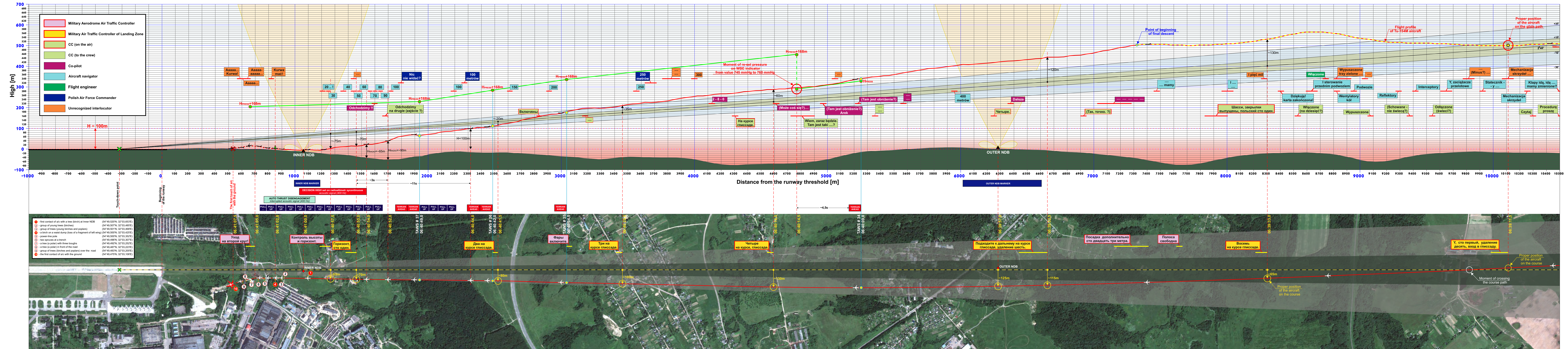


LANDING APPROACH PROFILE

Annex No 1.1 – Landing approach profile of Tu-154M aircraft tail number 101 at SMOLEŃSK
NORTH aerodrome on 10.04.2010 (from 3500 m)

Annex No 1.2 – Landing approach profile of Tu-154M aircraft tail number 101 at SMOLEŃSK
NORTH aerodrome on 10.04.2010 (from 10500 m)

Landing approach profile of Tu-154M aircraft tail number 101 at SMOLEŃSK NORTH aerodrome on 10.04.2010 (from 10500 m) according to UTC



- Military Aerodrome Air Traffic Controller
- Military Air Traffic Controller of Landing Zone
- CC (on the air)
- CC (to the crew)
- Co-pilot
- Aircraft navigator
- Flight engineer
- Polish Air Force Commander
- Unrecognized interlocutor

- - first contact of air with a tree (birch) at inner NDB (54°49.520'N, 32°03.653'E)
- - group of young trees (birches) (54°49.507'N, 32°03.469'E)
- - group of trees (young birches and poplars) (54°49.501'N, 32°03.469'E)
- - a birch on a wast dump (base of a fragment of left wing) (54°49.500'N, 32°03.429'E)
- - power-line pole (54°49.500'N, 32°03.302'E)
- - two telepoles at a trench (54°49.489'N, 32°03.307'E)
- - a tree (a poplar) with three boughs (54°49.492'N, 32°03.252'E)
- - a tree (a poplar) in front of the road (54°49.487'N, 32°03.223'E)
- - group of trees (birches and poplars) over the road (54°49.483'N, 32°03.209'E)
- - the first contact of air with the ground (54°49.475'N, 32°03.106'E)

Description and analysis of the operation of on-board systems of Tu-154M aircraft No 101

TABLE OF CONTENTS

1. TAWS and FMS.....	2
1.1. TAWS.....	2
1.2. Flight Management System (FMS).....	4
2. Recording equipment installed on Tu-154M aircraft	5
2.1. Flight recording systems	5
2.2. Comparison of records from the MLP-14-5, KBN-1-1 and ATM-QAR recorders	6
2.3. MARS-BM cockpit voice recorder.....	7
2.4. Synchronization of MSRP and MARS-BM records.....	9
3. Operational assessment of the Tu-154M aircraft systems based on an analysis of MSRP and ATM-QAR records.....	10
3.1. ABSU autopilot system.....	10
3.2. Hydraulic system	24
3.3. Analysis of the power plant operation	28
3.4. Fuel system.....	36
3.5. Tu-154M aircraft anti-icing system	37
3.5.1. Engine anti-icing system.....	37
3.5.2. Wing and fin anti-icing system	37
3.5.3. Slat anti-icing system	37
3.5.4. Ice warning system.....	38
3.5.5. PDD air pressure receiver anti-icing system.....	38
3.6. Analysis of electrical system operation	40
3.7. Operability of on-board instruments based on an analysis of a record of selected flight parameters.....	44
4. Aircraft use by the pilot on the flight during which the aviation occurrence took place ..	48
5. Conclusions on the expert examination of flight recorders from the Tu-154M aircraft....	56

1. TAWS and FMS

The Tu-154M aircraft No 101 was equipped with the Terrain Awareness and Warning System (TAWS) and the Flight Management System (FMS). Both systems were manufactured by Universal Avionics Systems Corporation (UASC), USA.

1.1. TAWS

The purpose of the TAWS is to warn the aircraft crew of flight conditions arising which can lead to inadvertent collision with terrain.

The TAWS fulfills the following functions:

- 1) Imaging of terrain configuration with reference to the current and forecasted aircraft position;
- 2) Triggering early warnings of ground proximity;
- 3) Triggering premature descent warnings;
- 4) Triggering of alerts in accordance with the functional modes of the standard Ground Proximity Warning System (GPWS) in the following modes:
 - a) excessive rate of descent;
 - b) excessive terrain approach rate;
 - c) loss of altitude after takeoff or during a go-around;
 - d) flight in the proximity of the ground in non-landing configuration;
 - e) unallowable deviation below glide path;
- 5) Visual and audible alerts for the crew;
- 6) Indication of the current flight plan from the FMS on the terrain background.

The structure of the TAWS and its interaction with the on-board equipment of the Tu-154M aircraft No 101 is shown in the chart below (Fig. 1).



SYSTEM Wczesnego Ostrzegania o Zbliżeniu z Ziemią TAWS	TERRAIN AWARENESS AND WARNING SYSTEM (TAWS)
ROZMÓWNIKA POKŁADOWA	SPU (headsets)
LEWY PILOTA	PILOT LEFT
PRAWY PILOTA	PILOT RIGHT
WSKAŹNIK TCAS	TCAS SPEAKER
PULPIT SYGNALIZACJI	INDICATOR PANEL
ZŁĄCZE DIAGNOSTYCZNE TAWS	TAWS TEST CONNECTOR
MODUŁ KONFIGURACJI	CONFIGURING MODULE
BLOK INTERFEJSU TSKA-E	TSKA-E INTERFACE UNIT
RW-5 NR 1	RV-5 No 1
RW-5 NR 2	RV-5 No 2
UNS NR 1	UNS No 1
UNS NR 2	UNS No 2

Fig. 1. TAWS structural diagram

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 forms advance warnings and alerts on potential dangers. The system generates ground proximity warnings and alerts by comparing the aircraft position parameters from the FMS with the corresponding parameters held in the terrain database. The terrain database residing in the system's memory contains data on points spaced approximately 0.5 mile apart around the world, 0.25 mile apart between S60° and N70° within 15 naval miles from every large airport and 0.1 mile apart within 6 naval miles of airports in the mountains.

The Supplement to the Tu-154M Flight Crew Operation Manual for aircraft equipped with TAWS contains the following additional limitation: “when landing at an airport not included in the airport database, the early ground proximity warning function of the TAWS

should 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 to the Flight Crew Operation Manual contains a warning concerning the prohibition of the use of TAWS information displayed on MFD-640 for.

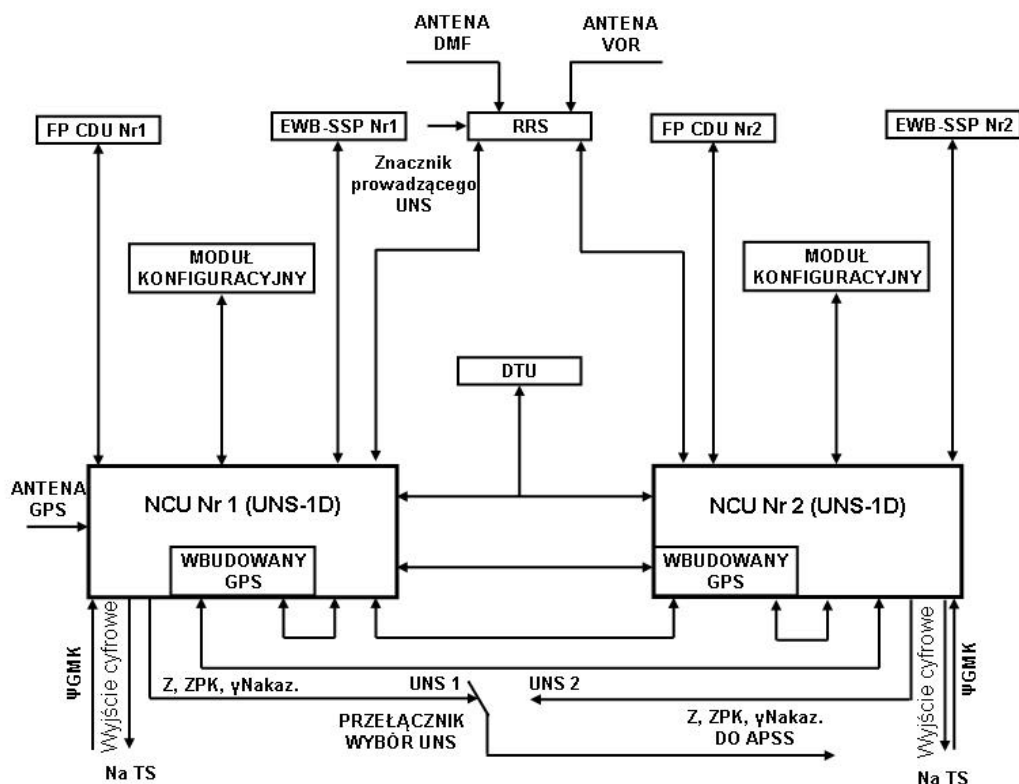
There is a special feature of the TAWS operation while piloting with the use of the QFE barometric altitude correction. To prevent false warnings, before setting the QFE at the electronic pressure altimeter (VBE-SVS) the QFE flight mode must be engaged by pressing the relevant light button (Supplement to the Flight Crew Operation Manual, Para 8.17.8a.2 (5)). However, the same paragraph of the Flight Crew Operation Manual contains a warning that simultaneous use of the 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.

1.2. Flight Management System (FMS)

The Flight Management System (FMS) supports in-flight navigation operations all over the world. The aircraft has two instances of the system installed. The FMS structure and its interaction with the on-board system gauges are shown on the chart below (

ANTENA DMF	DME ANTENNA
ANTENA VOR	VOR ANTENNA
FP CDU Nr1	FP CDU No1
WB-SSP Nr 1	VBE-SVS No 1
RRS	RRS
FP CDU Nr 2	FP CDU No 2
EWB-SSP Nr 2	VBE-SVS No 2
MODUŁ KONFIGURACYJNY	CONFIGURING MODULE
Znacznik prowadzącego UNS	UNS leading token
DTU	DTU
ANTENA GPS	GPS ANTENNA
NCU Nr 1 (UNS-1D)	NCU No 1 (UNS-1D)
NCU Nr 1 (UNS-1D)	NCU No 1 (UNS-1D)
WBUDOWANY GPS	BUILT-IN GPS
ΨGMK	ΨGMK
Wyjście cyfrowe	Discrete output
Z, ZPK, PK, γNakaz.	Z, STA, γSel
UNS 1	UNS 1
PRZEŁĄCZNIK WYBÓR UNS	SWITCH SELECT UNS
Z, ZPK γNakaz. DO APSS	Z, STA, γSel to ABSU
Na TS	To TC

Fig. 2).



ANTENA DMF	DME ANTENNA
ANTENA VOR	VOR ANTENNA
FP CDU Nr1	FP CDU No1
WB-SSP Nr 1	VBE-SVS No 1
RRS	RRS
FP CDU Nr 2	FP CDU No 2
EWB-SSP Nr 2	VBE-SVS No 2
MODUŁ KONFIGURACYJNY	CONFIGURING MODULE
Znacznik prowadzącego UNS	UNS leading token
DTU	DTU
ANTENA GPS	GPS ANTENNA
NCU Nr 1 (UNS-1D)	NCU No 1 (UNS-1D)
NCU Nr 1 (UNS-1D)	NCU No 1 (UNS-1D)
WBUDOWANY GPS	BUILT-IN GPS
ΨGMK	ΨGMK
Wyjście cyfrowe	Discrete output
Z, ZPK, PK, γNakaz.	Z, STA, γSel
UNS 1	UNS 1
PRZEŁĄCZNIK WYBÓR UNS	SWITCH SELECT UNS
Z, ZPK γNakaz. DO APSS	Z, STA, γSel to ABSU
Na TS	To TC

Fig. 2. Flight Management System (FMS) structural diagram

The Flight Management System provides lateral control signal (target roll) to the ABSU-154-2 autopilot as well as aircraft position information to the cockpit indicators (Z, ZPU) along

with the operability signal. The system does not provide vertical control signal (target pitch)

Section 8.16.9 of the Supplement to the Flight Crew Operation Manual restricts the use of the FMS:

- The use of the system under the Standard Instrument Departure (SID) and the Standard Terminal Arrival Route (STAR) procedures is allowed for reference only (no automatic control);
- The use of vertical navigation mode is allowed for reference only.

2. Recording equipment installed on Tu-154M aircraft

2.1. Flight recording systems

The following recorders of the Tu-154M aircraft were found at the accident site on 10 April 2010: flight data recorder MLP-14-5, quick access recorder KBN-1-1, the ATM-MEM15 memory unit (recovered from remnants of the ATM-QAR recorder). The K3-63 recorder was not found at the accident scene. All information recorded by the recorder is also recorded by the MSRP and ATM-QAR systems.

The readout of data from the MLP-14-5 and KBN-1-1 recorders was performed in Moscow at the headquarters of the Interstate Aviation Committee in the presence of Polish experts and a Polish military prosecutor. The Russian side handed over to the Committee a copy of the original data retrieved from the flight data recorder MLP-14-5 and the quick-access recorder KBN-1-1 on 31 May 2010.

Data readout from the ATM-MEM15 memory unit of the ATM-QAR recorder was carried out in Warsaw at the Air Force Institute of Technology. Readout of all data was successful. The files for analysis were created on the basis of calibration charts provided by the 36th Special Transport Air Regiment. The calibrations were confirmed by data supplied by the repair plant where the last overhaul of the aircraft was performed.

Data analysis was performed using the FDS (Flight Data Service) software, versions 6 and 8 developed by ATM (Advanced Technology Manufacturing).

2.2. Comparison of records from the MLP-14-5, KBN-1-1 and ATM-QAR recorders

In order to compare the content of files containing data recorded during the flight of 10 April 2010 by the MLP-14-5, KBN-1-1 and ATM-QAR a comparison of code values of selected parameters was performed. The comparison method was based on the recorded

structure. As the master unit containing time is the subframe¹, complete subframes were separated from the records, containing the aircraft code number². The first samples of these parameters were isolated from each subframe:

- pressure altitude;
- pitch;
- roll.

The parameters were selected as representative ones, as it is not possible to perform two identical flights, where any of the selected parameters could have the same value throughout the flight in both records.

The MSRP and ATM-QAR recorders record hours and minutes, while seconds are calculated by adding 0.5 s per each successive data frame (2 frames are recorded within 1 s). The calculations are performed based on data from each first frame after a full minute change.

As a result of the calculations performed, 229 benchmark points were obtained (at 1 min intervals). It was concluded that the number of record errors from the KBN-1-1 recorder was negligible. A large number of errors are clearly seen in the record from the MLP-14-5 recorder, but this does not affect the overall picture of the recorded flight.

The comparison result explicitly shows that three files:

- Msrp64.dta - decompressed record from the ATM-QAR recorder;
- KBN.DAT - record from the KBN-1-1 recorder;
- 85837.FDR.ALLData.dat - record from the MLP-14-5 recorder,

contain records of the same flight.

Owing to the completeness of data and a lack record distortions, the ATM-QAR record was selected for further work.

The compression algorithm hardwired in ATM-QAR series recorders causes a 1.5 s delay in data saving to memory. The last correct data were recorded at 0841:02.5³. In order to fill the missing 1.5 s of record, an attempt was made to retrieve data from the MLP-14-5 recorder⁴. According to the record made by the MLP-14-5 (85837.FDR.ALLData.dat file), 4

¹ A data structure unit in the MSRP system. It lasts 5 s and contains 10 frames. The first byte of each frame is used to record service data (hour, minute, day, month, last digit of the year, flight number, aircraft code number). Subsequent frames in the subframe contain the next of the 10 bytes of service data.

² A three-byte code corresponding to the aircraft serial number, in this case 085837.

³ The whole Appendix 2 refers to Warsaw local time as entered in the ATM-QAR recorder.

⁴ The record from the KBN-1-1 recorder ends several minutes before the beginning of the 41st minute, hence it was useless for the purpose.

frames were isolated, containing the seconds 41:02 and 41:03. In the ATM-QAR record, the last frame (last half-second) was removed and 4 frames were added to it from the MLP-14-5 record. As a result of the operations performed, a complete flight record was obtained for the Tu-154M aircraft No 101 of 10 April 2010, ending at 0841:04. It is assumed that within less than 0.5 s after 0841:04 the power supply system of the MSRP was damaged, which interrupted its operation.

2.3. MARS-BM cockpit voice recorder

The MARS-BM cockpit flight recorder installed in Tu-154M aircraft No 101 recorded the following acoustic information:

- Track 1 – pilot-in-command – pilot-in-command headset (with audio signal return);
- Track 2 – co-pilot – co-pilot headset (with audio signal return);
- Track 3 – aggregate signals from three microphones situated in the aircraft cockpit;
- Track 4 – encoded time signal (hour and minute given every 0.5 s).

The sound record in track 4 is a time record encoded in an eleven-position string of repeatable pulses at 0.5 s intervals.

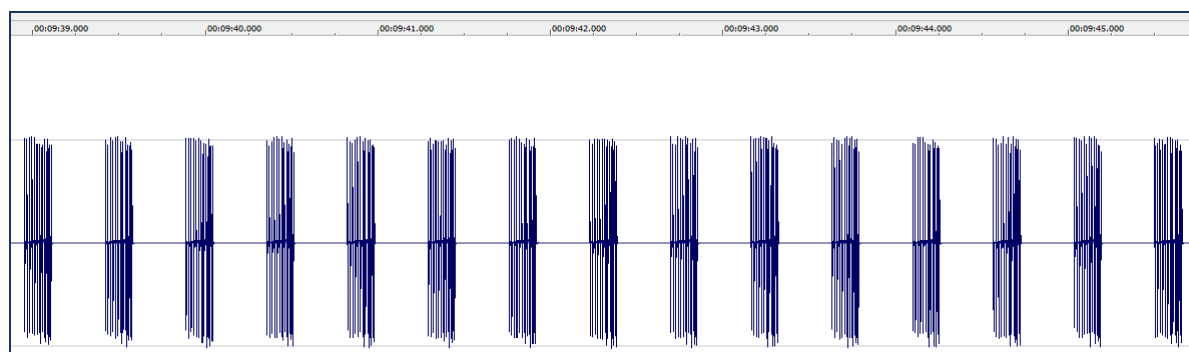


Fig. 3. Fragments of time marker signals

A single time marker consists of 11 evenly spaced timing pulses grouped in three sections (4-3-4). A timing pulse is followed by an information pulse. Such organization of the string of pulses allows information on minute and ten-minute units and hour units to be encoded in binary mode (Fig. 4).

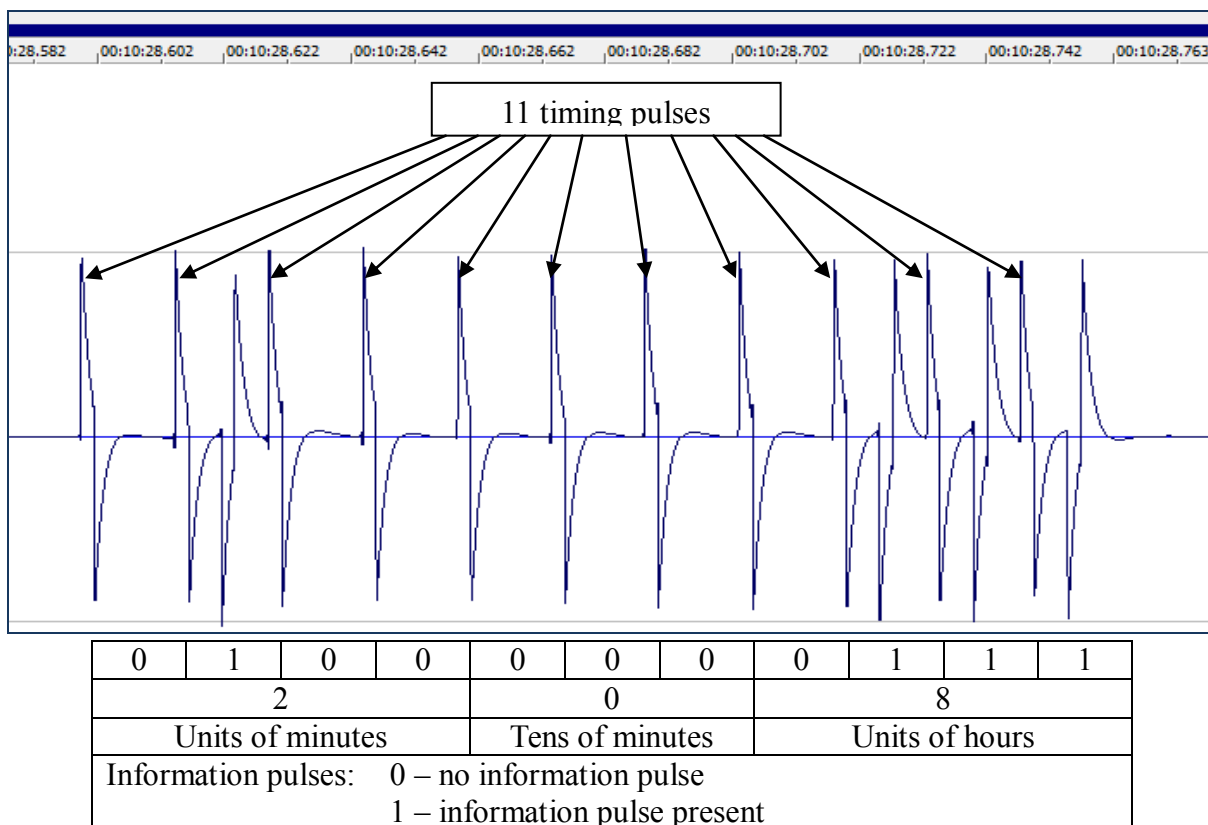


Fig. 4. Time encoding method in Track 4 – recording start at 8 hours 02 minutes

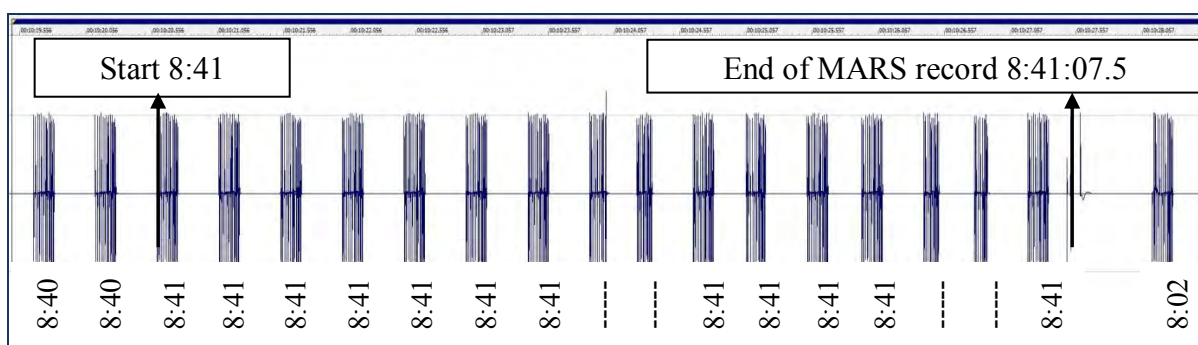


Fig. 5. View of the last 16 recorded time markers at 8:41

An analysis of the record on Track 4 shows that before the change of hour at the start of recording 12 identical time markers were recorded with encoded hour 8:02, which means that recording started no later than 0.5 s after 08:02:53.5. The end of the recording was identified in the same manner – it was determined that it was the 16th time signal with the same structure recorded at the end of the recording⁵ (Fig. 5). On that basis, it was determined that the end of recording by the MARS-BM recorder occurred no later than 0.5 s after 08:41:07.5.

