clash of motives: on the one hand he realized that landing in such conditions was unsafe, on the other hand he faced strong motivation to land exactly at the destination airdrome. In case of proceeding to an alternate airdrome the PIC expected negative reaction from the Main Passenger;
- lack of compliance to the SOP and lack of CRM in the crew;
- a significant break in flights in complicated weather conditions (corresponding to his weather minima 60x800) that the PIC had had as well as his low experience in conducting non-precision approach;
- early transition by the navigator to the altitude callouts on the basis of the radio altimeter indications without considering the uneven terrain;
- conducting flight with engaged autopilot and autothrottle down to altitudes much lower than the minimum descent altitude which does not comply with the FCOM provisions;
- late start of final descent which resulted in increased vertical speed of descent the crew had to maintain.

**The systematic causes** of the accident involving the Tu-154M tail number 101 aircraft of the Republic of Poland were significant shortcomings in the organization of flight operations, flight crew preparation and arrangement of the VIP flight in the special air regiment.

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<sup>54</sup> The coronary expertise revealed 0.6‰ of ethanol in the blood of the Commander-in-Chief of the Polish Air Forces

## 4. Safety Recommendations

4.1. Recommendations given in the course of investigation to the commander of the special air regiment of the Polish Air Forces:

4.1.1. Develop and implement the procedure of recurrent simulator training for the crews of Tu-154M aircraft including checkrides to confirm the weather minima, training for various types of approaches as well as emergency situations training with an emphasis on the crew actions in case of TAWS warnings;

4.1.2. Develop and implement SOP guidelines for Tu-154M crews emphasizing the crew interactions:

- during a non-precision approach with regard to monitoring the height by the flight instruments and distance from the runway;
- using autoflight modes;
- setting the decision height bug on the radio altimeter depending on the type of approach;

4.1.3. When dispatching flights consider the necessity of collecting all weather, navigation and other kinds of information for the intended flight route as well as the destination and alternate aerodromes especially when flying to aerodromes not listed in the AIP of the State of intended landing.

4.2. States: Consider the practicability of amending the national regulations to prohibit the presence of persons not included in the flight task in the cockpit as well as to determine liability for violating this provision.

4.3. States: Consider the practicability of amending the national regulations providing that any passenger flight regardless of the type of aviation shall be only conducted in compliance with the rules stipulated by the ICAO Convention, its Annexes and other pertinent documents including the rules of crew training, aircraft preparation as well as passenger and crew insurance aspects and carrier liability.

4.4. States: Consider the practicability of amending the national regulations providing all the necessary conditions including technical (check) flights to provide safety of international flights on airways and to aerodromes not open for international air navigation.

4.5. Ministry of Defense of the Republic of Poland and Ministry of Defense of the Russian Federation: take measures to enhance the role and efficiency of state control over flight safety in state aviation and eliminate the shortcomings mentioned in the Report.