The total time of recording is **38 min 14 s**.

⁵ Four incorrect pulse strings in the final stage of the recording were caused by vibrations resulting from the aircraft's collision with trees.

2.4. Synchronization of MSRP and MARS-BM records

The MSRP recording system uses the ITW-4 unit to measure flight time. Current time is entered in the ITW-4 before flight by the personnel preparing the aircraft. On 10 April 2010, Warsaw time was entered in the ITW-4. Flight time measured by the ITW-4 is recorded directly on the fourth track of the MARS-BM cockpit voice recorder and, owing to the encoding method adopted, it is recorded with delay in the MSRP and ATM-QAR systems. The maximum delay in time record in the MSRP and the ATM-QAR compared with the MARS-BM does not exceed 5 s.

The delay of record in MSRP compared with the MARS-BM was determined by comparing the moment of occurrence of phenomena characteristic of the collision with an obstacle, in consequence of which the tip of left wing was ripped off. According to the MSRP record, the collision with the birch was recorded at 0840:59.375 of MSRP time (an abrupt change in vertical acceleration). According to an analysis of the cockpit voice recorder, the impact noise occurred at 0841:02.8 of MARS-BM time.

The above data shows that MSRP time is delayed by 3.425 s compared with MARS-BM time. A delay of 3 s was adopted for further analyses.

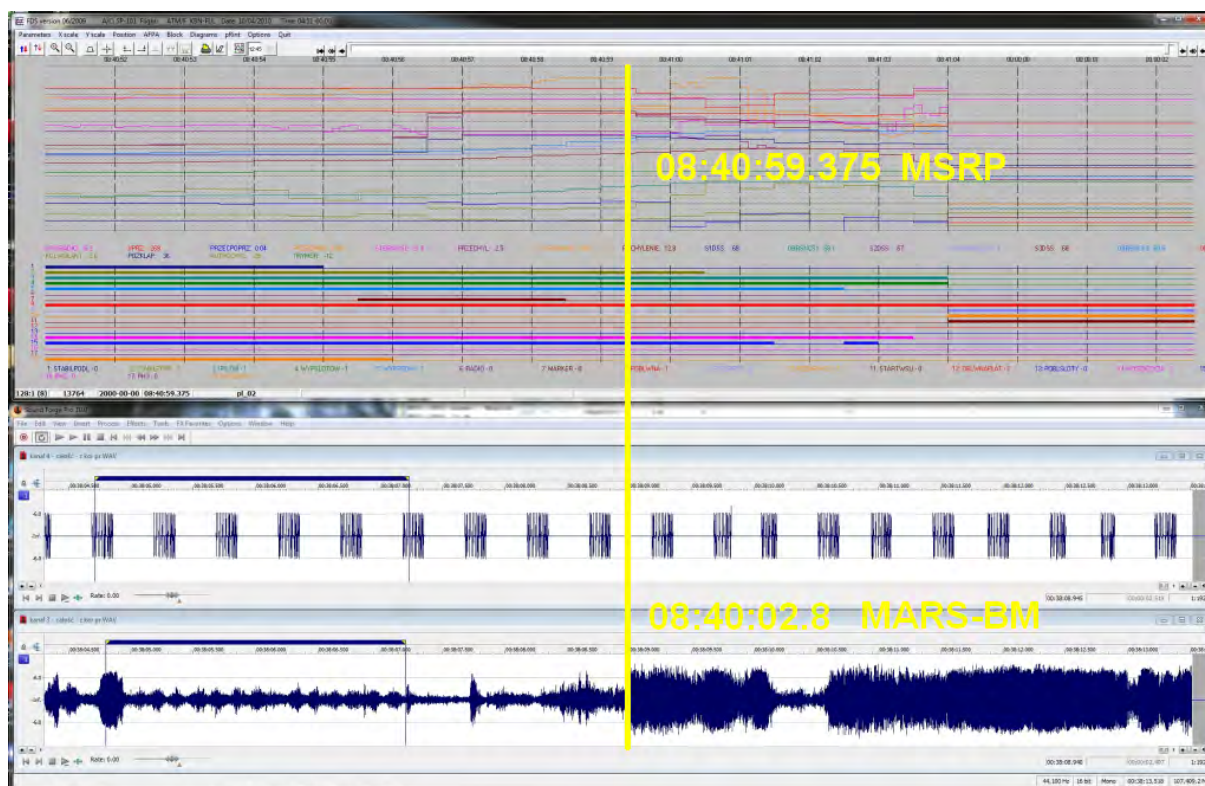


Fig. 6. Dependence of MSRP and MARS-BM time on birch impact

3. Operational assessment of the Tu-154M aircraft systems based on an analysis of MSRP and ATM-QAR records

3.1. ABSU autopilot system

Tu-154M aircraft No 101 was equipped with the ABSU-154-2 autopilot system, and it could be controlled over the whole operational balances as well as flight heights and speeds, except takeoff (up to the height of 400 m) and landing (below 30 m).

The ABSU system ensures:

- Maintenance of the assumed stability and controllability characteristics in all flight stages (except takeoff up to the height of 400 m and landing, below 30 m);
- Automatic control of the aircraft in all stages of the flight according to signals from the piloting/navigation instruments;
- Automatic or directive (instruction-based) aircraft control during landing approach to the height of 30 m;
- Automatic initiation of go-around;
- Automatic stabilization of the indicated airspeed (using the autothrust system) during landing approach to the height of 4-6 m.

Depending on the selected operation mode, automatic stabilization of the pitch and roll angles, course, pressure altitude, indicated airspeed or the Mach number is possible. It is also possible to perform an en-route flight according to navigation points programmed in the FMS or signals from a VHF omnidirectional range (VOR).

Operation of the ABSU in selected operation modes:

1) stabilization and control in the pitch and roll channels

This mode is used for automatic control of the aircraft observing the pitch and roll angles. The angles can be changed without disengaging the mode by means of the ПАЗБОПОТ and СПИСК-ПОДЪЕМ wheel on the PN-46 control panel. It is possible to stabilize roll angles to the values of 23-30° and pitch angles to $17^{\circ} \pm 2.5^{\circ}$. Signals from the FMS can be used for aircraft control in the roll channel. The pitch channel is not interfaced to the FMS.

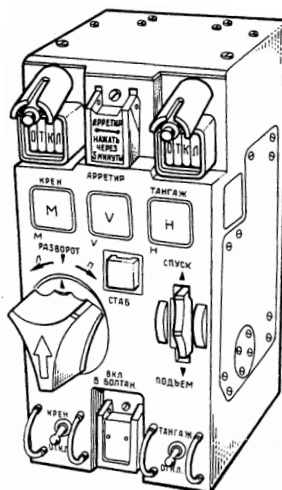


Fig. 7. PN-46 panel

2) approach (path)

This mode is used for directive or automatic control of the aircraft in the pitch channel with descent to 30 m at ICAO Category II aerodromes and to 60 m at Category I aerodromes. In this mode, the aircraft automatic control system is interfaced to a ground unit – receives signals from the ILS.

The mode can be switched off automatically if the “landing approach” (ЗАХОД) mode was active previously, or manually using the ГЛИСС button on the PN-5 panel.

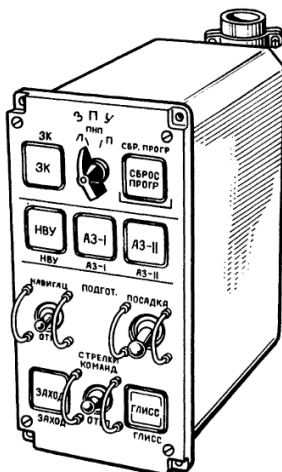


Fig. 8. PN-5 control panel

Automatic switch-on takes place upon the interception of the glide path (when the aircraft reaches a location where path signals from the ILS are equalized) provided that the aircraft has been configured for landing (flaps extended more than 36°). For flaps at 28°, the “path” mode should be activated manually using the ГЛИСС button on the PN-5 control panel.

At threshold altitudes of 250 m, 100 m and 30 m, gain and delay factors change for the different components of the automatic control system, and the value of the allowed

roll angle changes to ensure stable and safe aircraft control in the final stage of the flight.

The activation of the “landing approach” and “path” modes is conditional on the existence of course and path channel readiness signal generated by the KURS-MP70 unit (reception of ILS radio signals). If the ЗАХОД or ГЛИСС buttons are pressed with no ILS signals present, the mode will not be enabled in full – indicator lamps will be off, and automatic control in the pitch channel will switch off. Overpowering of autopilot is indicated by an audible signal and the “roll control” and “pitch control” lamps.

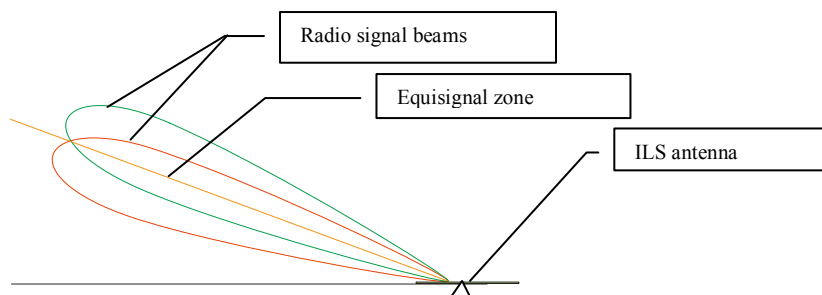


Fig. 9. Diagram of equisignal zone formation for a path by ILS

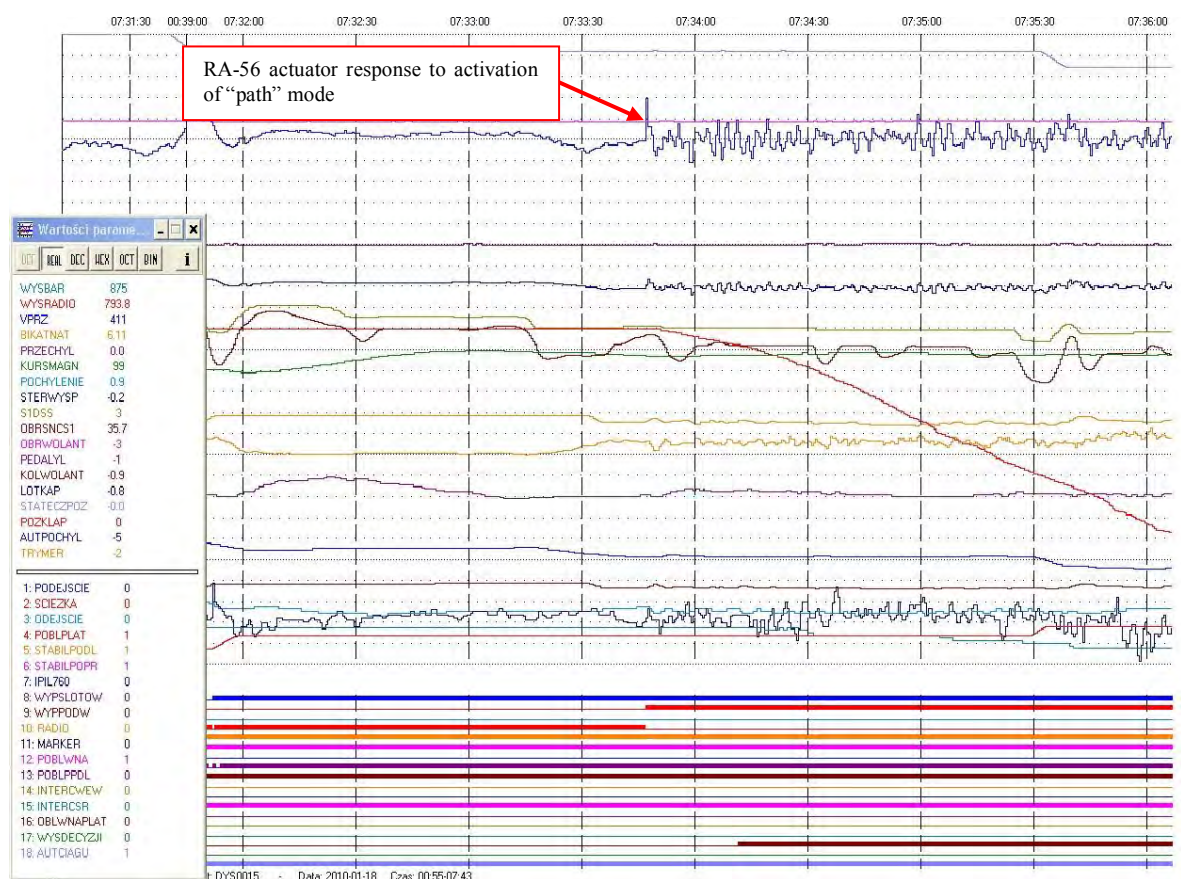


Fig. 10. Typical pattern of flight parameters on the activation of the “path” mode

Fig. 10 shows a typical pattern of operational parameters of the automatic control system at the time the “path” mode is activated. Characteristically, the response of the RA-56 servo mechanism is much faster, as are the corresponding elevator deflections

after the “path” mode is activated. Upon activation of this mode, a single change in position of the RA-56 servo actuator follows, i.e. changing the elevator position, due to which the aircraft switches from level flight to descending flight.

3) Go-around mode

This mode is used for automatic control of the aircraft during the go-around procedure. The mode can be activated if the automatic control system previously operated in “**path**” mode. The mode can be activated using the buttons on the control columns or by setting at least two throttle levers to takeoff position.

After activating the “**go around**” (**УХОД НА ВТОРОЙ КРУГ**) mode, the power mechanism shifts the throttle levers to takeoff position, and the automatic control system maintains the air speed in accordance with the program depending on flap positions. When gaining height, the crew is required to change flap positions (which will allow speed to be increased further automatically) and to retract the landing gear. Speed is stabilized after the set speed is reached. At the same time a fixed roll angle is given in the pitch channel:

- 10° for flaps at 45°,
- 2° for flaps at 28°,
- 2.5° for retracted flaps.

Once the aircraft reaches the speed provided for in the programme (the above values) for the different flap positions, the ABSU stabilizes the roll angles. If the indicated airspeed is less than the programmed value, the roll angle of the aircraft is reduced.

The ABSU roll channel operates in course stabilization mode.

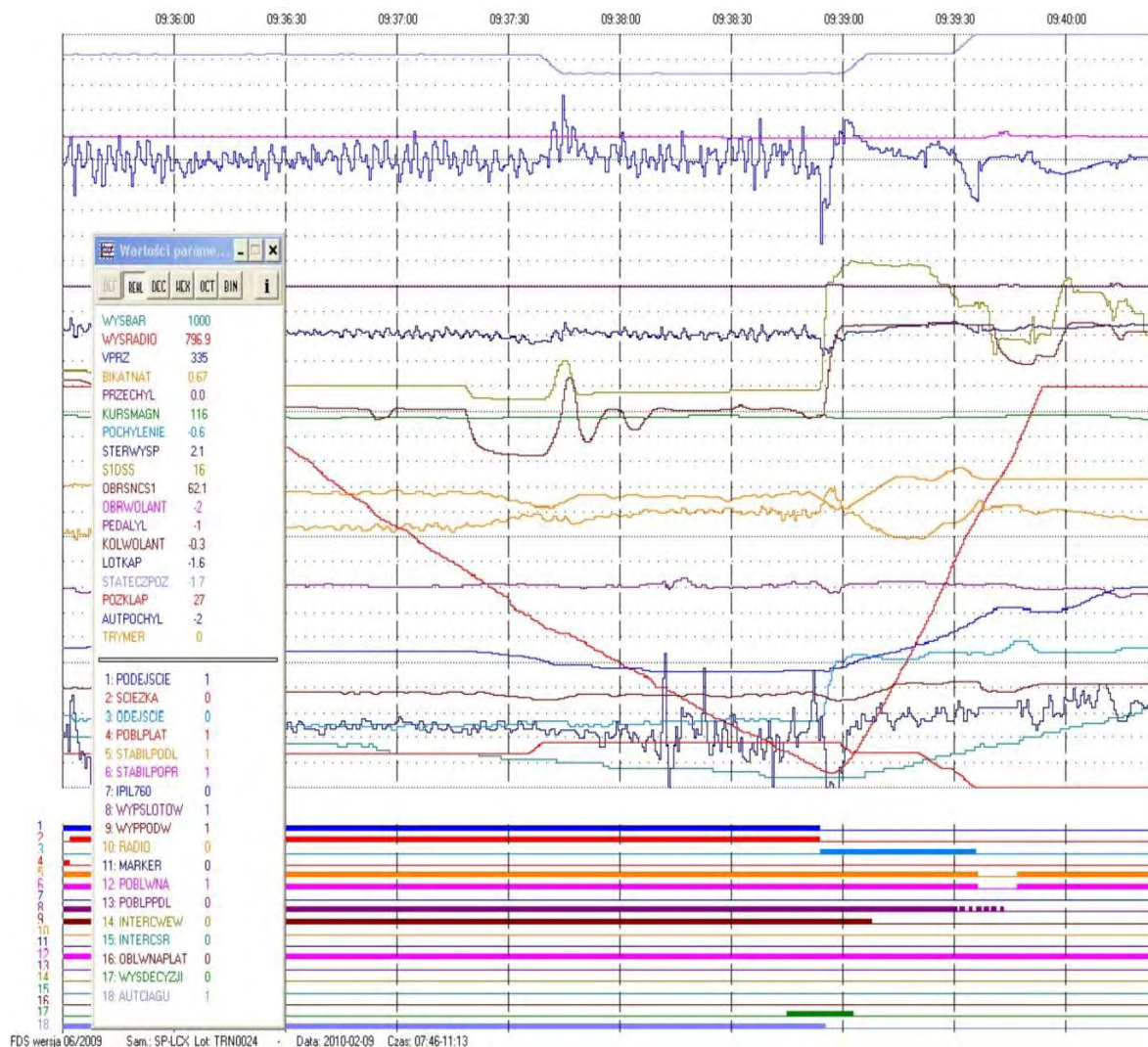


Fig. 11. Typical pattern of flight parameters at the moment the “go around” mode is activated

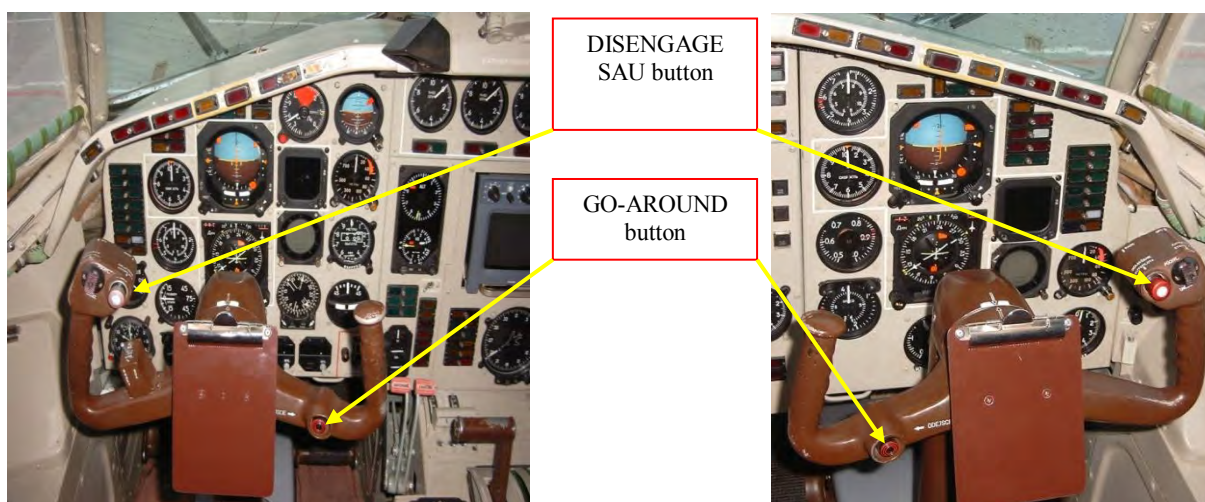


Fig. 12. Distribution of SAU control buttons on steering wheels

NOTE: pressing the ГЛИСС button with the ПОСАДКА switch in ON position on the PN-5 panel is prerequisite for subsequent activation of the “go around”

mode. The initiation of the automatic go-around mode is possible both by means of the buttons on the steering wheels, and by shifting the throttle levers, even with no ILS path signal occurring, but in this case upon pressing the ГЛНСС button on the PN-5 panel automatic control will be disengaged in the pitch channel. Automatic control in the roll channel does not disengage.

After pressing the GO-AROUND button, the automatic control system is switched on in the pitch channel. Shifting the throttle levers to the takeoff mode proceeds automatically if the autothrottle system was engaged previously.

The activation of the “go around” mode initiated by shifting the throttle levers requires at least two throttle levers to be moved on the center panel to the extreme front position. It is not possible to engage this mode by shifting the throttle levers on the flight engineer’s panel.

The altitude that the Tu-154M aircraft loses from the moment the “go around” mode is engaged depends on the vertical speed of descent. The approximate height loss values are shown in Fig. 13.



Рис. 6.9. Траектория движения самолета Ту-154М при уходе на второй круг:

- 1 – точка принятия решения об уходе на второй круг и дачи взлетного режима;
- 2 – точка выхода двигателей на максимальный режим и начало искривления траектории;
- 3 – самая низкая точка траектории

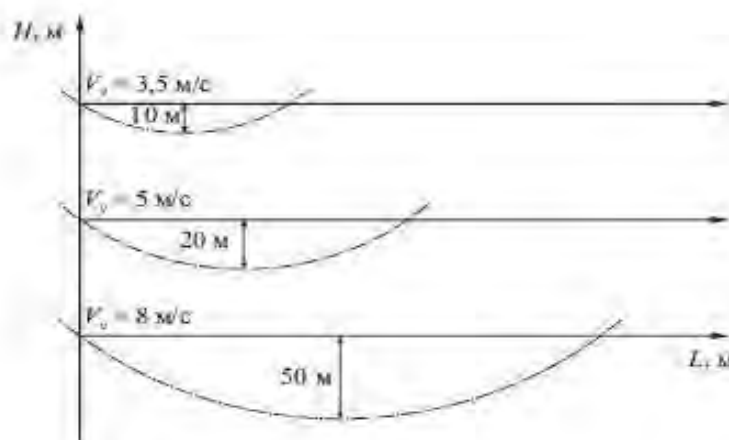


Рис. 6.10. Просадка самолета Ту-154М при уходе на второй круг

Fig. 13. Approximate heights necessary to initiate climb after engaging the “go around” mode

4) Operational analysis of the aircraft control system

The operation of the aircraft control system ABSU-154-2 during the aircraft's flight on 10 April 2010 was analyzed on the basis of records from the flight recorder ATM-QAR.

The crew engaged automatic stabilization in the pitch and roll channels 55 s after takeoff from the WARSZAWA-OKECIE airport (0727:14⁶). The aircraft attained the height of 512 m and continued climbing to cruising height. The flight to the SMOLENSK SEVERNY airdrome, approach and descent on the glide path was made with the autopilot engaged in the pitch and roll channels. Automatic stabilization in the pitch channel was disengaged by shifting the control column by more than 50 mm at 0840:55 at the height of 21.9 m according to the radio altimeter reading. Disengagement of automatic stabilization in the roll channel took place after the control column was turned by an angle of more than 30° at 0841:00.5 at the height of 6.2 m according to the radio altimeter reading.

The SMOLENSK SEVERNY airdrome was not equipped with the ILS system, which prevented the use of the ABSU operation mode, in which the aircraft position descending on the glide path is adjusted automatically with the use of signals proportional to the angular deviation from the path. In the pitch channel, the crew were using the mode in which the aircraft roll angle is stabilized automatically. The value of the angle could be changed by means of the СПУСК-ПОДЪЕМ wheel situated on the PU-46 panel. The stabilization of the aircraft roll angle does not ensure a steady speed of descent, and, the more so, it does not ensure keeping the aircraft automatically on the glide path with the accuracy required of this stage of flight. Changes in the position of the RA-56 servo actuator and the MET-4U trimmer actuator in the roll channel show that when descending the crew were adjusting the aircraft position on the path – the position of the СПУСК-ПОДЪЕМ on the PU-46 panel was changed multiple times.

Settings of the ABSU operating modes are not recorded. The Committee were unable to explicitly determine in what mode the autopilot system operated in the roll channel in the last stage of the flight (after the “fourth turn” is taken to land). Probably it was the mode⁷ in which the aircraft was automatically kept on course automatically to

⁶ Warsaw time.

⁷ Other operating modes of the ABSU system in the roll channel, which the crew may have used, are roll angle stabilization – in such a case it was possible to control the aircraft using the ПАЗБОПОТ wheel situated on the PU-46 panel next to the СПУСК-ПОДЪЕМ wheel or the automatic heading hold mode, the value of which can be changed using the wheel on the PNP-1 indicator.

navigation point DRL10 programmed in the FMS.

The following charts show selected records of the registered flight parameters of Tu-154M aircraft No 101 on 10 April 2010.

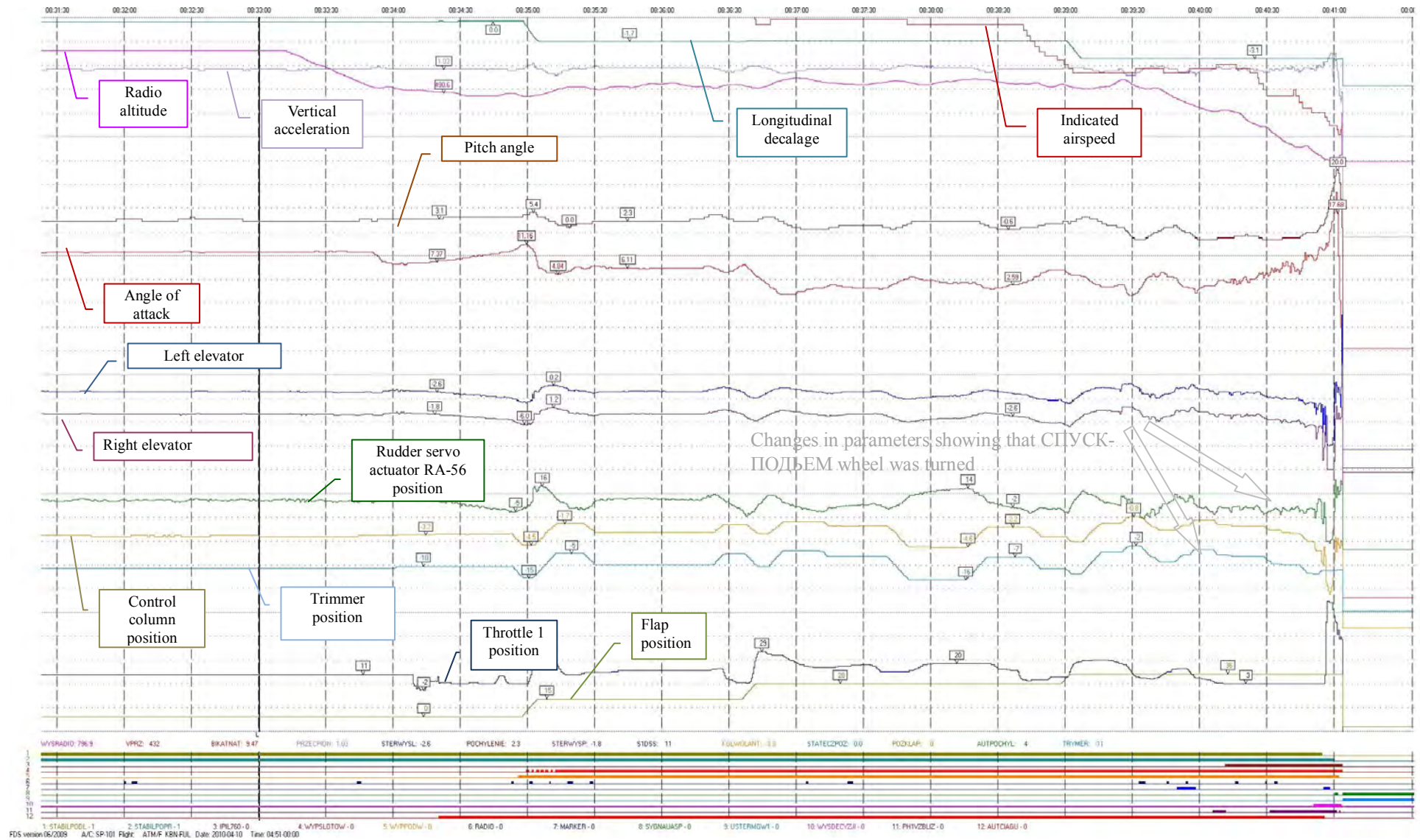


Fig. 14. Selected parameters during landing approach – pitch channel

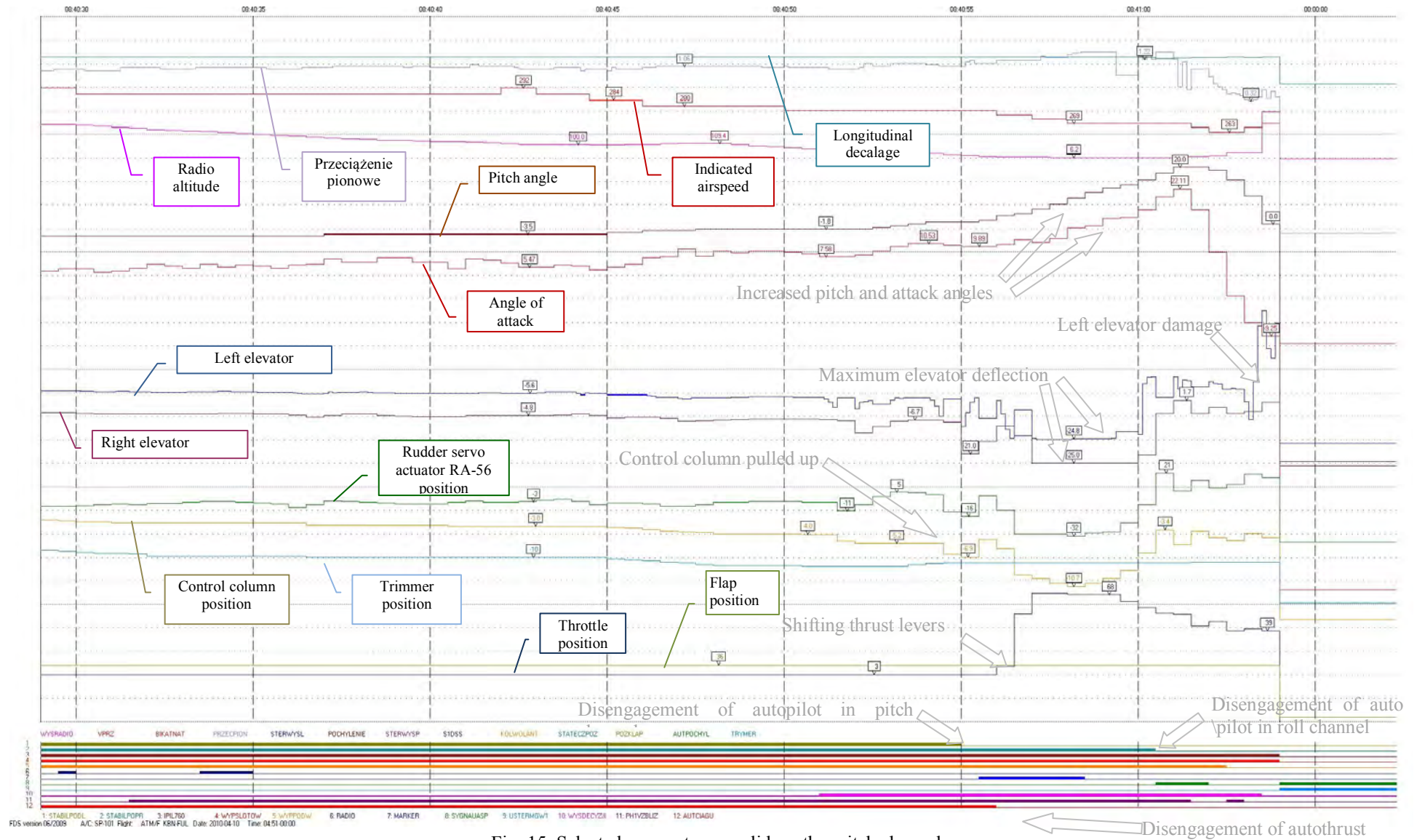


Fig. 15. Selected parameters on glide path – pitch channel

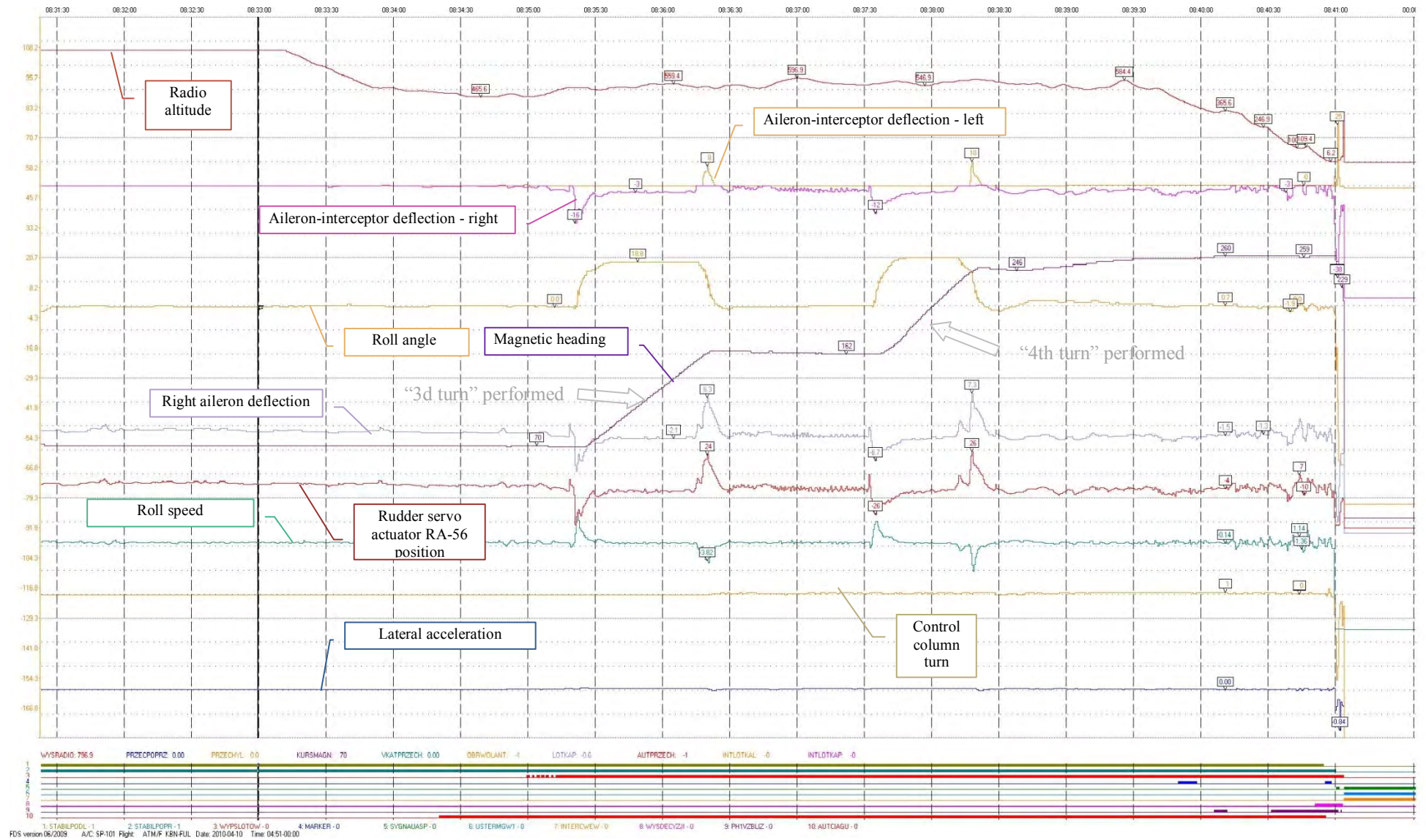


Fig. 16. Selected parameters during landing approach – roll channel – aileron control

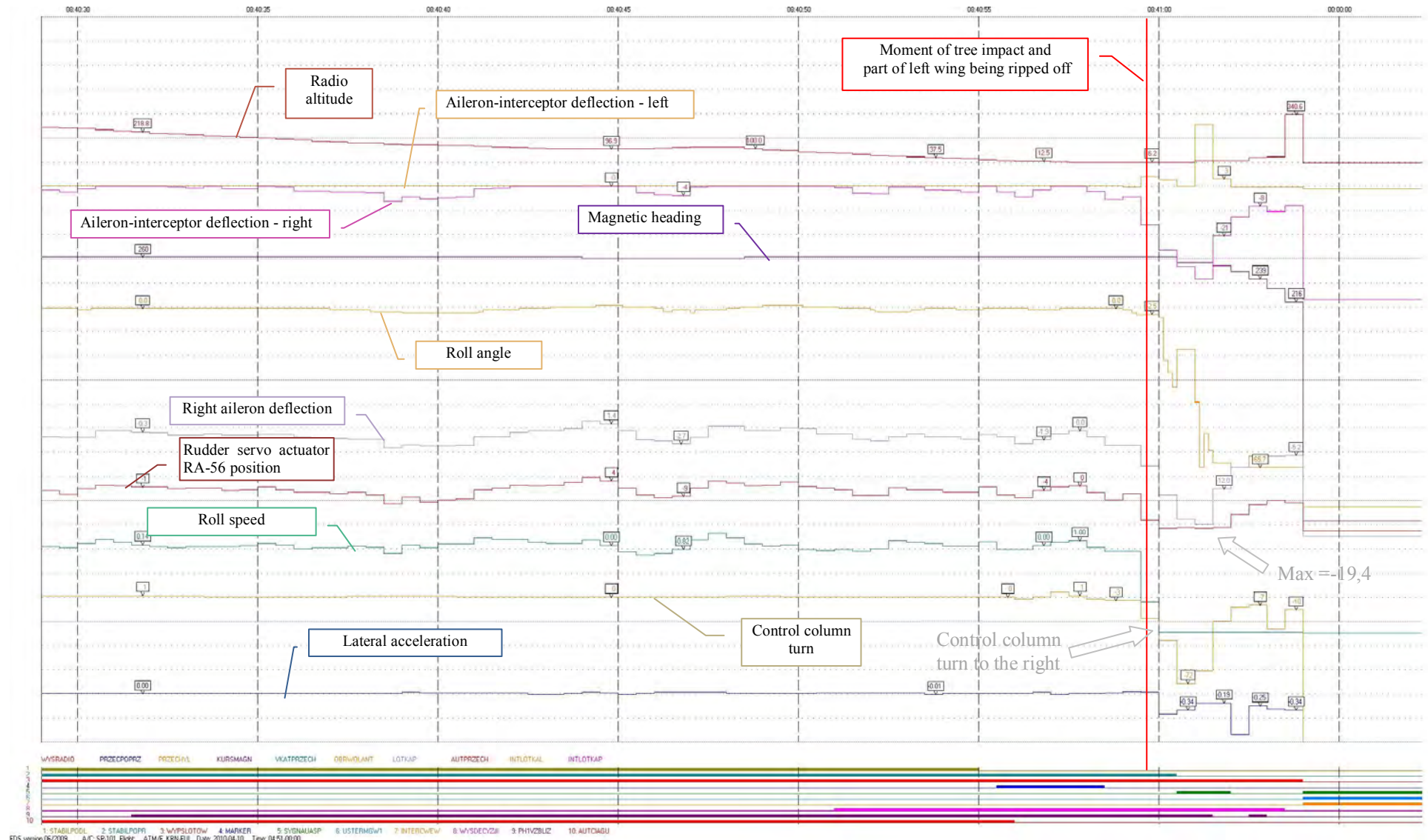


Fig. 17. Selected parameters on glide path – roll channel – aileron control

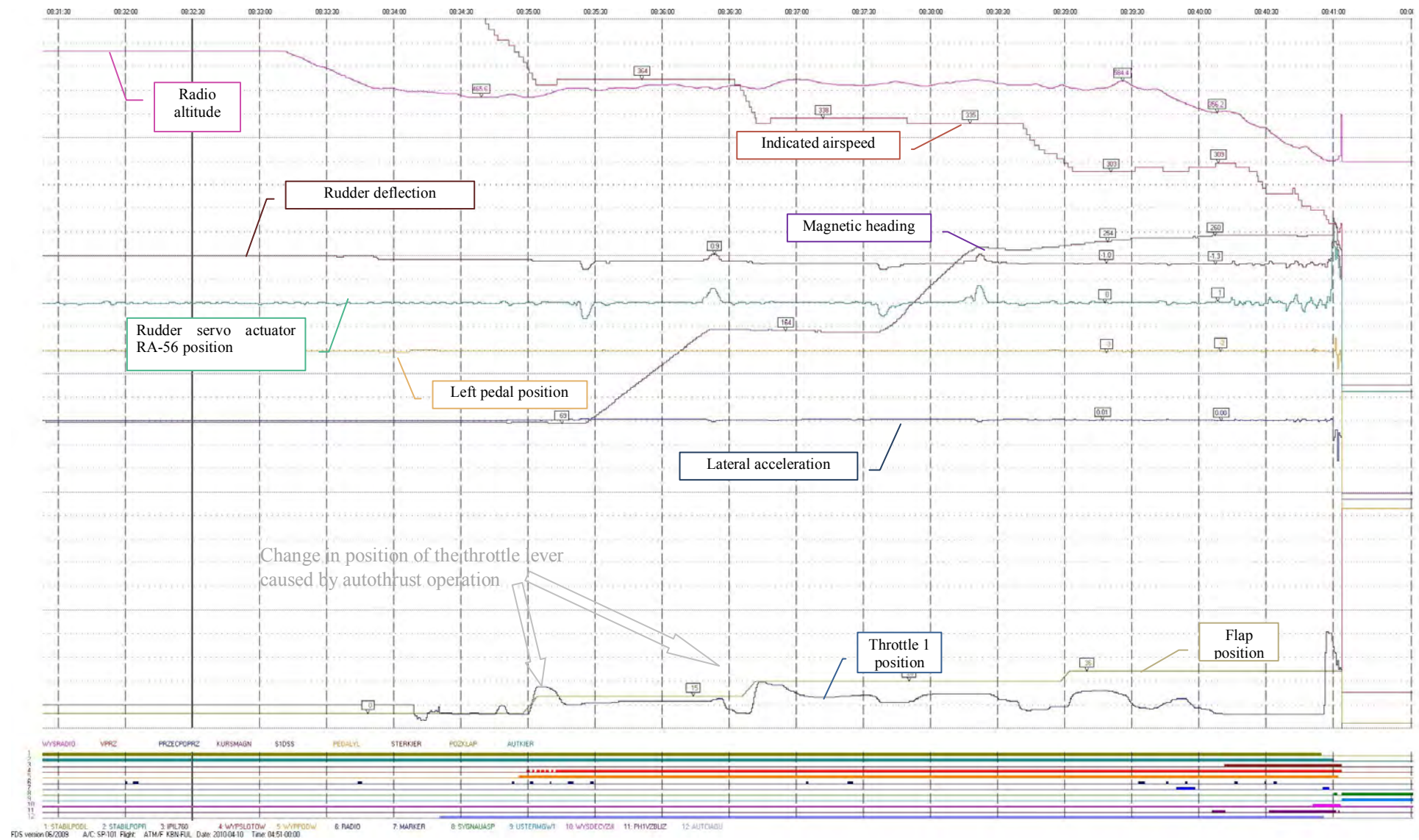


Fig. 18. Selected parameters during landing approach – roll channel – rudder

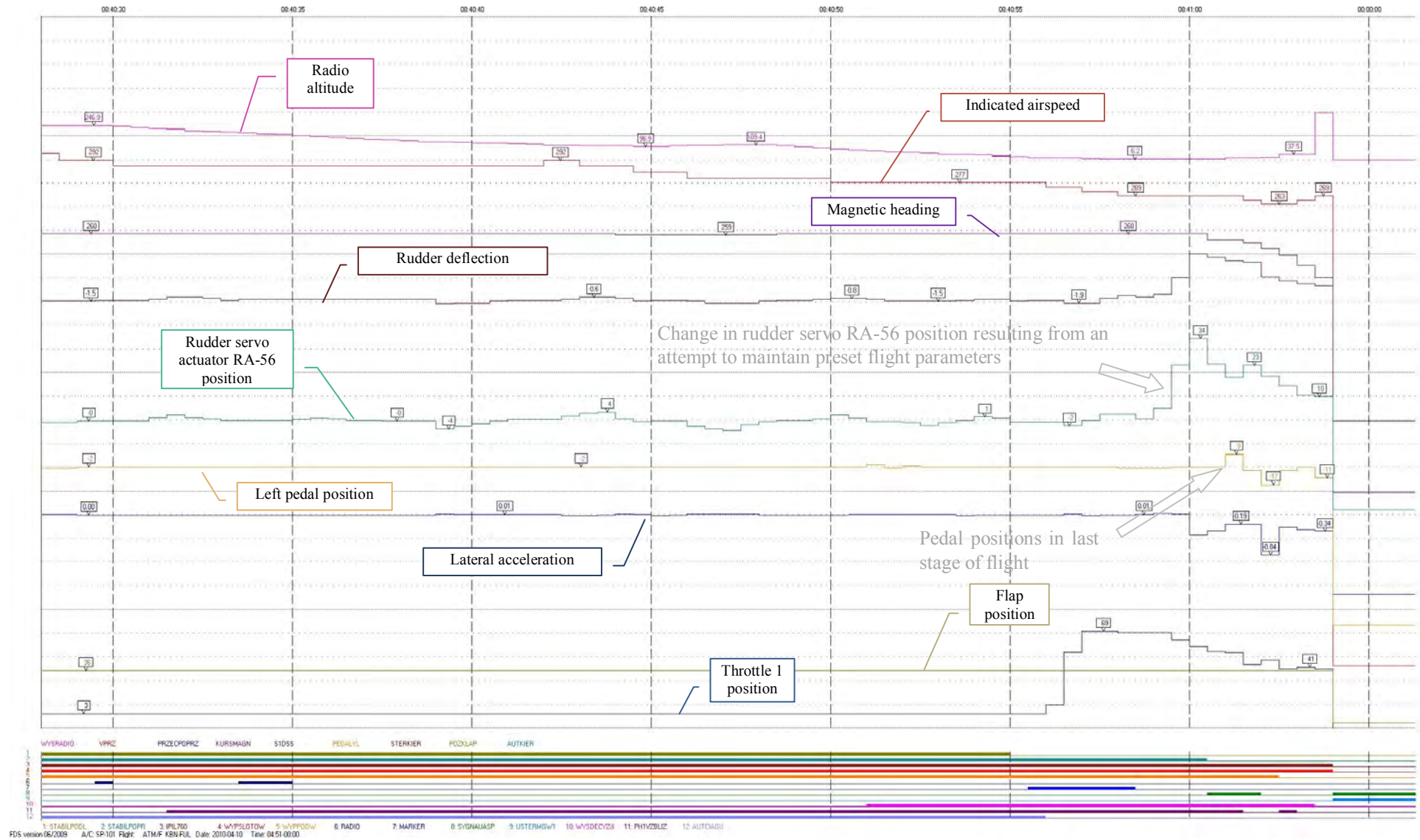


Fig. 19. Selected parameters on glide path – roll channel – rudder

Conclusions on the operation of the ABSU system:

- 1) No anomalies were found in the operation of the ABSU automatic control system. The movements of actuator shafts changing the position of elevators, ailerons, and rudder were fluid and did not extend to reach extreme values.
- 2) During landing approach the crew used the ABSU:
 - a) in the pitch channel in the automatic aircraft roll angle stabilization mode;
 - b) in the roll channel (probably) in the track line stabilization mode.
- 3) The MSRP, ATM-QAR and MARS-BM did not record the disengagement of the automatic control system (e.g. by pressing the button on the steering wheel) in the pitch channel prior to the commencement of the go-around maneuver, which indicates that the crew did not prepare the ABSU system in a manner that would enable go-around to be initiated automatically.
- 4) After the alert was triggered for the height set on the RA, the control column was pulled aft slightly without disengagement of the automatic control mode – the ABSU system responded by adjusting the RA-56 actuator shaft position in the pitch channel.
- 5) The automatic control system was disengaged by shifting the control column and turning the steering wheel.
- 6) After the throttle levers were shifted to takeoff mode, they were moving back, which may indicate that nobody controlled their position. The brakes holding the throttle levers in the set position were released, as the autothrust was previously engaged.
- 7) The pressing of the GO-AROUND button does not leave a trace in the MSRP/ATM-QAR record if the go-around mode does not go active.
- 8) At the time the pilot-in-command took the go-around decision, the aircraft was descending at a rate of 6.2 m/s. Completion of the maneuver (assuming that the procedure would be performed correctly – correct angle of attack, engine operation in takeoff mode) required the procedure to be initiated at a height of more than 35 m above terrain obstacles.

3.2. Hydraulic system

The MSRP system records signals providing failure information on hydraulic systems No 1, 2 and 3 in the form of on/off signals. These are the following channels:

- PH1VZBLIZ excessive pressure drop (to a value below 100 kg/cm²) in hydraulic system No 1 or indications of instructions generated by the TAWS;
- PH2 excessive pressure drop (to a value below 100 kg/cm²) in hydraulic system

No 2;

PH3 excessive pressure drop (to a value below 100 kg/cm²) in hydraulic system

No 3.

In the final stage of the flight signals with a value of 1 were recorded several times in the PH1VZBLIZ channel. The signals came from the TAWS and not from the pressure warning indicator of hydraulic system No 1.

In addition, the MSRP/ATM-QAR recorder records information that allows conformity to be assessed between steering wheel and autopilot movements and the deflection of aircraft control planes. These are the following channels:

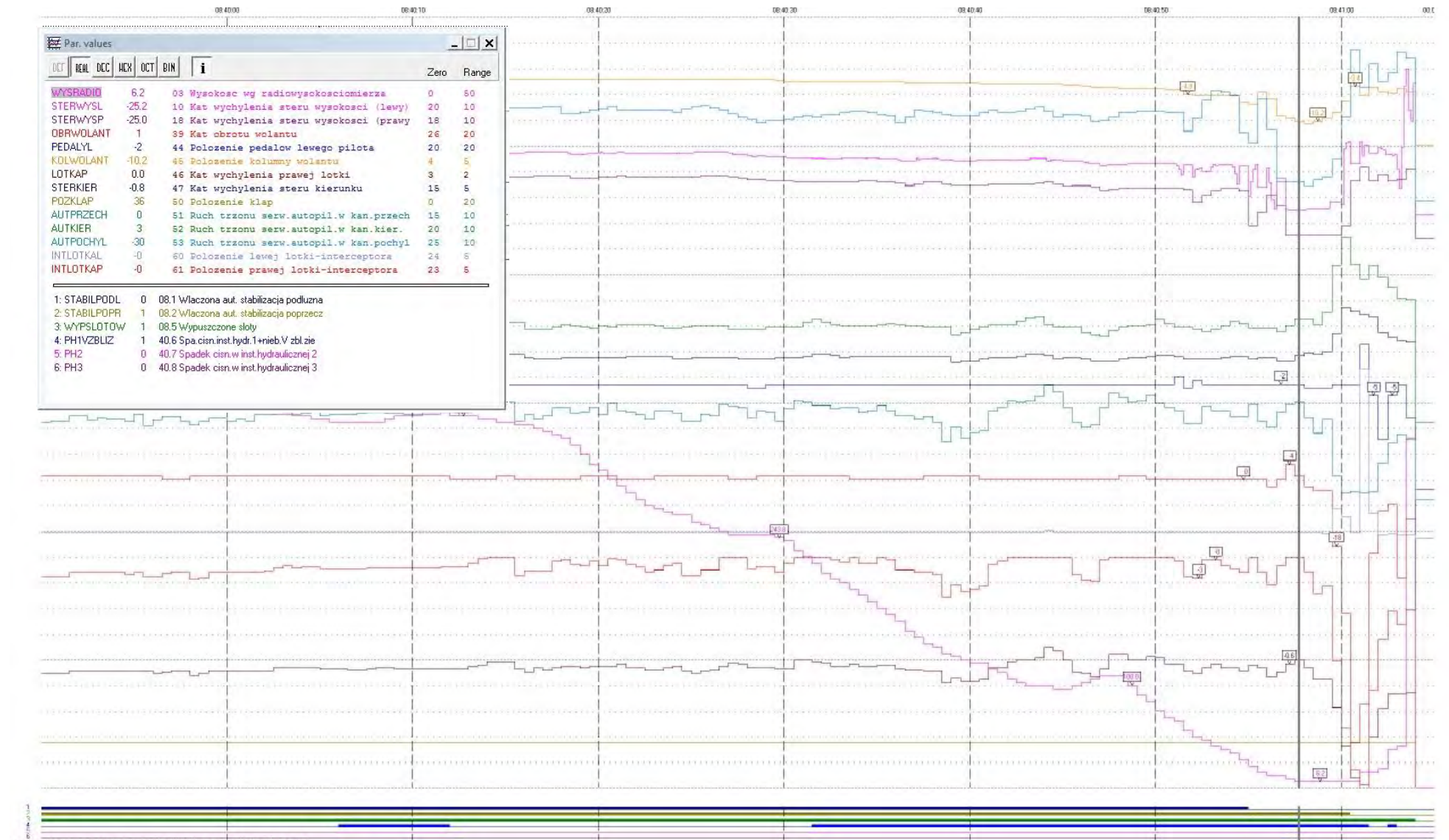
Table 1. Flight parameters for the assessment of hydraulic system operation

No	Mnemonic	Description
1.	PEDALYL	position of left pilot's left pedal
2.	KOLWOLANT	position of control column
3.	OBRWOLANT	steering wheel rotation angle
4.	AUTPRZECH	autopilot actuator shaft travel in roll channel
5.	AUTKIER	autopilot actuator shaft travel in directional channel
6.	AUTOPOCHYL	movement of autopilot actuator shaft travel in pitch channel
7.	STABILPOPR	automatic roll stabilization engaged
8.	STABILPODL	automatic pitch stabilization engaged
9.	STERWYSL	elevator deflection angle (left)
10.	STERWYSP	elevator deflection angle (right)
11.	STERKIER	rudder deflection angle
12.	LOTKAP	left aileron deflection angle
13.	INTLOTKAL	left aileron-interceptor position
14.	INTLOTKALP	right aileron-interceptor position
15.	POZKLAP	flap position
16.	WYPSLOTOW	slats lowered

Change in parameters was compared in the following channels:

- OBRWOLANT, AUTOPRZECH, LOTKAP with STABILPOPR signal active,
- OLWOLANT, AUTOPOCHYL, STERWYSL, STERWYSP with STABILPODL signal active,
- PEDALYL, AUTKIER, STERKIER.

Final Report – Appendix 2. Description and analysis of operation of on-board system of Tu-154M aircraft No 101



FDS version 06/2009 A/C SP-101 Flight PLF0101A WAW-SMO Date 10/04/2010 Time 00:00:00

Wysokość wg radiowysokościomierza	Radio altitude
Kat wychylenia steru wysokości (lewy)	Elevator deflection angle (left)
Kat wychylenia steru wysokości (prawy)	Elevator deflection angle (right)

Kat obrotu wolantu	Control column rotation angle
Położenie pedałów lewego pilota	Position of left pilot pedals
Położenie kolumny wolantu	Control column position
Kat wychylenia prawej lotki	Left aileron deflection angle
Kat wychylenia steru kierunku	Rudder deflection angle
Położenie klap	Flap position
Ruch trzonu serw. autopil. w kan.przech.	Autopilot actuator shaft travel in roll channel
Ruch trzonu serw. autopil. w kan.kier.	Autopilot actuator shaft travel in directional channel
Ruch trzonu serw. autopil. w kan.pochyl	Autopilot actuator shaft travel in pitch channel
Położenie lewej lotki-interceptora	Aileron-interceptor position (left)
Położenie prawej lotki-interceptora	Aileron-interceptor position (right)
Włączona aut. stabilizacja podłużna	Automatic pitch stabilization engaged
Włączona aut. stabilizacja poprzecz	Automatic roll stabilization engaged
Wypuszczone sloty	Slats lowered
Spa.cisn.inst.hydr.1+nieb. V zbl.zie	Pressure drop in hydr. system 1+ground prox.V
Spadek cisn.w inst hydraulicznej 2	Pressure drop in hydr. system 2
Spadek cisn.w inst hydraulicznej 3	Pressure drop in hydr. system 3

Fig. 20. Hydraulic system operation based on control planes

Conclusions:

- 1) In the time interval from the takeoff to 0841:03 no signals appeared in the PH1VZBLIZ, PH2 and PH3 channels indicating a failure of any of the three hydraulic systems. This is in agreement with the MARS-BM records, in which there is flight engineer call out on a hydraulic system failure.
- 2) It was ascertained that throughout the time interval from takeoff to 0841:03:
 - the deflections of the right aileron were in accordance with the movements of the steering wheel and the autopilot actuator,
 - the elevator deflections were in accordance with the movements of the control column and the autopilot actuator,
 - the rudder deflections were in accordance with the movements of pedals and the autopilot actuator.
- 3) The change of parameters in POZKLAP channel was compared. It was found out that throughout the 0840:59–08:41:03 time interval the flap position did not change.
- 4) The change of parameters in WYPSLOTOW channel was compared. It was found out that throughout the 0840:59–08:41:03 time interval the slats were retracted.
- 5) In the time interval from 0840:59 to 0841:03, there were no discrepancies between the movements of the steering wheel and pedals and the response of the aircraft control planes, which means that hydraulic systems ensured correct control of the aircraft.

3.3. Analysis of power plant operation

The assessment of the power plant operation during the aircraft flight from WARSAW to SMOLENSK together with an analysis of the final stage of the flight (from about 7 km to runway threshold) was made on the basis of an analysis of operating parameters of the engines mentioned in Tables 2 and 3 and shown in chart form.

Table 2. Continuous parameters

No	Parameter	Measurement range	Transmitter/ system
1.	Temperature of captured air streams	-60 - +150°C	P-5
2.	Pressure altitude	-250 - 13000 m	DWBP-13
3.	True altitude	0 - 750 m	RV-5MD1
4.	Indicated airspeed	60 - 800 km/h	DAS
5.	Lateral acceleration	-1.5 (right) - 1.5 (left) g	MP-95
6.	Vertical acceleration	-2(±0.5)g (down) - 5(±1)g (up)	MP-95
7.	Engine 1 throttle 1 position	-33° (reverse) - 70°	MU-615A
8.	Vibration of engine 1 rear support	0 – 100%	IW-50P-A-3
9.	Engine 1 SNC speed	10 - 110%	DTE-6T
10.	Engine 1 gas temperature	200 - 1200 °C	2IA-7A
11.	Engine 2 throttle position	0° - 70°	MU-615A
12.	Vibration of engine 2 rear support	0 - 100%	IW-50P-A-3
13.	Engine 2 SNC speed	10 - 110%	DTE-6T
14.	Engine 2 gas temperature	200 - 1200 °C	2IA-7A
15.	Engine 3 throttle position	-33° (reverse) - 70°	MU-615A
16.	Vibration of engine 3 rear support	0 - 100%	IW-50P-A-3
17.	Engine 3 SNC speed	10 - 110%	DTE-6T
18.	Engine 3 gas temperature	200 - 1200 °C	2IA-7A
19.	Aggregate fuel quantity	0 - 40 t	SUIT4-1T
20.	N1 vibration of engine 1 (only ATM-QAR)	0 - 100%	CA-151
22.	N2 vibration of engine 1 (only ATM-QAR)	0 - 100%	CA-151
23.	N1 vibration of engine 2 (only ATM-QAR)	0 - 100%	CA-151
24.	N2 vibration of engine 2 (only ATM-QAR)	0 - 100%	CA-151
25.	N1 vibration of engine 3 (only ATM-QAR)	0 - 100%	CA-151
26.	N2 vibration of engine 3 (only ATM-QAR)	0 - 100%	CA-151

Table 3. Discrete parameters

No	Parameter	Measurement range
1.	Engagement of engine IPOs	Heating curtains
2.	Fire in starter motor compartment high temperature in rear accessory compartment	Fire alarm system SSP-2A Temperature alarm 5747T
3.	Starting the starter motor front toilet tank overflow	START button D-713 limit switch
4.	High engine vibration	IW-50P-A-3
5.	Oil pressure drop in engines	MSTW-2,2
6.	Filings in engine oil	Filings filter indicator
7.	High temperature of exhaust gases	2IA-7A
8.	Engine 1 failure	Case 4, 5, 6, 7 or 11 for engine 1
9.	Engine 2 failure	Case 4, 5, 6, 7 or 11 for engine 2
10.	Engine 3 failure	Case 4, 5, 6, 7 or 11 for engine 3
11.	Fire in engine compartment	Fire alarm system SSP-2A
12.	Ice warning	SO-121WM indicator
13.	Autothrust engagement	ABSU
14.	N2 (only ATM-QAR)	CA-151 / EVM-219
15.	Flight over markers	RPM-70 marker receiver

Based on an analysis of selected parameters read from the ATM-QAR recorder, it was found out that engine operation parameters were in compliance with the applicable technical specifications (TS) from the start-up, throughout the flight until the accident. The speeds of each engine changed in line with changes in the position of the corresponding throttle levers. Gas temperatures downstream of the turbine and speeds of low pressure compressors (LPCs) of all engines running within the same throttle lever setting ranges were at the same level and took rated values in compliance with the applicable TS. An analysis of the motor operation parameters showed that as the flight conditions changed – change of height and temperature – the engines operated in a stable manner within the ranges in compliance with the TS (“Двигатель Д-30КУ 2 серии Руководство по технической эксплуатации”, “Ту-154М. Руководство по летной эксплуатации”), which is indicative of correct operation of the engine automatic control systems.

Engine vibrations were measured in Tu-154M aircraft No 101 by two independent systems for each of the engines. The basic system measured vibrations of the front and rear engine supports (only rear support vibrations were recorded), and an additional system (AVM-

219 by Vibrolot Ltd.) measured “N1” vibrations of the low-pressure rotor and “N2” vibrations of the high-pressure rotor (both parameters were recorded). An analysis of vibration records showed that until the collision with the first obstacles, their values complied with the technical specifications and were significantly lower than the limit ranges: 55% - indicating maximum/dangerous engine vibration (according to IW-50) and 65% - indicating the maximum/high engine vibration (according to AVM-219). The maximum values of vibrations and their change for all (three) engines were registered during the aircraft takeoff (e.g. maximum instantaneous value of vibrations at the rear support of engine 3 reached about 20.38%).

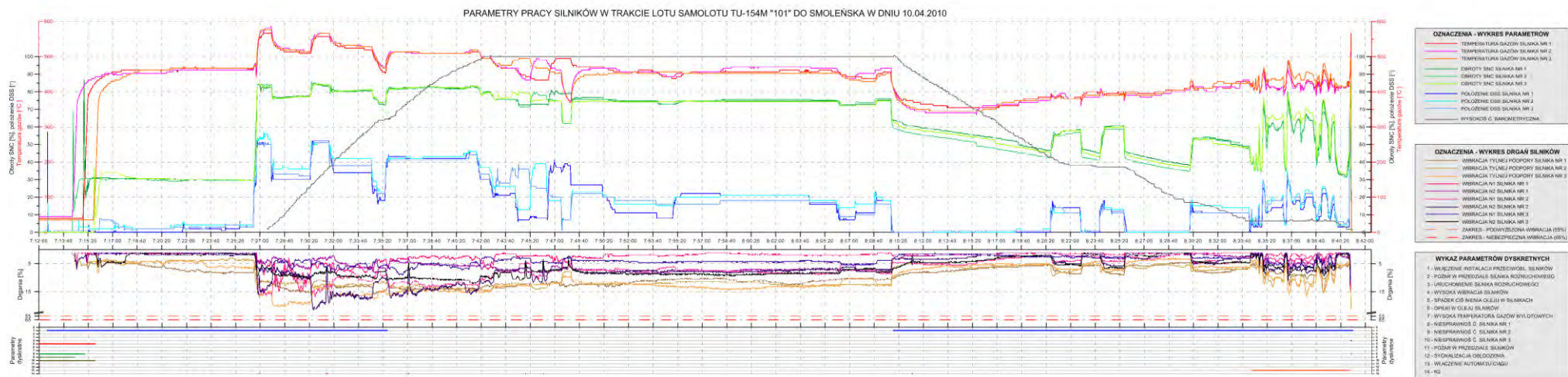
The abrupt changes in vibration values in the form of instantaneous peaks, which can be seen on charts representing the vibrations of high pressure rotors of engines 1, 2, 3 (measures by the AVM-219 system) are attributable to the measurement of the second harmonic of “N2” high-pressure rotors, performed cyclically by the crew during the flight (2XN2) switch. In this measurement, the on/off 2n2 instruction is recorded and the „N2” signal recorded for all three engines is replaced by the 2n2 signal.

An analysis of the record of discrete parameters related to the operation of the power plant from the start-up of the engines to 0841:03.5, i.e. 0.5 s before the end of the reliable record on the ATM-QAR recorder, showed the absence of any signals of emergency conditions such as:

- fire in the engine compartment,
- filings in engine oil,
- engine pressure drop,
- high temperature of exhaust gases,
- high engine vibrations,
- failure of engine 1,
- failure of engine 2,
- failure of engine 3,

which testifies to correct operation of the engines during the flight. No “fire in starter motor compartment” signal was recorded either. The information shown in the record of discrete parameters concerning the failure of engines 1, 2, 3 before their start-up and the “engine oil

pressure drop” signal is correct and in compliance with the engine and recording device operating principle.



PARAMETRY PRACY SILNIKÓW W TRAKCIE LOTU SAMOLOTU TU-154M „101” DO SMOLEŃSKA W DNIU 10.04.2010	ENGINE OPERATION PARAMETERS DURING TU-154M AIRCRAFT NO 101 FLIGHT TO SMOLENSK ON 10 APR 2010
OZNACZENIA – WYKRES PARAMETRÓW	DESIGNATIONS – PARAMETER CHART
TEMPERATURA GAZÓW SILNIKA NR	ENGINE NO [...] GAS TEMPERATURE
OBROTÓW SNC SILNIKA NR	ENGINE NO [...] SNC SPEED
POŁOŻENIE DSS SILNIKA NR	ENGINE NO [...] THROTTLE LEVER POSITION
WYSOKOŚĆ BAROMETRYCZNA	PRESSURE ALTITUDE
OZNACZENIE – WYKRES DRGAŃ SILNIKÓW	DESIGNATION – ENGINE VIBRATION CHART
WIBRACJA TYLNEJ PODPORY SILNIKA NR	ENGINE NO [...] REAR SUPPORT VIBRATION
WIBRACJA NR [...] SILNIKA NR [...]	VIBRATION NO [...] OF ENGINE NO [...]
ZAKRES – PODWYŻSZONA WIBRACJA	MODE – INCREASED VIBRATION
ZAKRES – NIEBEZPIECZNA WIBRACJA	MODE – DANGEROUS VIBRATION

WYKAZ PARAMETRÓW DYSKRETYCH	LIST OF DISCRETE PARAMETERS
WŁĄCZENIE INSTALACJI PRZECIWOBL. SILNIKÓW	ENGINE ANTI-ICING SYSTEM ON
POŻAR W PRZEDZIALE SILNIKA ROZRUCHOWEGO	FIRE IN STARTER MOTOR COMPARTMENT
URUCHOMIENIE SILNIKA ROZRUCHOWEGO	STARTING THE STARTER MOTOR
WYSOKA WIBRACJA SILNIKÓW	HIGH ENGINE VIBRATION
SPADEK CIŚ. OLEJU	OIL PRESSURE DROP
OPIŁKI W OLEJU SILNIKÓW	FILINGS IN ENGINE OIL
WYSOKA TEMPERATURA GAZÓW WYLOTOWYCH	HIGH PRESSURE OF EXHAUST GASES
NIESPRAWNOŚĆ SILNIKA NR	ENGINE NO [...] INOPERATIVE
POŻAR W PRZEDZIALE SILNIKÓW	FIRE IN ENGINE COMPARTMENT
SYGNALIZACJA OBLODZENIA	ICE WARNING INDICATOR
WŁĄCZENIE AUTOMATU CIĄGU	AUTOTHRUST ON
PARAMETRY DYSKRETNE	DISCRETE PARAMETERS
DRGANIA	VIBRATIONS
OBROTY SNC	SNC SPEED
POŁOŻENIE DSS	THROTTLE LEVER POSITION
TEMPERATURA GAZÓW	GAS TEMPERATURE

Fig. 21. Engine operation parameters of the Tu-154M aircraft

At 0840:55.5, when the speeds of low pressure power transmission of engines 1, 2, 3 reached 41.9%, 38.6%, 45.2%, respectively (which roughly corresponds to a slightly above idle mode), all throttle levers were set manually, with a rate of 1 s, to 69° position, i.e. to takeoff mode – which led to simultaneous disengagement of the autothrottle. Gas temperatures downstream of the turbine and low-pressure power transmission speeds of all engines increased smoothly, without ground loops and hovering. When the tip of the left wing of the aircraft collided with a large birch tree at 0840:59.375, the speeds of low-pressure power transmissions of engines 1, 2, 3 increased to 68.1%, 61.9%, 68.6%, respectively.

At 0841:02.9, the speeds of low-pressure power transmissions of engines 1, 2, 3 reached the values of 83.8%, 84.0%, 83.3%, respectively, which roughly corresponds to “nominal” mode. Hence the engines had not managed to reach the takeoff mode. The low-pressure power transmission speeds increased from approximately the idle mode to values roughly corresponding to nominal mode within 7.4 s. The time and manner of engine acceleration testify to their good condition and correct adjustment.

Analyses of the above data and their imaging showed that all the recorded engine operation parameters until the collision with obstacles took values in accordance with those specified in the operation manual for the respective operation modes. The variability charts for those parameters for engines 1, 2 and 3 are almost identical – the engines operated correctly.

A visual inspection of the engines at the crash site and an analysis of the photographic material collected shows that:

- none of all three engines showed any body damage characteristic of disintegration of rotating components of engines in flight,
- the engines and their casings have no traces of fire,
- the nature of the engine damage (mud drawn inside and bent blades) confirms that they operated at the time of crash,
- no damage or any traces were found which could confirm an engine failure due to a cause other than collision with the ground,

hence it can be concluded beyond any doubt that there was nothing to cause **incorrect operation of the power plant in flight.**

3.4. Fuel system

An analysis of the refueling of the aircraft during the 2 weeks preceding the accident, carried out on the basis of the documents held by the 36th Special Transport Air Regiment showed that the fuel pumped into Tu-154M aircraft No 101 from 26 March to 9 April 2010 was in accordance with the list of fuels approved by the manufacturer for use on this type of aircraft and met the criteria. Additional laboratory tests of fuel with which the aircraft was refuelled on 9 April showed that the fuel properties were in compliance with the standards. The test results of fuel samples taken in the presence of members of the Committee from the aircraft wreck at the accident site, which were carried out in Russia, confirmed the good quality of the fuel loaded into the aircraft tanks in Poland.

Based on the entries in Maintenance Log Book of Aircraft No 101, 90A837, RWD 343/14, p. 20/109 it was determined that on 10 April 2010 there was 18 672 kg of fuel in the aircraft before the flight.

At 0840:53.9, when the aircraft roll angle was 0° and the pitch angle was 0°, the aggregate quantity of fuel in the aircraft tanks was 10 600 kg.

MSRP flight recorders record data concerning the fuel system on two tracks:

- aggregate fuel quantity – a continuous parameter, a signal proportional to the aggregate fuel quantity is fed from the BPS-3-1T unit forming part of the SUIT4-1T fuel measurement and consumption control system. The recorded signal range is 0-40 t.
- manual fuel consumption – a discrete parameter, a signal being registered on failure or manual disengagement of the fuel consumption automatic control system forming part of the SUIT4-1T fuel measurement and consumption control system. In the event of failure or disengagement of the automatic control unit an indicator lamp is also lit on the flight engineering's panel.

At 07:58:57.5, a signal appeared in the record of the flight recorders indicating a failure or manual disengagement of the SUIT4-1T fuel consumption control and measurement system. The signal appeared in the same channel (ODSCIEZKI), in which the descent path deviation limit signal appeared. According to “Ту-154М. Руководство по летной эксплуатации”, Section 8.3.2.(6)1, p. 8.3.5, the flight engineer should immediately report to the pilot-in-command the detected deviations in the operation of the fuel system. There is no such report in the MARS-BM record, hence it can be supposed that the switching of the fuel consumption control and measurement system to manual mode was intentional. The record

started as late as 0802:53.5, so the flight engineer's report (if any) may have not been recorded. According to information obtained from the former Head of the Aeronautical Engineering Section of the 36th Special Airlift Regiment, the automatic fuel control system on the Tu-154M was switched off when it was necessary to manage fuel so that it was not necessary to trim the aircraft ailerons, which allowed fuel consumption to be reduced.

According to the record from the flight recorders, at 0830:44 the fuel consumption control and measurement system was again operating in automatic mode. This condition continued until the accident. The change in the operation of the fuel system was not accompanied by any report by the flight engineer to the pilot-in-command, as required in such a situation.

3.5. Tu-154M aircraft anti-icing system

3.5.1. Engine anti-icing system

The de-icing of engines is performed by heating air intake noses, 1st stage WNA blades and the engine spinner with hot air taken from the engine. Each engine has its independent anti-icing system. The activation of the anti-icing system of each engine is signalled by a yellow indicator lamp situated next to each switch (

Fig. 22). The MSRP flight recorder records the switching on of the engine inlet anti-icing system – POBLWNA parameter.

3.5.2. Wing and fin anti-icing system

The noses of the centre-wing section and the fin are heated with hot air taken from the engines. The activation of the heating system is signaled by two yellow lamps LEFT and RIGHT installed above the switch of the system (

Fig. 22). The MSRP flight recorder the switching on of the wing and fin anti-icing system – POBLPLAT signal, and airframe ice warning – the OBLWNA PLAT signal, which is generated by the SO-121WM ice warning indicator with DSL-40 sensor and PE-11M electronic unit.

3.5.3. Slat anti-icing system

Power is supplied to the anti-icing system from generator No 2 with 115/200 V, 400 Hz alternating current. The anti-icing system is controlled by means of the SLOTY (SLATS) switch on the flight engineer's panel. System operation is checked by monitoring the SLOTY (SLATS) yellow indicator lamp coming on cyclically and the deflection of the ammeter needle. The indicator lamp comes on for 38.5 with a cooling break of 115.5 s. During flight under ice buildup conditions the system can operate without limitations. When

parking on the ground, the system is protected by the landing gear load limit switch.

3.5.4. Ice warning system

Ice buildup is indicated by the red OBLODZENIE (ICE) indicator lamp (Fig. 22). The operability of the system is checked by the internal system of the warning indicator and it is indicated by a yellow lamp reading SPRAWNY (OPERABLE). The MSRP flight recorder records the ice warning indicator activation signal – OBLWNAPLAT.

3.5.5. PDD⁸ air pressure receiver anti-icing system

In order to protect the PPD from ice buildup, the receivers are fitted with electric heating elements fed with 27 V DC. The MSRP recorder records only the switching on of the pilot-in-command PPD (the switch circled in red below).



Fig. 22. PPD heating system switching and checking panel (left) and anti-icing system control panel (right) of the Tu-154M aircraft

⁸ PPD – air pressure receiver

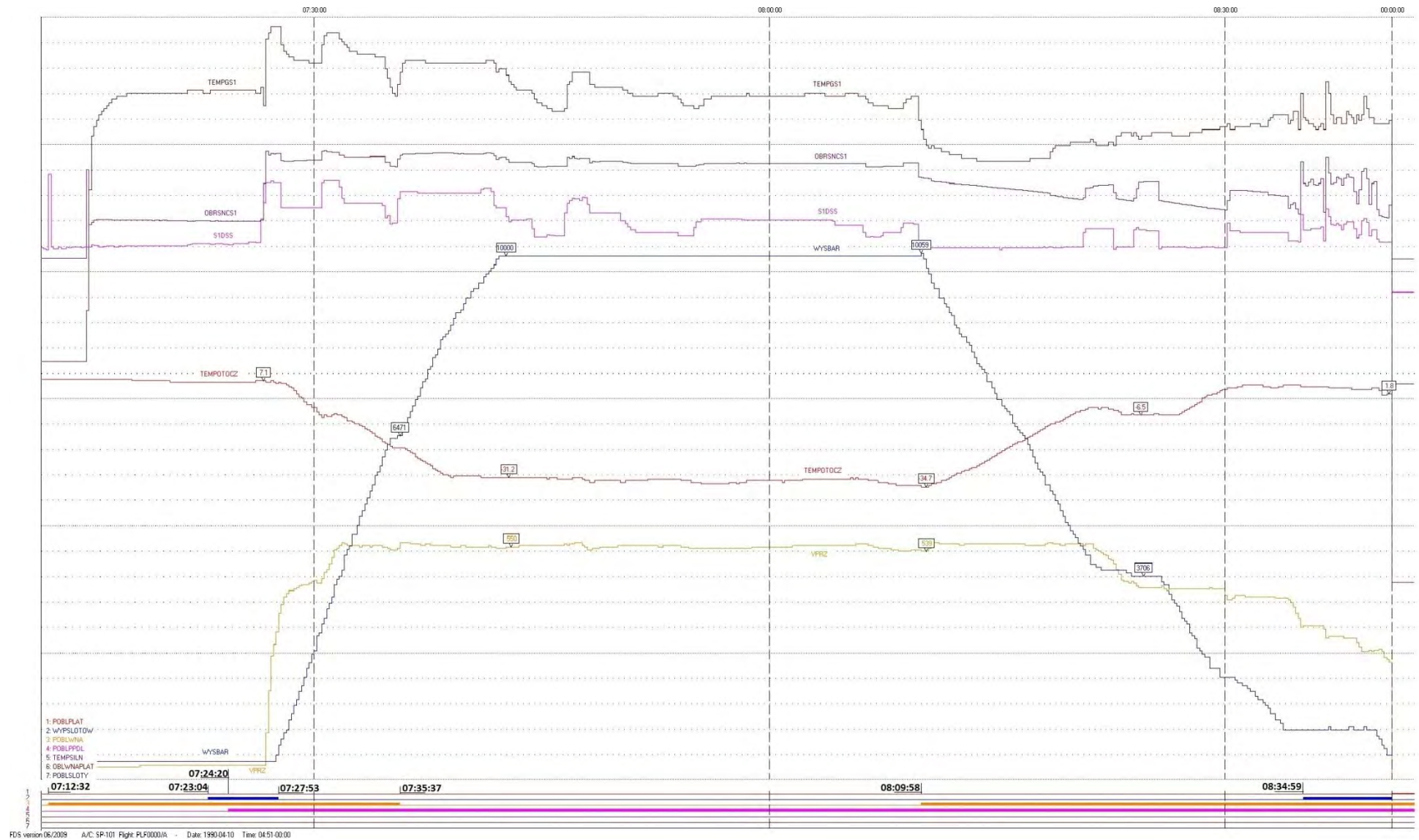


Fig. 23. Anti-icing system operation record

Conclusions:

- 1) The slat anti-icing system was not switched on throughout the flight.
- 2) The anti-icing system on WNA inlets was on from 07:12:32 directly before starting the engines and it operated uninterruptedly until switched off at 07:35:37 when climbing at 6471 m. The remaining climb stage and the whole flight at the altitude of 10 000 m was performed with the system off. The system was switched off again at 0809:58 at 10 000 m directly prior to the commencement of descent for landing, and the system was on until the accident.
- 3) The pilot-in-command PPD heating system was switched on at 07:24:20 before the takeoff and it remained on until the accident.
- 4) During the flight of 10 April 2010, the anti-icing systems operated in accordance with the technical specifications. No ice buildup signals were logged by the recorder.

3.6. Analysis of electrical system operation

The aircraft is provided with the following electric power supply systems:

- the main power supply system feeding three-phase alternating current at 115/200 V and constant frequency of 400 Hz

The power supply sources for this system are three type GT40PCz6 generators installed on each engine. Upon the manual or automatic disconnection of the generator the network disconnection signal is generated for the generator concerned (G1NIESPR, G2NIESPR, G3NIESPR). System failure is also signaled in the event of absence of power supply to the NKP left bus from generator No 1 or the NPK right bus from generator No 3 (NPKP3SIEC1, NPKL1SIEC3). In such cases, the system automatically switches to power supply from the second generator, which is indicated on the instrument panel – Fig. 24 and recorded by the recorder. The emergency source for the main power supply system is the TA-6A power generating set. During the generating set startup the STARTWSU signal is recorded;

- secondary 36V AC power supply system with constant frequency of 400 Hz

The system power supply sources are two type TS330SO4B transformers fed from the main power supply system with three-phase alternating current (generators). Power is supplied to the generators from the left and right NPK bus. In the event of failure of one transformer, the damaged transformer network is automatically or manually switched over to the operational transformer.

During normal operation, the left 36V bus is fed from transformer No 1. Under emergency

conditions, PTS-250 No 2 converter is automatically connected to the bus, serving as the emergency source of supply for the system. The left bus is supplied with voltage in the same manner from transformer No 2 and under emergency conditions from PTS-250 No 1 converter; in addition, the converter is used to supply power to the artificial horizon AGR under its normal operating conditions.

- Secondary 27V DC power supply system

The system consists of two networks: left and right. The sources of power supply are WU-6B rectifiers No 1 for the left network and 2 for the right network. There is also a standby rectifier installed in the system, which connects to the left or right network in the event of failure instead of the damaged WU. WU-6B rectifiers are supplied with power from relevant 115/200V buses of the main power supply system. Four on-board batteries provide an emergency power supply for that system.

The recorder records as an analogue signal the value of voltage on the 27 V left bus and as discrete signal the presence of 27V voltage on the right bus.

The operation of the electrical system of the Tu-154M aircraft is monitored by MSRP system based on the following parameters:

Table 4. Analogue parameters of the electrical system

No	Description	Mnemonic
1.	27 V network voltage – voltage value is recorded on the right AZS board of the 27V power supply system	TABPL27V

Table 5. Discrete parameters of the electrical system

No	Description	Mnemonic
1.	Switching power supply of NPK bus ⁹ of the right network to network No 1	NPKP3SIEC1
2.	Switching power supply of NPK bus of the left network to network No 3	NPKL1SIEC3
3.	Disconnection of generator No 3 from network	G3NIESPR
4.	Disconnection of generator No 2 from network	G2NIESPR
5.	Disconnection of generator No 1 from network	G1NIESPR
6.	Presence of 27 V voltage on the left AZS board ¹⁰	TABLAZS27V
7.	36 V voltage on PTS-250 No 1 converter bus	SZYNAWA36V
8.	36 V voltage on left bus (of PTS-250 No 2)	LSIEC36V
9.	36 V voltage on right bus	SIECPR36V

⁹ NPK – Navigatsionno Pilotazhny Complex

¹⁰ AZS – Automat Zabezpieczenia Sieci (Automatic Network Protection System)

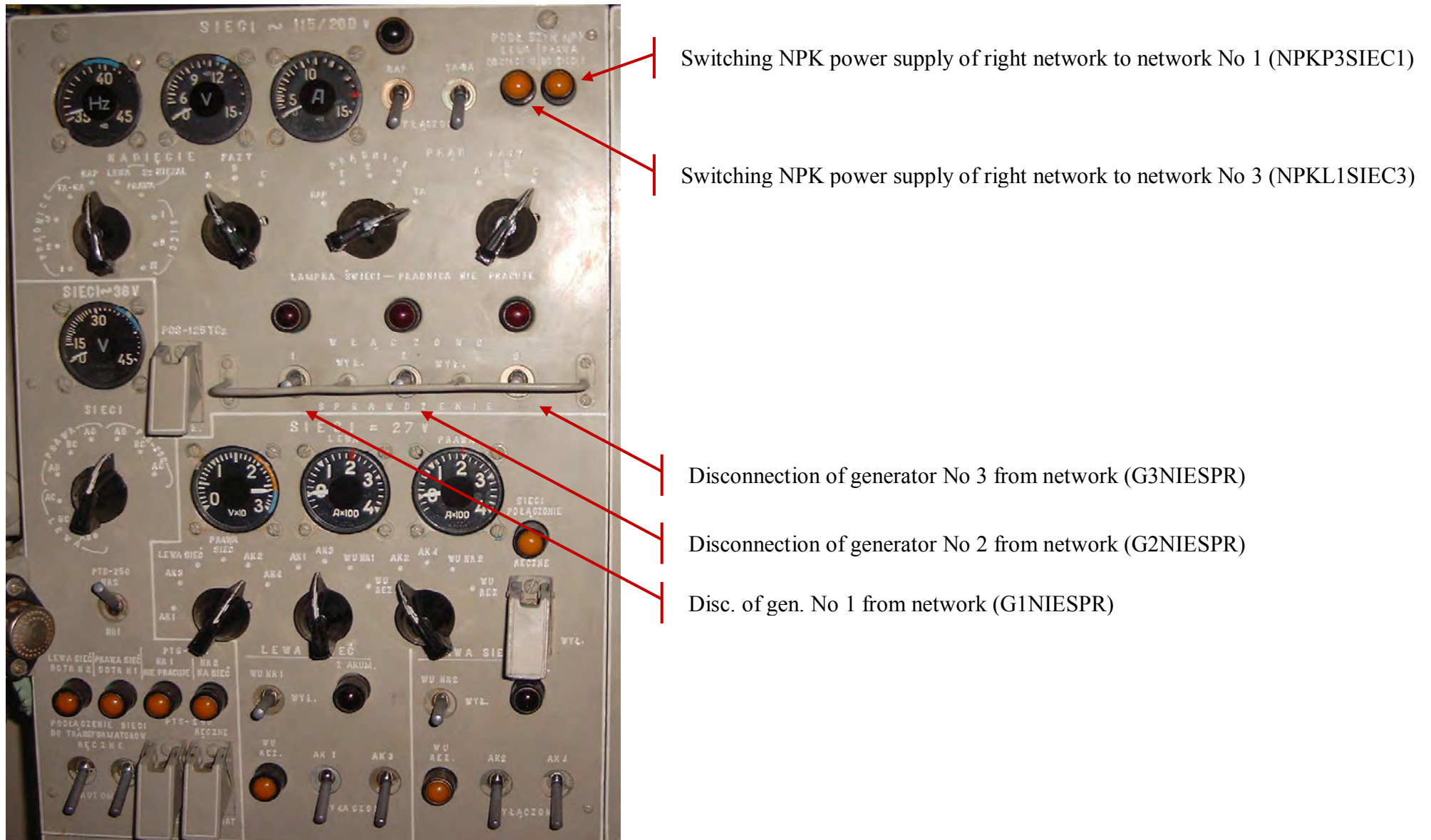
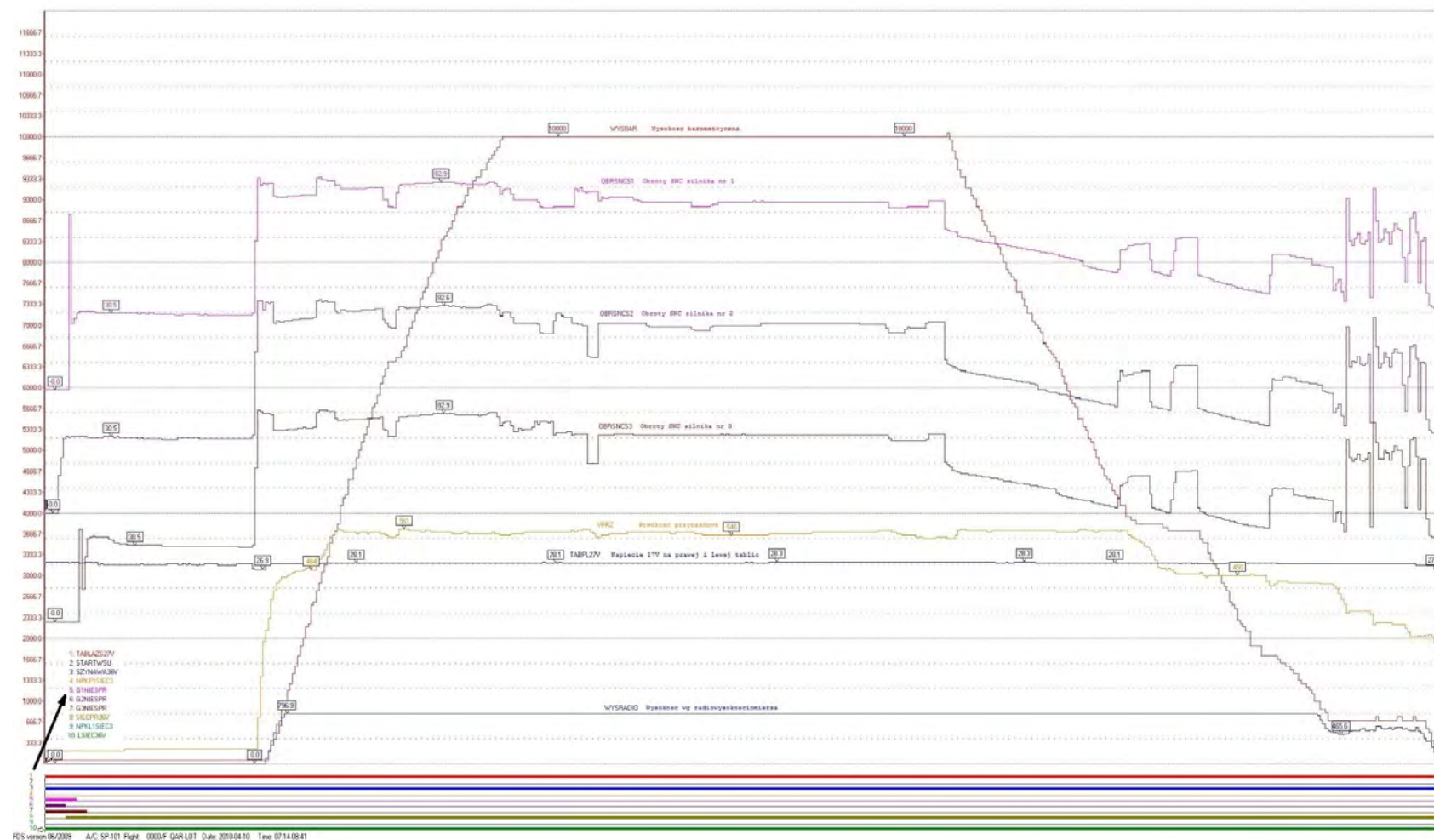


Fig. 24. Tu-154M aircraft power supply control panel (flight engineer)



RDS version 06/2005 A/C SP-101 Flight: 0000F GARLOT Date: 20100410 Time: 0714:09:41

Wysokość barometryczna	Pressure altitude
Obrotów SNC silnika nr 1	SNC speed of engine No 1
Napięcie 27V na prawej i lewej tablicy	27V voltage on right and left channels
Wysokość wg radiowysokościomierza	Radio altitude

Fig. 25 Flight parameters for the electrical system

Conclusions:

- 1) During the flight of 10 April 2010, the generators feeding the main power supply system with three-phase alternating current at 115/200 V and constant frequency of 400 Hz were connected to the network directly after each of the engines was started in the following sequence: engine No 2 – generator No 2, engine No 1 – generator No 1, engine No 3 – generator No 3. No signals occurred during the flight to indicate automatic or manual disconnection of any generator from the network, which means that the system was supplied with power in accordance with the technical specifications throughout the flight.
- 2) No signals occurred during the flight to indicate a change in the configuration of power supply to the left and right NPK bus. The buses were supplied with power in accordance with the technical specifications throughout the flight.
- 3) No signal occurred during the flight to indicate the switching on of emergency power supply from the TA-6A power generator set.
- 4) No signals occurred during the flight to indicate incorrect operation of the 36V power supply system or signals to indicate automatic or manual switching on of emergency sources of power supply to the system.
- 5) No signals occurred during the flight to indicate a failure of the 27V DC power supply system; voltage on the left bus ranged within the limits provided for in the technical specifications; no signal occurred to indicate the absence of voltage on the left bus.

3.7. Operability of on-board instruments based on an analysis of a record of selected flight parameters

The MSRP system allows an analysis of the operation of on-board instruments only at the basic level. This is due to the fact that the system records a very limited set of parameters.

Table 6. Analogue parameters

No	Parameter	Measurement range		Mnemonic
		od	do	
1.	Roll angle from left PKP	-82.5 °	+82.5°	PRZECHYL
2.	Gyromagnetic course	0	360°	KURSMAGN
3.	Pitch angle from MGW No 3	-83°	83°	POCHYLENIE
4.	Roll angle from right PKP	-82.5°	+82.5°	PKPPRZECH

Table 7. Discrete (bistable) parameters

No.	Parameter	Mnemonic
1.	Readiness of left artificial horizon – indication of operability of artificial horizon; lack of signal is indicated by a red flag AΓ appearing on the PKP-1 indicator on the left instrument panel	SPRHORL
2.	Readiness of right artificial horizon – indication of operability of artificial horizon; lack of signal is indicated by a red flag AΓ appearing on the PKP-1 indicator on the right instrument panel	SPRHORP
3.	Operability of RA No 1 – signal generated by the radio altimeter internal control system	SPRRW5NR1
4.	Operability of RA No 2 – signal generated by the radio altimeter internal control system	SPRRW5NR2
5.	No artificial horizon control – indicates power failure or inoperability of the BKK-18 roll angle unit. This is indicated by the appearance of the warning “BRAK KONTR. AG” on the pilot-in-charge or co-pilot instrument panel or the appearance of AΓ flags on both PKP-1 indicators	AGBEZKONTR
6.	Failure of MGW No 1 gyro vertical – a signal indicating the inoperability of the MGW gyro vertical	USTERMGW1

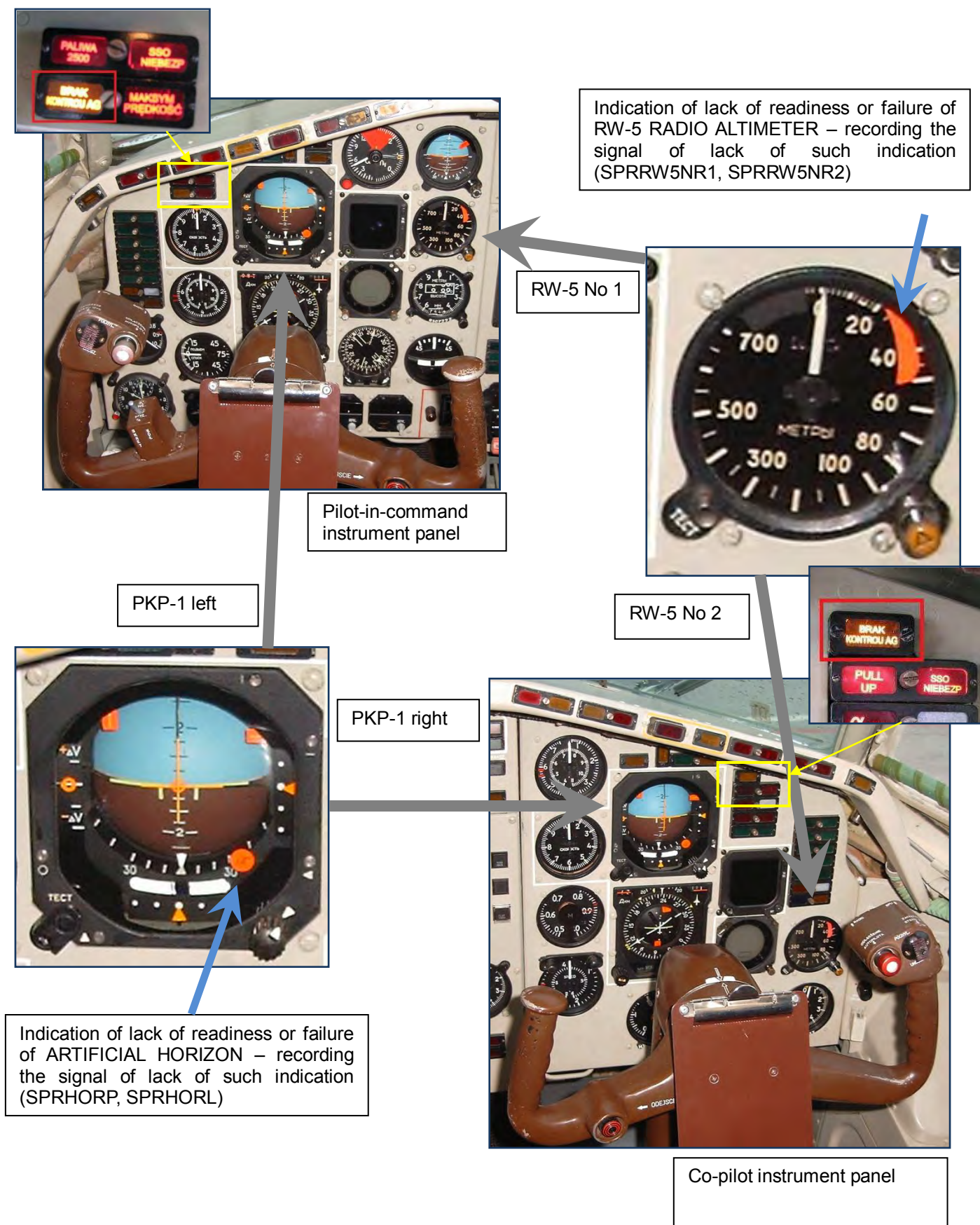


Fig. 26. Indication of lack of readiness or inoperability of ARTIFICIAL HORIZON and lack of readiness or failure of RADIO RW-5 ALTIMETER on right and left instrument panels, and BRAK KONTROLI AG (NO AG CONTROL) INDICATION

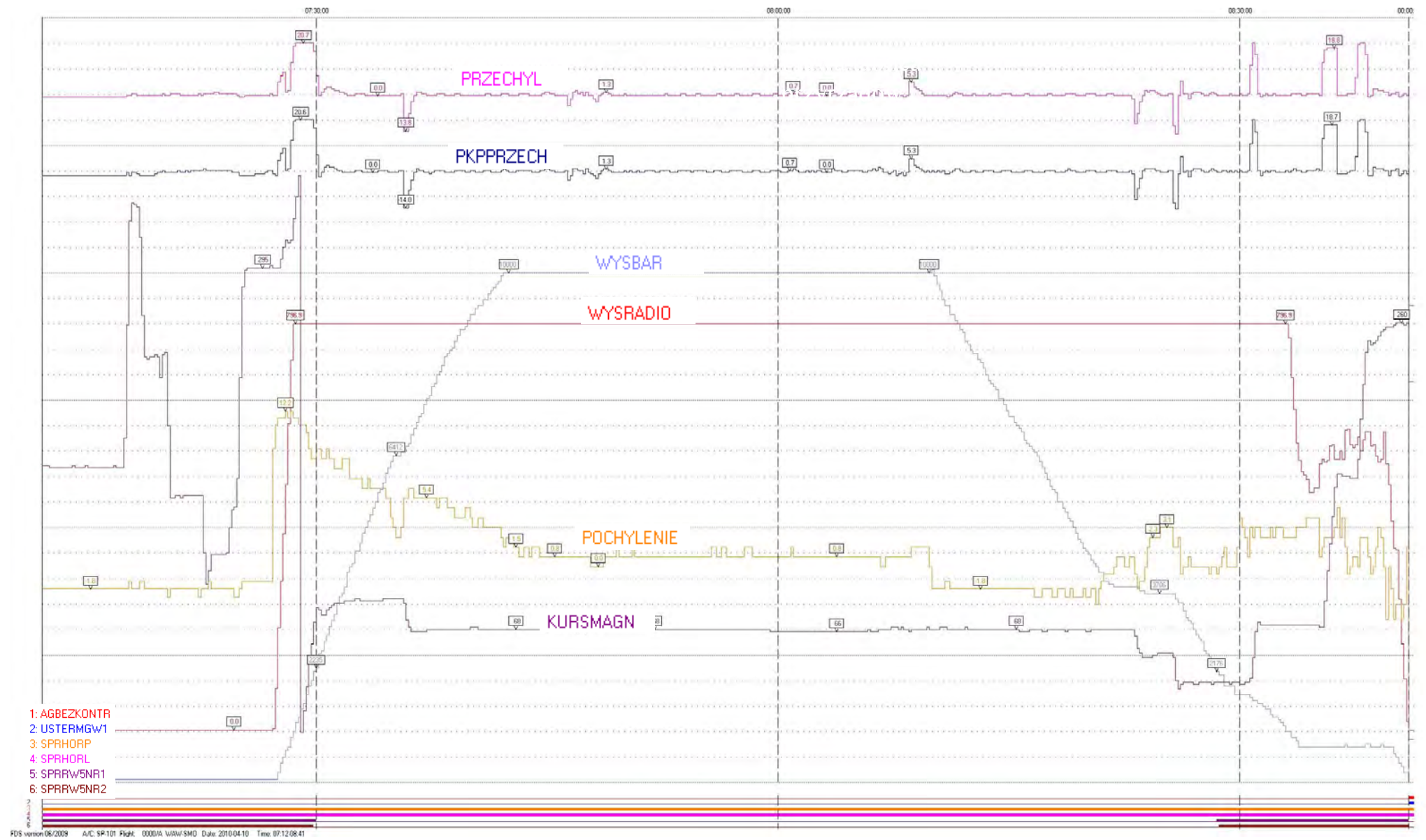


Fig. 27. Flight parameters for selected on-board instruments

PRZECHYL	ROLL
PKPPRZECH	PKP ROLL
WYSBAR	PRESSURE ALTITUDE
WYSRADIO	RADIO ALTITUDE
POCHYLENIE	PITCH
KURSMAGN	MAGNETIC COURSE

Conclusions:

- 1) Throughout the flight, no signals occurred to indicate the interoperability of artificial horizons on the left and right instrument panels and no MGW control gyro vertical inoperability signal occurred.
- 2) Throughout the flight, no signals occurred to indicate the interoperability of radio altimeters RV-5 on left and right instrument panel.
- 3) Throughout the flight, no signal occurred to indicate the interoperability of roll control unit BKK-18.
- 4) Throughout the flight, the difference of roll angles on PKP-1 indicator on the left instrument panel and PKP-1 indicator on the right instrument panel did not indicate any inoperability or incorrect operation of the indicators.
- 5) Throughout the flight, the roll angle and course indications were continuous, without step changes in value indicative of any inoperability of the signal transmitters.
- 6) Changes in all parameters reliably represent the position of the aircraft relative to geometrical axes.

4. Aircraft use by the pilot on the flight during which the aviation occurrence took place

The analysis was performed on the basis of a record from the ATM-QAR recorder, as compared with the operating limitations contained in “Ту-154М. Руководство по летной эксплуатации Книга 1, 2”, (Tu-154M. Flight Crew Operation Manual. Parts, 1, 2) and the recommendations arising from the air traffic regulations.

The FDS (Flight Data Service) software, version 6 and version 8 by ATM (Advanced Technology Manufacturing), was used for the purposes of the analysis. Using the AFPA (Automatic Flight Parameters Analysis) rules, the aircraft flight parameters were checked in terms of exceeding the operational limitations. The analysis concerned parameters recorded by the recorder from the start-up of the engines, i.e. 7:12:00, to 8:41:04, ATM-QAR time.

Table 8. Results of AFPA analysis performed on the 10 April 2010 flight data.

AFPA C5-1			
No	No of procedure	Description of procedure	Duration and values of additional parameters
1.	AL35A	Taxiing, lift devices lowered Fig. 28	Duration: 07:23:04-07:23:07 POZKLAP: 4 WYPSLOTOW: 1
2.	AL35A	Taxiing, lift devices lowered Fig. 28	Duration: 07:24:53-07:25:17 POZKLAP: 28 WYPSLOTOW: 1
3.	AL29A	Retraction of flaps from 28 below V_p < 330 km/h Fig. 28	Duration: 07:27:29-07:27:30 VPRZ: 327 POZKLAP: 27
4.	AL09A	Retraction of flaps at V_p < 410 km/h Fig. 28	Duration: 07:27:45-07:27:46 POZKLAP: 0 VPRZ: 389
5.	AL31A	Flight at $V > 460$ km/h below FL100 /acc to ICAO/ Fig. 29	Duration: 07:29:12-07:30:53 VPRZ: 493 WYSBAR: 3000 WYSRADIO: 796.9
08:40:59.375 – collision with tree			
6.	AL19A	SPS warning	Duration: 0841:00-08:41:01 SYGNAUASP: 1
7.	AL24A	Roll > 15 on landing	Duration: 0841:00-08:41:03 PKPPRZECH: -65.2 WYSRADIO: 15.6 PRZECHYL: -63.8 DUZEPRZECH: 1
8.	AL25A	Roll > 15 at ≤ 250 m	Duration: 0841:00-08:41:03 PKPPRZECH: -65.2 WYSRADIO: 15.6 PRZECHYL: -63.8 DUZEPRZECH: 1
9.	AL26A	Roll > 30	Duration: 0841:01-08:41:03 PKPPRZECH: -65.2 WYSRADIO: 15.6 WYSBAR: 188 PRZECHYL: -63.8 DUZEPRZECH: 1
10.	AL27A	Warning STRONG ROLL	Duration: 0841:00-08:41:03 PRZECHYL: -16.9 PKPPRZECH: 22.0 WYSRADIO: 6.2 WYSBAR: 188 DUZEPRZECH: 1
11.	AL23A	Vertical acceleration < 0.2 with high lift devices	Duration: 0841:04-00:00:29 PRZEPION: 0.47 POZKLAP: 36 INTERCSR: 0 INTERCWEW: 0 WYPSLOTOW: 1

AFPA C5-2 NO WARNINGS OF EXCEEDED LIMITATIONS			
AFPA C5-3			
Ni.	No of procedure	Description of procedure	Duration and values of additional parameters
12.	AT30	AWARIA I.HYDR.1/NIEB. ZIEMIA (FAILURE I. HYDR.1/DANGER GROUND) warning Fig. 32	Duration: 0840:06-08:40:11 VPRZ: 306 WYSBAR: 562 WYSRADIO: 356.2 PH1VZBLIZ: 1
13.	AT30	AWARIA I.HYDR.1/NIEB. ZIEMIA (FAILURE I. HYDR.1/DANGER GROUND) warning Fig. 32	Duration: 0840:31-08:41:01 VPRZ: 288 WYSBAR: 375 WYSRADIO: 218.8 PH1VZBLIZ: 1
08:40:59.375 – impact with tree			
14.	AT30	AWARIA I.HYDR.1/NIEB. ZIEMIA (FAILURE I. HYDR.1/DANGER GROUND) warning	Duration: 0841:02-23:04:11 VPRZ: 263 WYSBAR: 188 WYSRADIO: 37.5 PH1VZBLIZ: 1
15.	AT37	NIESPRAWNOŚĆ RW5 NR 1 (RW5 NO 1 INOPERABLE)	Duration: 0841:02-23:04:11 WYSRADIO: 18.8 WYSBAR: 188 SPRRW5NR1: 0 SPRRW5NR2: 1

The exceeded limitations listed in Sections 6-11 and 14-15 (grey in the table above) occurred after the commencement of the destruction process following the aircraft collision with the birch of about 30-40 cm in diameter.

The aircraft configuration during takeoff and during landing was shown in Fig. 30 and in Fig. 31. According to the data presented in the charts, in all flight stages the aircraft had a configuration in compliance with the Tu-154M Flight Crew Operation Manual.

Based on a record from the cockpit voice recorder MARS-BM it was determined that lights were lowered during the performance of the landing procedure at 8:39:23 at aircraft speed of 303 km/h – in accordance with technical specifications.

All the exceeded limitations mentioned in Sections 1-5 and 12-13 were not due to incorrect operation of the aircraft, but resulted from incorrect use of the aircraft by the crew.

The analysis did not reveal any emergency conditions of systems or instrument failures. The manner in which all parameters developed is not indicative of any malfunctioning of units, systems and equipment on board throughout the flight until the moment the left wing of the aircraft aircraft collided with the tree with a diameter of about 30-40 cm.

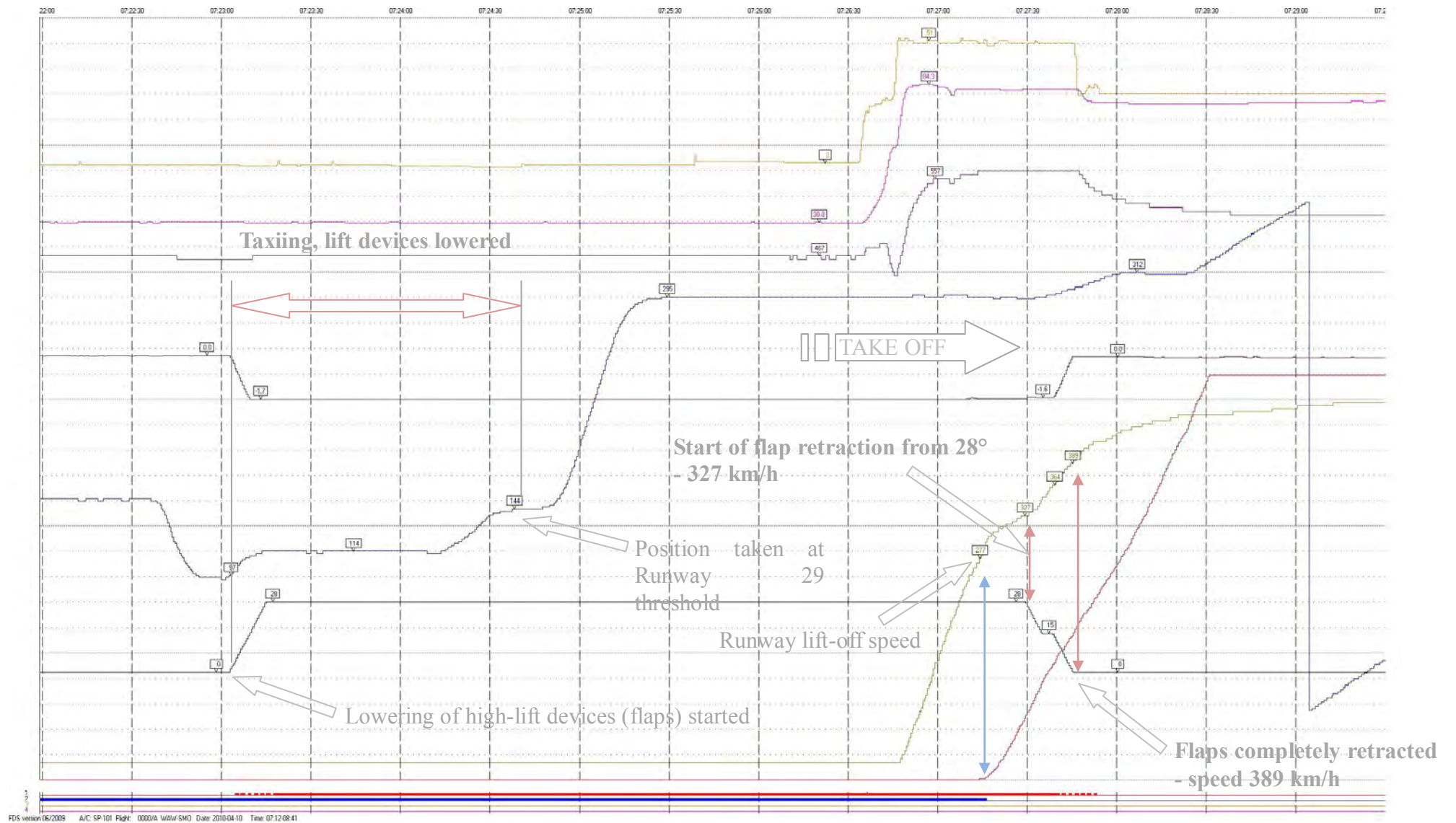


Fig. 28. Selected parameters of the taxiing and takeoff stage

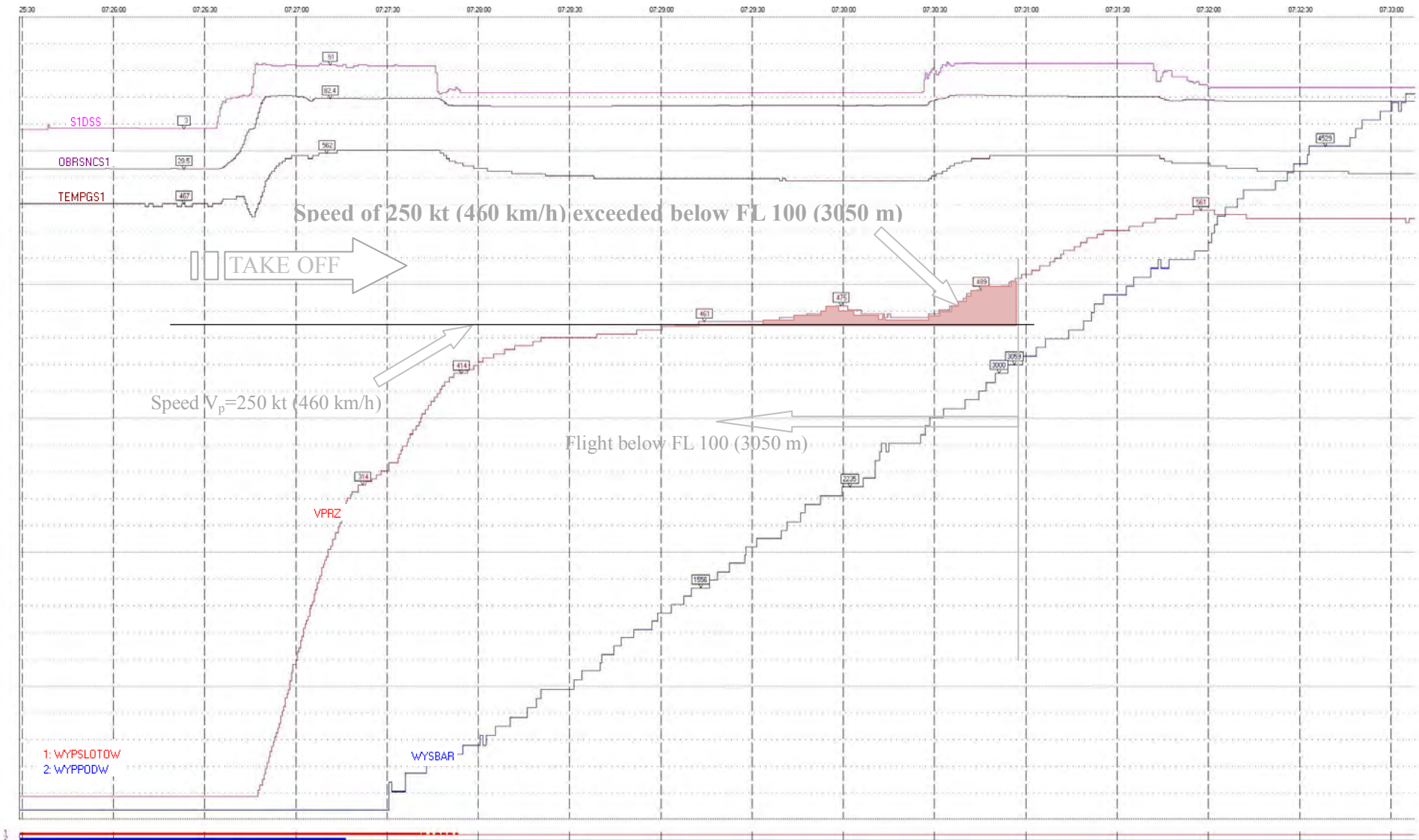


Fig. 29. Exceeding the speed of 250 kt (460 km/h) during flight below FL 100 (3050 m)

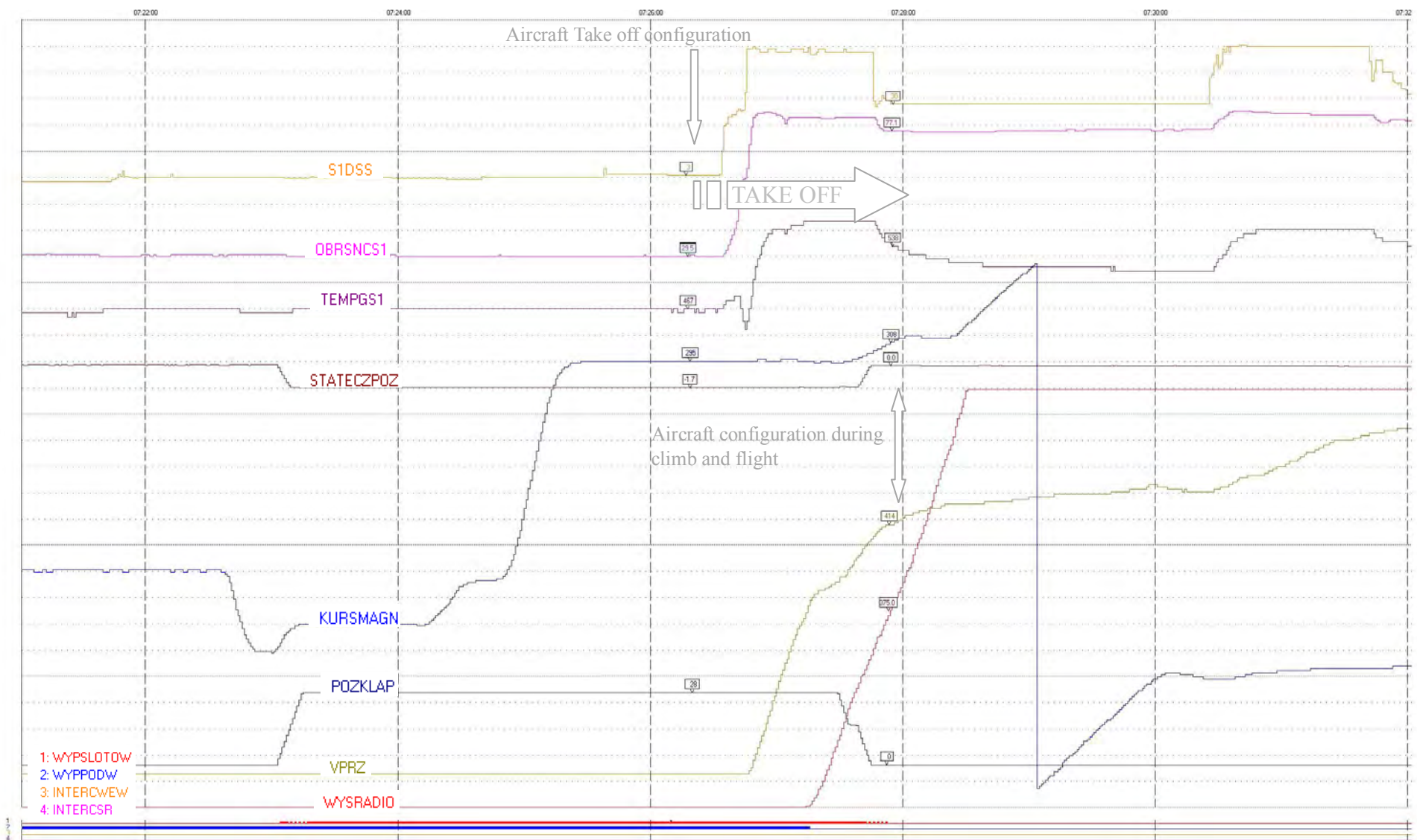


Fig. 30. Aircraft configuration during takeoff, climb and flight

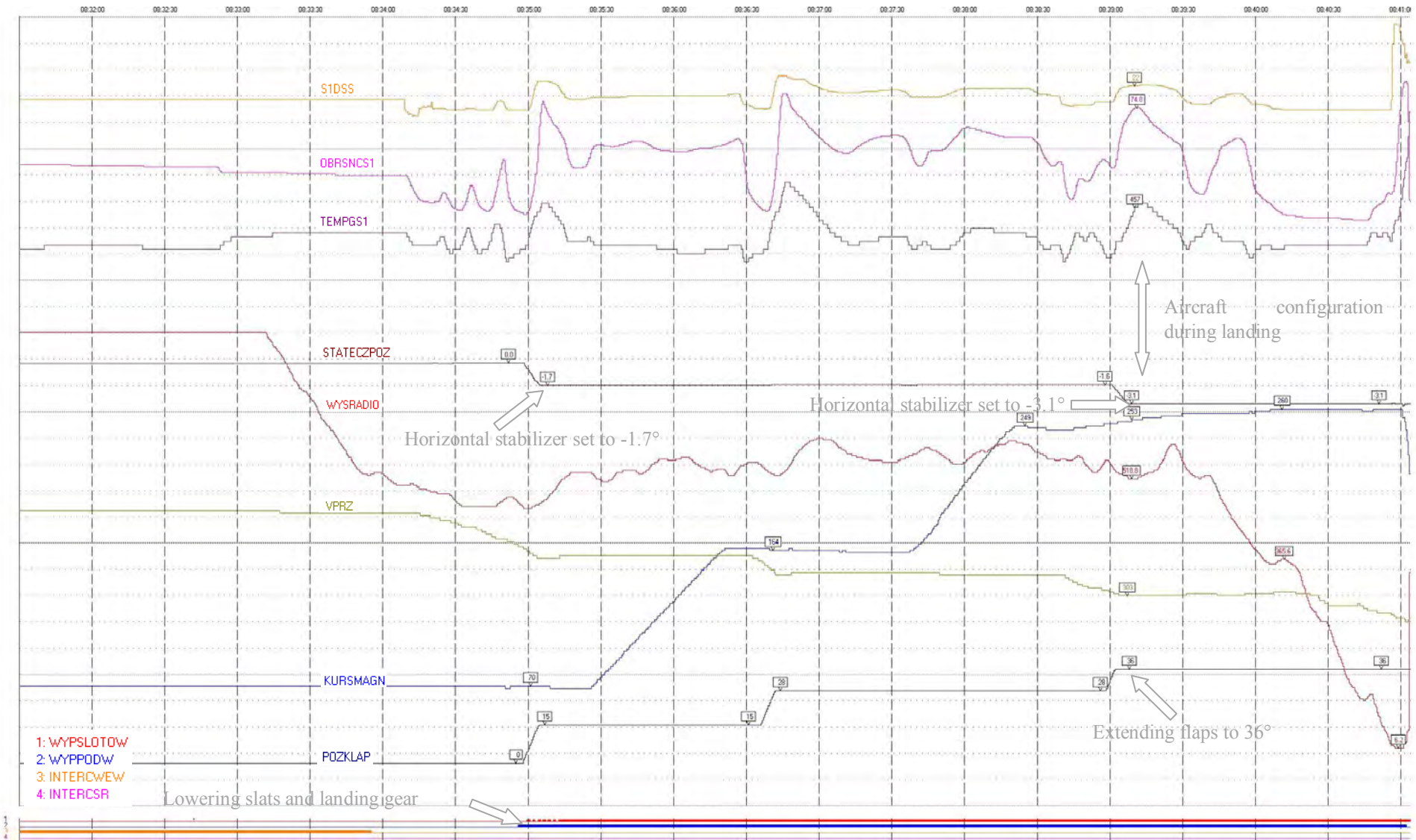


Fig. 31. Aircraft configuration during landing

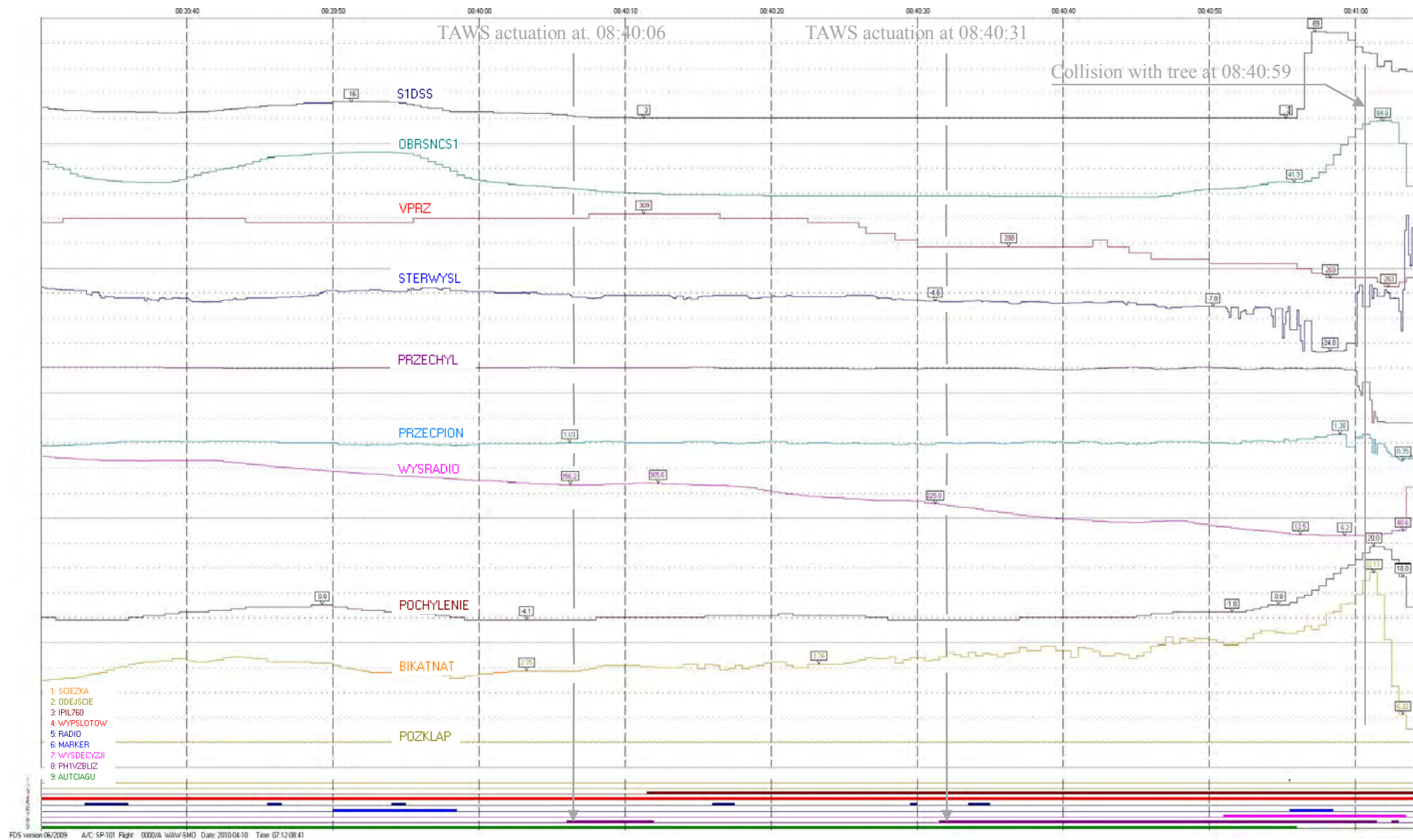


Fig. 32. TAWs signal actuation (parameter PH1/VZBLIZ)

Conclusions:

- 1) Throughout the flight of 10 April 2010, until the aircraft collided with a tree of 30-40 cm in diameter, no signals occurred indicative of the inoperability of any system, device or component of the aircraft monitored by the MSRP and ATM-QAR systems.
- 2) During the flight, the following operational limitations were exceeded by the aircraft crew while piloting:
 - a) taxiing with high-lift devices lowered (duration of about 1 min 35 s);
 - b) flaps retracted from 28° below indicated airspeed of $V_p < 330$ km/h ($V_p = 317$ km/h);
 - c) full retraction of wing flaps at indicated airspeed below $V_p < 410$ km/h ($V_p = 389$ km/h);
 - d) flight at indicated airspeed above $V_p > 250$ kt (460 km/h) below FL100 (3050 m);
 - e) two occurrences of the ground proximity warning generated by TAWS.
- 3) There was no causality between exceeding the operational limitations mentioned in Para 2 (a)-(d) and the occurrence of the accident (for a detailed description see the piloting part).
- 4) The events mentioned in Para 2 (e) were confirmed during analysis of the TAWS unit.

5. Conclusions on the expert examination of flight recorders from the Tu-154M aircraft

- 1) The MSRP system operated on 10 April 2010 for 3 hours 48 min and 29 s from its activation at 4:52:35 to its destruction in the accident at 8:41:4 (MSRP time).
- 2) Throughout the recording period data was recorded in a continuous and reliable manner, and the number of recording errors fell within the acceptable limit specified by the system manufacturer.
- 3) A comparison of the MSRP data (MLP-14-5 and KBN-1-1 recorders) and ATM-QAR recorder data clearly shows that that the records retrieved from all three recorders concern the same flight.
- 4) The total duration of the record from the MARS-BM recorder is 38 min 14 s and it covered the period from 8:02:53.5 to 8:41:07.5 (MARS-BM time).
- 5) An analysis of the parameters recorded by the MSRP system, the ATM-QAR and the MARS-BM voice recorder shows that MSRP/ATM-QAR time is delayed 3.425 s compared with MARS-BM time. A delay of 3 s was taken for the purposes of the analysis.
- 6) Throughout the flight¹¹, until the aircraft collided with the tree of 30-40 cm in diameter, no signals occurred indicative of the inoperability of any system, device or component of the aircraft monitored by the MSRP and ATM-QAR systems.

¹¹ Throughout the flight – this means the time from the start-up of the engines before the flight to the collision of the aircraft with the tree of 30-40 cm in diameter.

- 7) In analyzing the record retrieved from the ATM-QAR flight recorder, no anomalies were found in the operation of the ABSU automatic control system. The movements of actuator shafts changing the position of elevators, ailerons and rudder were fluid and did not reach extreme values.
- 8) An analysis of the operation of the aircraft power system did not reveal any signals indicative of inoperability of any of the primary and secondary power supply sources. The on-board systems and devices were powered in line with their technical specifications throughout the flight.
- 9) Throughout the flight, the anti-icing systems operated in accordance with the technical specifications; throughout the flight, there were no signals of ice recorded by the recorder.
- 10) Throughout the flight, there were no signals indicative of the inoperability of artificial horizons and radio altimeters on the left and right instrument panel. Changes in all parameters reliably represent the position of the aircraft relative to the geometrical axes.
- 11) There was no causality between the fact that operational limitations were exceeded by the aircraft crew during the flight and the occurrence of the accident.
- 12) An analysis of the records of flight parameters and cockpit conversations did not show any anomalies of the navigation systems attributable to the impact of any unknown sources of radiation, including mobile phones.



Fig. 2. Plan of the passenger compartment of the aircraft Tu-154M tail number 101 (90A837):

- a) As approved and authorized by the manufacturer;
- b) After modifications made in 36th Special Transport Air Regiment on 6 April, 2010

There were five seats in the cockpit (Fig. 3). During the scheduled flight on 10 April, 2010, there should have been only four crew members in the cockpit, i.e.:

- Pilot-in-Command (Captain);
- Co-pilot;
- Navigator;
- Flight engineer.

The arrangement of seats of the respective crew members in the cockpit can be seen in figure 3.

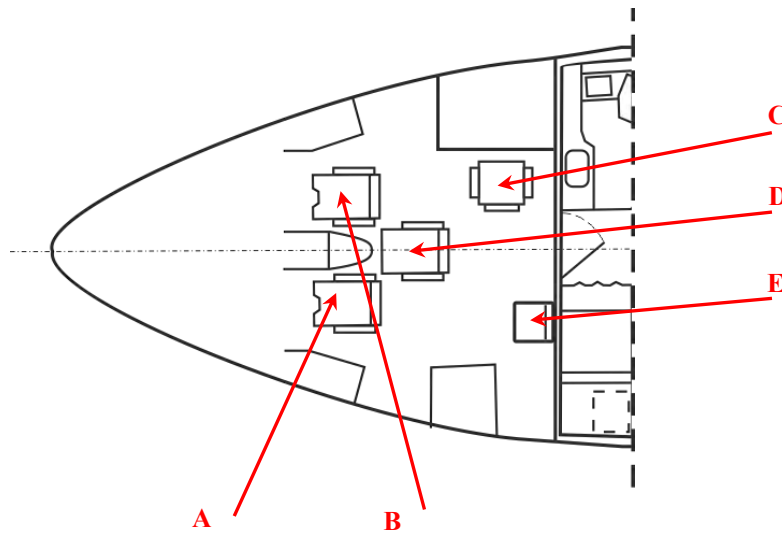


Fig. 3 The arrangement of seats of the respective crew members in the cockpit:
A – Pilot-in-Command (Captain);
B – Co-pilot;
C – Flight engineer
D – Navigator;
E – Instructor (only for training flights)

Figure 4 shows the cockpit and the most important instruments and panels used during the final stage of flight. Within the Pilot-in-Command's sight there were three instruments showing the barometric altitude:

- a) WBE-SWS Flight Environment System displaying the altitude in [m] or [ft];
- b) Altitude indicator UWO-15M1B in the instrument set SWS-PN-15-4B showing the altitude in [m];
- c) Altimeter/variometer KAV-485 showing the altitude in [ft];

and an indicator of radio altimeter A-034-4 showing the altitude in [m].

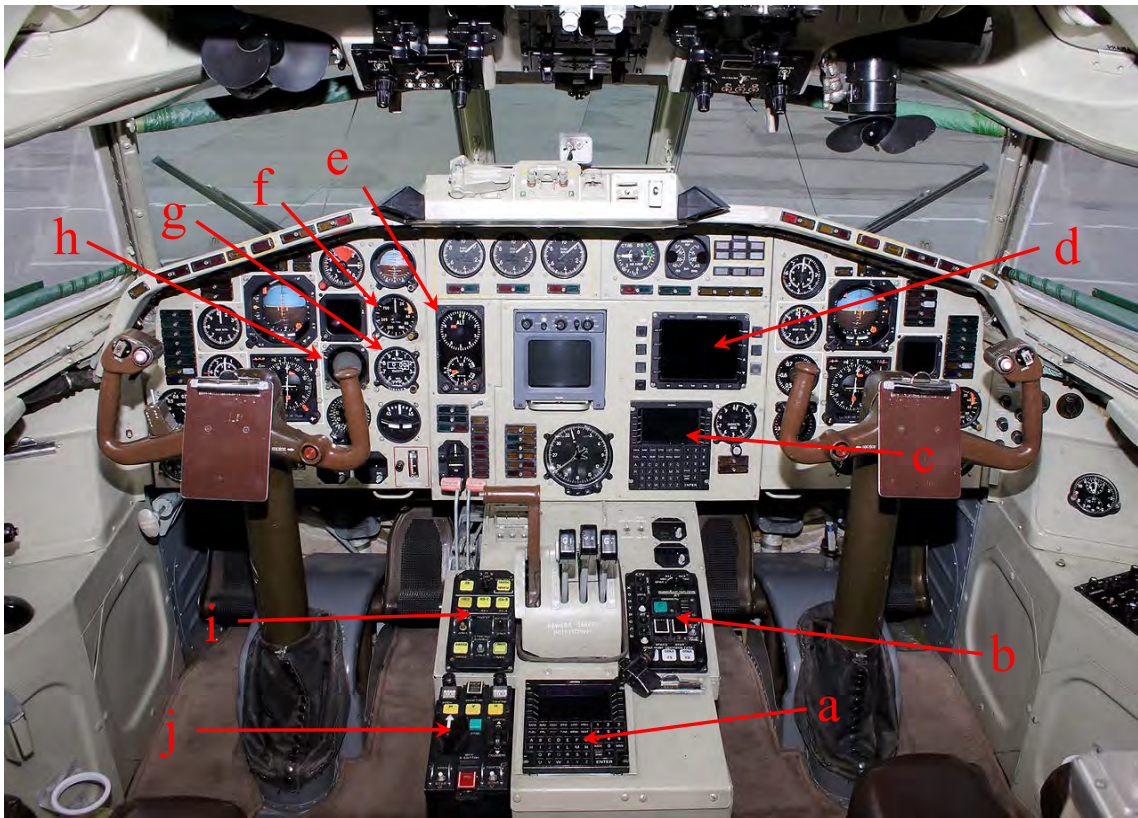


Fig 4. The control panel of the Pilot-in-Command and the Co-pilot of the aircraft Tu-154M tail number 101:

- a - UNS-1D – the panel of the flight management system (FMS);
- b - PN-6 – the autothrottle control panel;
- c - UNS-1D – the flight management system (FMS) panel;
- d - MFD-640 – multifunctional display;
- e - KAV-485 – altimeter / variometer (indications in [ft]);
- f - A-034-4 – the radio altimeter indicator (indications in [m]);
- g - UWO-15 M1B – the altitude indicator in the instrument set SWS-PN-15-4B (indications in [m]);
- h - WBE-SWS – Flight Environment System of the Pilot-in-Command ([m] or [ft]);
- i - PN-5 – the ABSU navigation panel;
- j - PU-46 – the ABSU control panel.

At the time of collision (contact) with the first ground obstacle (the tip of a birch in the vicinity of the inner marker), the configuration of the aircraft Tu-154M, tail number 101, was as presented in Fig. 5.

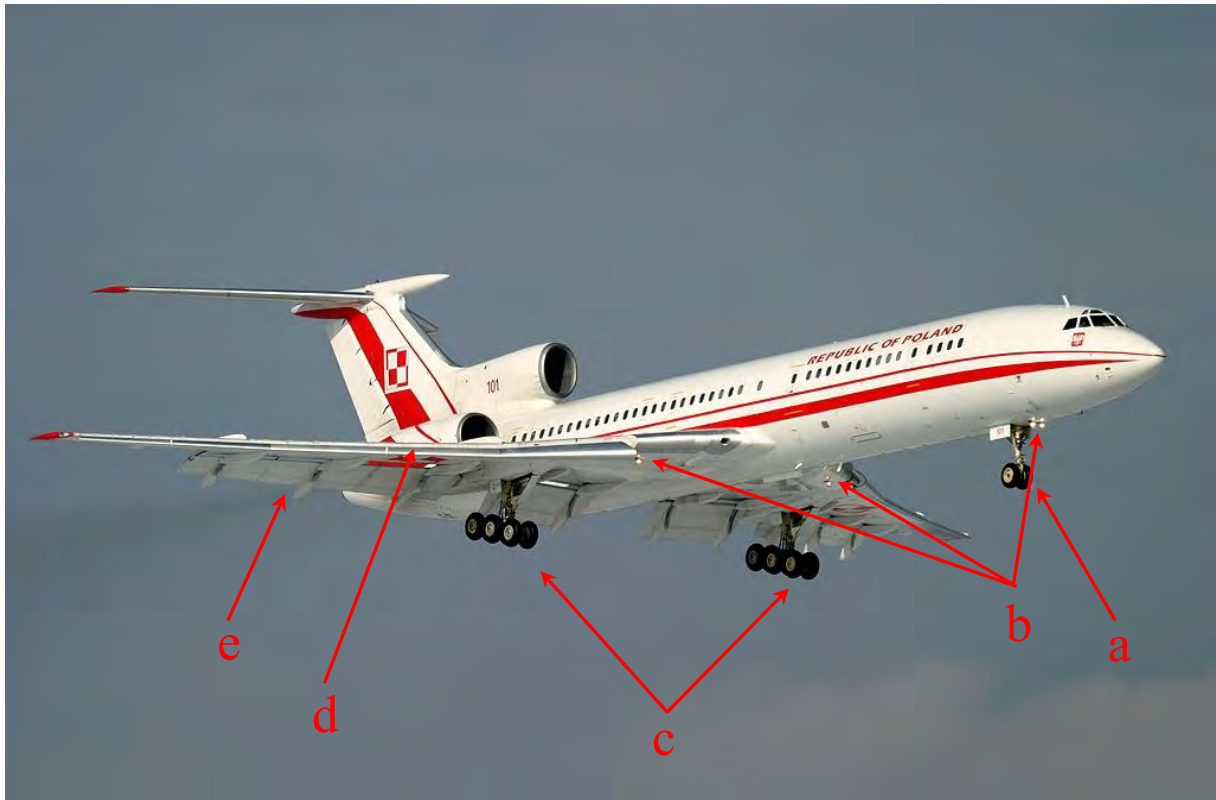
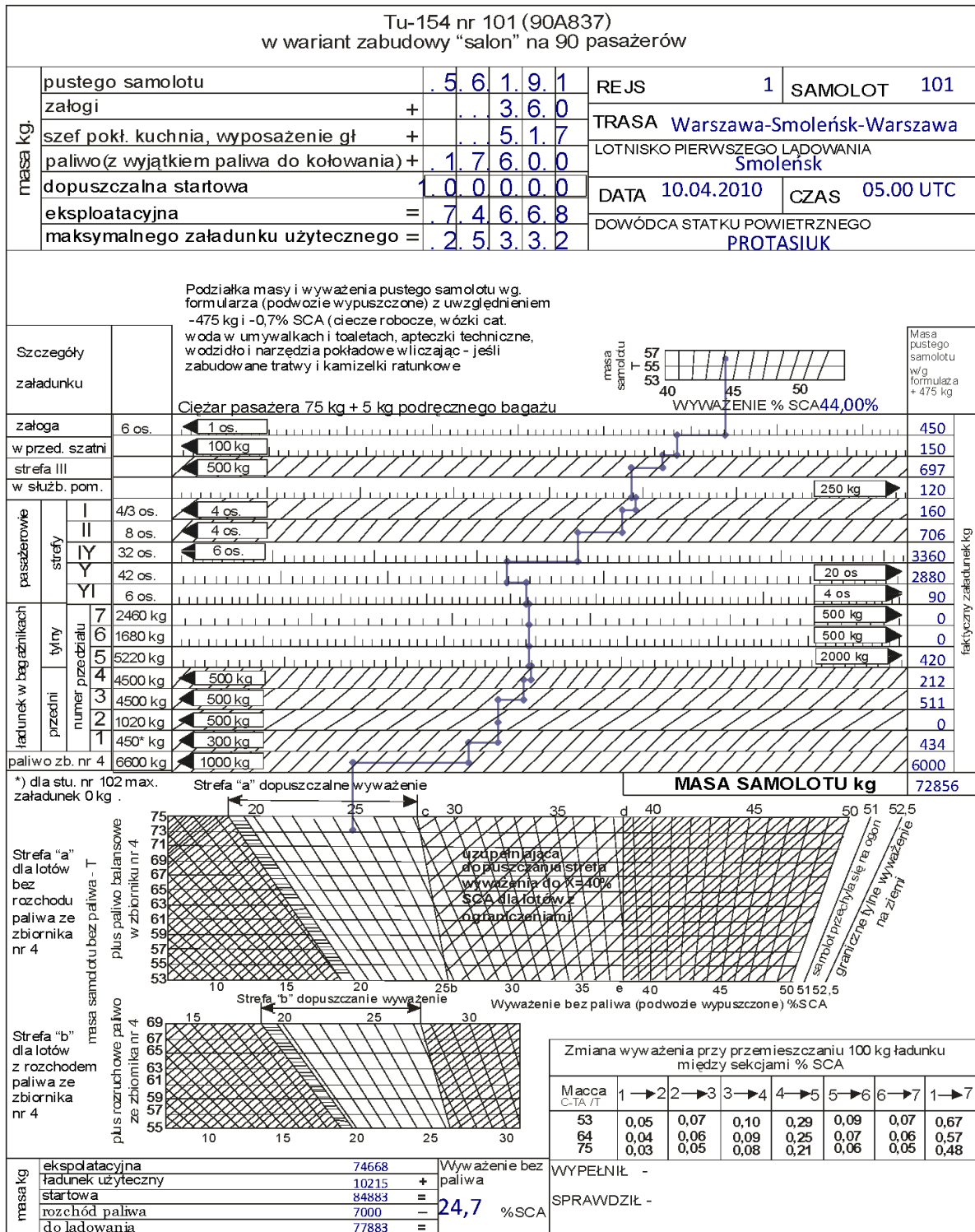


Fig. 5. Aircraft Tu-154M, tail number 101, in the landing configuration This is confirmed by the extended:
a – Front landing gear;
b – Spotlights;
c – Main landing gear;
d – Slats;
e – Flaps.

The examination and evaluations carried out at the scene of accident together with the detailed analysis of flight parameters and conversations between the crew members confirmed that on contact with the first terrain obstacle - the tip of a birch in the vicinity of the middle marker - and during the further flight and at the moment of the crash the aircraft Tu-152M, tail number 101, was in the landing configuration. Table 1 presents the positions of different parts of the aircraft which confirm beyond doubt that such was the configuration of the aircraft.

Upon departure from the WARSZAWA-OKĘCIE airport the aircraft's tanks contained 17,600 kg of fuel (according to the ATM QAR recorder), including 6,000 kg in tank 4 (ballast tank). The aircraft's weight calculated for the data as of April 10th, 2010, 0500 UTC, was **84,883 kg**. The center of gravity was at **27.7%** - middle position (Fig. 6).



Dopuszczalne przednie wyważenie do startu-21% , lądowania- 18%

START 27,8 % SCA

Dopuszczalne tylne wyważenie do startu-32% , lądowania- 32%

LĄDOWANIE 26,8 % SCA

Fig. 6. Balance chart for the aircraft Tu154M, tail number 101, prepared using data as for the flight of April 10th, 2010.

Final Report - Annex No. 3. Configuration of the Aircraft at the Moment of the Crash

Tu-154 nr 101 (90A837) w wariant zabudowy „salon” na 90 pasażerów	Tu-154, tail number 101 (90A836), “lounge” version for 90 passengers
Masa pustego samolotu	Weight empty weight
załogi	crew
szef pokł. kuchania, wyposażenie gł.	chief of onboard kitchen, main equipment
paliwo (z wyjątkiem paliwa do kołowania)	fuel (except for taxiing fuel)
dopuszczalna masa startowa eksploatacyjna	allowed take-off weight operational
maksymalnego ładunku użytecznego	max. payload
Rejs	Flight
Samolot	Aircraft
Trasa Warszawa-Smoleńsk-Warszawa	Route Warsaw-Smolensk-Warsaw
Lotnisko pierwszego lądowania Smoleńsk	First landing airdrome
Data	Date
Czas	Time
Dowódca statku powietrznego	Aircraft commander
Podziałka masy i wyważenia pustego samolotu wg formularza (podwozie wypuszczone) z uwzględnieniem -475 kg i -0,7% SCA (ciecze robocze, wózki cat. woda w umywalkach i toaletach, apteczki techniczne, wozidło i narzędzia pokładowe wliczając - jeśli zabudowane tratwy i kamizelki ratunkowe	Scale of weight and balance of empty aircraft acc. to form (landing gear extended) including -475 kg and -0.7% MAC (working liquids, catering carts, water in washbasins and toilets, technical emergency kit, tow bar and onboard tools, including rafts and lifebelts, if built-in.
Ciężar pasażera 75 kg + 5 kg podręcznego bagażu	Passenger weight 75 kg + 5 kg of hand luggage
Masa samolotu	Aircraft weight
Wyważenie % SCA 44,00	Balance MAC% 44.00
Masa pustego samolotu wg formularza + 475 kg	Empty weight acc. to form + 475 kg
Szczegóły ładunku	Details of load
Załoga	Crew
w przedniej szatni	in front dressing-room
strefa III	Zone III
w służb. pom.	in service room
pasażerowie	passengers
strefy	zones
ładunek w bagażnikach	load in luggage compartments
przedni	front
tylny	rear
numer przedziału	compartment no.
os.	persons
paliwo w zbiorniku nr 4	fuel in tank 4
faktyczny ładunek	actual load
dla stu. nr 102 max ładunek 0 kg	for aircraft tail no. 102 max. load 0 kg
Strefa „a” dopuszczalne wyważenie	Zone “a” of allowed balance
Masa samolotu	Aircraft weight
Strefa „a” do lotów bez rozchodu paliwa ze zbiornika nr 4	Zone “a” for flight without drawing fuel from tank 4
Strefa „b” do lotów z rozchodem paliwa ze zbiornika nr 4	Zone “b” for flights with drawing fuel from tank 4
Masa samolotu bez paliwa	Aircraft weight without fuel
plus paliwo bilansowe w zbiorniku 4	plus balance fuel in tank 4
plus rozruchowe paliwo ze zbiornika 4	plus start-up fuel from tank 4
Uzupełniająca dopuszczalna strefa wyważenia do X=40% SCA do lotów z ograniczeniami	Supplementary allowed balance zone for X=40% MAC for flight with restrictions
Strefa „b” dopuszczalne wyważenie	Zone “b” of allowed balance
Wyważenie bez paliwa (podwozie wypuszczone) % SCA	Balance without fuel (landing gear extended) %MAC
Samolot przechylił się na ogon	Aircraft leans towards the tail
Graniczne tylne wyważenie na ziemi	Maximum permissible rear balance on the ground

Final Report - Annex No. 3. Configuration of the Aircraft at the Moment of the Crash

Zmiana wyważenia przy przemieszczeniu ładunku 100 kg między sekcjami %SCA	Change of balance corresponding to relocation of a load of 100 kg between sections %MAC
Macca	Weight
Masa kg	Weight kg
eksploatacyjna	operating
ładunek użyteczny	payload
startowa	take-off
rozchód paliwa	fuel usage
do lądowania	for landing
Wyważenie bez paliwa	Balance without fuel
Wypełnił	Filled
Sprawdził	Checked
Dopuszczalne przednie wyważenie do startu-21%, lądowanie-18%	Allowed forward balance for take-off - 21%, for landing - 18%
Dopuszczalne tylne wyważenie do startu-32%, lądowanie-32%	Allowed rear balance for take-off - 32%, for landing - 32%
Start	Take-off
Lądowanie	Landing

Final Report - Annex No. 3. Configuration of the Aircraft at the Moment of the Crash

Item	Specification	Position	Confirmation of position - only on the basis of		Figure	Remarks
			Time acc. to UTC [QAR]	Communications [MARS-BM]		
1	Extension of flaps	36°	0639:01.5 - 0639:05.5	Co-Pilot and Navigator 0639:01.0 and 0639:07.0	7	Earlier (acc. to MARS 0636:44.5) displaced to 28°
2	Slats	extended	0635:15.5		6	Navigator is saying about “wing mechanization” from 0639:09.5 to 0639:12.0.
3	Stabilizer	-3°	0639:04 - 0639:10		13	Unrecognized voice 0639:15,0
4	Spring loaders	flight spring loaders off	Non-recorded parameter	Pilot-in-Command 0639:18,5		
5	Spoilers	retracted	0633:58.5	Pilot-in-Command 0639:20.0	9	
6	Spot lights	extended, on	Non-recorded parameter	Pilot-in-Command 0639:23.5	8	
7	Landing gear	extended	0634:59	Navigator 0639:26.0	10, 11, 12	
8	Wheel fans	on	Non-recorded parameter	Engineer 0639:27.5		
9	Front wheel control	10°	Non-recorded parameter	Pilot-in-Command 0639:30.5		
10	Confirmation of “landing” chart completion		–	Navigator 0639:32.0		
Other positions of the aircraft systems at the moment of the crash						

Item	Specification	Position	Confirmation of position - only on the basis of		Figure	Remarks
			Time acc. to UTC [QAR]	Communications [MARS-BM]		
1	Automatic stabilization in longitudinal channel	on	0528:11.5			Switched off with a movement of control column 0640:58 acc. to QAR
2	Automatic stabilization in bank angle channel	on	0528:11.5			Switched off with a turn of control wheel at 0641:03.5 acc. to QAR
3	Autothrust	on	0634:20.5			Switched off with a forward movement of DSS 0640:59 acc. to QAR
4	Outer marker signal	enabled	0639:53 - 0640:01.5			
5	Inner marker signal	enabled	0640:58.5 - 0641:01.5			
6	Deicing system of engine inlets	on	0610:01.5			Enabled on the beginning of descent before landing

Table 1. Positions of specific elements and mechanisms of the aircraft Tu-152M, tail number 101, confirming its landing configuration

At the moment of the crash the aircraft's tanks contained **10,600 kg** of fuel, as confirmed by the data registered on the QAR recorder and the calculations based on the documents (maintenance book, refueling log). The total weight of the plane at the time was **77,883 kg** (as calculated using the passenger list, luggage weight and remaining fuel - Fig. 6). Until the aircraft finally hit the ground, its landing gear, flaps, slats, stabilizer and spot lights were in the landing position - as on the collision with the first birch in the vicinity of the inner NDB.

The descent and approach were carried out with the autopilot system enabled. The following operating modes of the system were selected:

- automatic stabilization and control in the pitch channel;
- automatic stabilization and control in the bank angle channel;
- automatic stabilization and control of the aircraft indicated speed with the autothrust system.

The autopilot system maintained (stabilized) the current pitch and course of the aircraft by operating the elevator and ailerons. The set flight speed was maintained by changing engine thrust. The pilot was able to control the plane with the knobs on the PU-46 panel by changing the set values of pitch and roll (change of the course).

The following figures explicitly confirm the positions of particular elements of the aircraft at the scene of accident.



Fig. 7. The slats of the left and right wing of the aircraft in the extended position



Fig. 8. Flaps in the displaced position



Fig. 9. The front spot lights in the extended position



Fig. 10. The spoilers in the retracted position



Fig. 11. The nose gear leg in the extended position



Fig. 12. The right main landing gear in the extended position



Fig. 13. The left main landing gear in the extended position



Fig. 14. The tail plane set at -3°

It has been explicitly determined that at the moment of the crash the aircraft Tu-154M, tail number 101 (90A837), was in the landing configuration. The improper internal configuration of the aircraft, consisting in the change of the number of passenger seats, did not have an effect on the crash.

AIRCRAFT IMPACT GEOMETRY

1. Positions of the control surfaces and operational statuses of devices of the Tu-154M 101 airplane based on the recorded flight data and conversations from the moment of activation of the radio altimeter.



Fig. 1. Flight route and important points:

- 1 - radio altimeter activated (RA);
- 2 - birch tree in proximity of the inner NDB (INDB);
- 3 - inner NDB pole (INDB);
- 4 - birch tree – where the left wing tip separated;
- 5 - receding control wheel turn – end of the attempt to maintain level flight;
- 6 - end of QAR recording;
- 7 - first impact of the airplane with the ground.

In order to establish the impact geometry of the Tu-154M 101 with the ground, seven points were examined (fig. 1) with respect to which the Committee selected approximately 30 parameters related to the position (setting) of certain components of the airplane, its configuration, and the responses by the crew in the corresponding flight stages. Table 1 shows the findings with respect to the control surface positions and selected flight parameters.

Point	Parameter	UTC	Distance to threshold	Pitch angle	Angle of attack	Roll angle	Indicated speed	Radio altitude	Steering column tilt	Left elevator displacement	Right elevator displacement	Steering wheel turn	Right aileron displacement	Rudder pedals position	Rudder displacement	Throttle lever position Engine 1	Throttle lever position Engine 2	Throttle lever position Engine 3	Temperature Engine 1	Temperature Engine 2	Temperature Engine 3	LPC speed Engine 1	LPC speed Engine 2	LPC speed Engine 3	Lateral g-load	Vertical g-load	Gyromagnetic course	Pitch channel stabilization	Roll channel stabilization	Automatic thrust
-	-	GG:MM:SS	m	deg	deg	deg	km/h	m	deg	deg	deg	deg	deg	-	deg	deg	deg	deg	°C	°C	°C	%	%	%	g	g	deg	-	-	-
1	Radio altimeter activated (RA)	06:40:54,0	1538	-1,8	7,58	0,7	277	65,6	-4,0	-7	-6,5	0	-0,6	0	-1	3	7	6	424	414	419	38,1	35,2	40,5	0,01	1,03	260	ON	ON	ON
2	Birch tree at INDB	06:40:59,5	1099	3,1	10,32	0,0	274	12,5	-5,8	-14	-9,2	-2	-2,7	-2	-1,3	10	19	21	419	414	419	41,9	38,6	45,2	0	1,19	260	OFF	ON	OFF
3	Inner NDB	06:41:00,0	1065	3,8	11,37	-0,6	274	9,4	-9,2	-13	-13	0	-1,9	-2	-1,9	53	57	64	429	424	424	42,9	39,5	45,7	0,03	1,19	260	OFF	ON	OFF
4	Birch tree, separation of left wing section	06:41:02,8	855	12,8	15,78	-2,5	269	6,2	-9,6	-22	-26	-3	-3,1	-3	0	68	67	68	448	438	448	68,1	61,9	68,6	0,04	0,88	260	OFF	ON	OFF
5	Receding wheel turn – end of attempt to maintain level flight	06:41:04,5	795	20	22,11	-90*	269	15,6	-5,3	1,6	1,7	-61	-19,4	9	7,1	52	51	47	490	467	490	84,3	79,8	82,9	-0,19	1,22	254	OFF	OFF	OFF
6	End of QAR record	06:41:05,5	625	18,9	8,63	-120*	263	17	-4,5	-3,6	-1,2	-9	-7,6	-17	3,7	46	47	33	510	486	500	84,8	83,5	83,8	-0,8	0,56	246	OFF	OFF	OFF
7	Impact with ground	06:41:07,5	535	-6*	-10*	-150*	260*	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	240*	OFF	OFF	OFF

Tab. 1. The Tu-15M 101 airplane's parameters and values of its control surfaces in seven relevant points (* computed value)

- Airplane positions in the space between inner NDB until impact established on the basis of traces of collisions with terrain obstacles.



Fig. 2. Terrain obstacles and ground impact point:

- 1 - first birch tree trimmed;
- 2 - young birch cluster;
- 3 - young birch cluster;
- 4 - young birches and poplars;
- 5 - birch – separation of a part of the left wing;
- 6 - trees with limb diameters of up to 10 cm;
- 7 - power line;
- 8 - firs;
- 9 - birch;
- 10 - single fir tree;
- 11 - poplar;
- 12 - poplar;
- 13 - center of tree cluster west of the Minsk road;
- 14 - left wing mark (furrow) in the ground;
- 15 - left elevator and tail marks in the ground.

In order to establish the geometry of the impact of the Tu-154M 101 airplane with the ground, 13 obstacles were examined (fig. 2) which were subsequently used to establish the position of the airplane at every collision with each of those obstacles. The information identifying the location of each of the obstacles and marks on the ground is contained in the Final Report (Chapter 1.12, Wreckage). Table 2 shows the findings concerning the airplane's position between the inner NDB and the crash site.

Point	Terrain obstacles and ground impact points	Terrain height	Terrain height relative to RWY threshold	Distance to RWY threshold	Deviation from RWY axis	Terrain obstacle trimming height	Pitch angle	Roll angle	Altitude above ground	Altitude relative to RWY threshold
1	First birch tree	239	-15	1099	-39	10	3.1	0	10	-5
2	Young birch cluster	246	-8	932	-59	4	11.1	0	4	-4
3	Young birch cluster	246	-8	919	-54	4	11.9	0	4	-4
4	Young birches and poplars	247	-7	901	-64	4	12.5	-0.6	4	-3
5	Birch – part of left wing separates	250	-4	855	-63	5	12.8	-2.5	5.1	1.1
6	Trees with trunk diameter up to 15 cm	253	-1	808	-57	9	15.6	-16	7	6
7	Power line	253	-1	777	-59	7	16.8	-35	-	-
8	Firs	254	0	729	-64	13	20.0	-50	16	16
9	Birch	254	0	709	-68	13	21.0	-65	19	19
10	Single fir	256	+2	691	-71	8	20.0	-90	18	20
11	Poplar	257	+3	671	-68	13	19.0	-120	18	21
12	Poplar	257	+3	640	-76	13	18.9	-120	17	20
13	Tree cluster	255	+1	616	-82	10	15.6	-130	17	18
14	Left wing marks in ground	253	-1	518	-93	-	-6	-150	0	-1
15	Left aileron and tail marks in ground	253	-1	535	-105	-	-6	-150	0	-1

Tab. 2. The Tu-15M 101 (90A837) flight parameters describing its position on collision with terrain obstacles and on impact with the ground

3. Examination of the Tu-154M 101 airplane's position upon collision with terrain obstacles and the geometry of the impact with the ground

The first point which was examined was that of activation of the A-034-4 radio altimeter (fig. 1). The airplane was about **1,538 m** away from the runway threshold conducting an approach with the ABSU automatic control system switched on. The following control modes were activated:

- automatic pitch channel stabilization and control;
- automatic roll channel stabilization and control;
- automatic indicated speed stabilization and control using automatic thrust control.

The automatic control system was maintaining (stabilizing) the pitch and roll of the aircraft by changing the positions of the elevator and ailerons. The preset forward speed was maintained by varying the engine thrust. The pilot was steering the airplane by setting pitch and course with dials on the PU-46 panel. About 4.5 sec. later, the ABSU's pitch channel was deactivated by movement of the steering column. In the same instant, the throttle levers of all three engines were moved to the take-off position. However, due to inertia and the terrain profile, the plane continued to come closer to the ground. 1099 m away from the runway threshold and in the proximity of the inner NDB, the first collision with a terrain obstacle took place (fig. 3). The right wing sheared the tip of a birch tree with no ensuing damage to the plane which would affect its airworthiness. At that moment, the plane was about 10 m above ground. Roll was 0° and pitch was about 3.1° . The airplane's center of gravity was approx. **5 m** below the runway threshold.

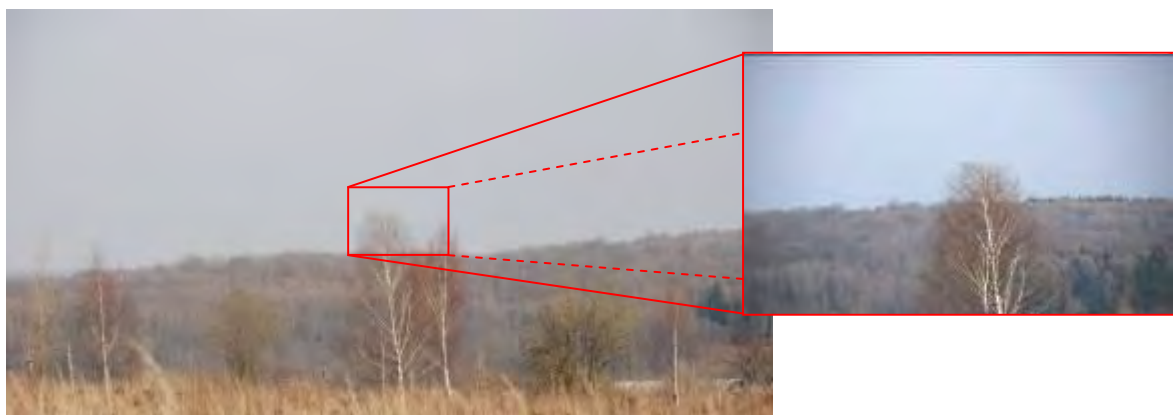


Fig. 3. Birch tree in the vicinity of inner NDB (item 2 – fig. 1 and item 1 - fig. 2) sheared by the right wing edge

167 m and **180 m** away from the first collision with the terrain obstacles, impacts with trees and bushes followed (fig. 4). Those were clusters of young birch trees, which were sheared at about **4 m** above ground by the left wing edge of attack (slat). Even though the

plane started climbing slowly and was **4 m** below the runway threshold, its altitude above ground dropped due to the terrain profile from **10 m** in the vicinity of the inner NDB to **4 m** in the area covered with young trees and bushes.



Fig. 4. Cluster of young birches (item 3 fig. 2) sheared by the slat

Upon traveling further 18 m, the fuselage and wings collided with trees whose trunk diameter was about **10 cm**. At this moment, the wings were level and the pitch angle increased to aprox. **12°** (fig. 5 and 6). The local trees and bushes were sheared at 4 m above ground. The airplane's position at this point was about 3 m below the runway threshold.



Fig. 5. Trees (item 4 fig. 2) damaged by landing gear and fuselage



Fig. 6. Trees (item 4 fig. 2) damaged by the tip of the left wing

These impacts caused indentations in the edges of attack (deployed slats) and deformations of the wing skin on the underside of the wing and the deployed flaps. Despite the sustained damage, the plane maintained its air worthiness and continued to climb.

855 m away from the runway threshold, the left wing collided with a large birch tree, about **5.1 m tall** (Fig. 6), which led to the separation of a large (about 6 m) section of the left wing including the aileron. At that point, the center of gravity of the airplane was about **1.1 m** above the runway threshold, roll was about **-2.5°** (left roll), and pitch increased to **12.8°**.



Fig. 7. Birch tree (item 4 fig. 1 item 5 fig. 2) damaged upon collision with the left wing

The imbalance of lift which occurred as result of the loss of a part of the left wing was impossible to counter by displacing the right aileron. That initiated a left roll of the plane in relation to its longitudinal axis with a simultaneous change in the flight direction by approx. **3.5°**. That change in flight direction resulted from the airplane's response to an impact against

its structure at a point **10.8 m** away from its vertical axis. Simultaneously, all (three) hydraulic system depressurized.

Travelling further **47 m**, the plane continued to collide with trees of limb diameters of up to **15 cm** (Fig. 8) over a distance of **20 m**. Roll increased dramatically and reached approx. **-16°** (left).



Fig. 8. Trees damaged (item 6 fig. 2) by wings and fuselage with roll of approx. -16° (left)

Turning the steering wheel and applying rudder pedals did not stop the leftward roll of the airplane. With roll of about **-35°**, having travelled about **80 m** since the loss of the left wing section, the plane passed over a medium-voltage power line, damaging it (Fig. 9). It is possible that the power line was severed not by the plane itself but by the limbs of trees which had been broken away a dozen meters earlier and travelled in the flight direction.



Fig. 9. Severed power cables (item 7 fig. 2)

50 m later, the airplane's roll increased to **-50°**. Thereafter, at a distance of about 40 m, the plane collided with several thicker trees, such as firs and birches, causing their limbs to

break (Fig. 10) and increasing roll to approx. -90° . Those impacts caused extensive damage to the leading edges and numerous damages to the elevators and rudder surfaces.

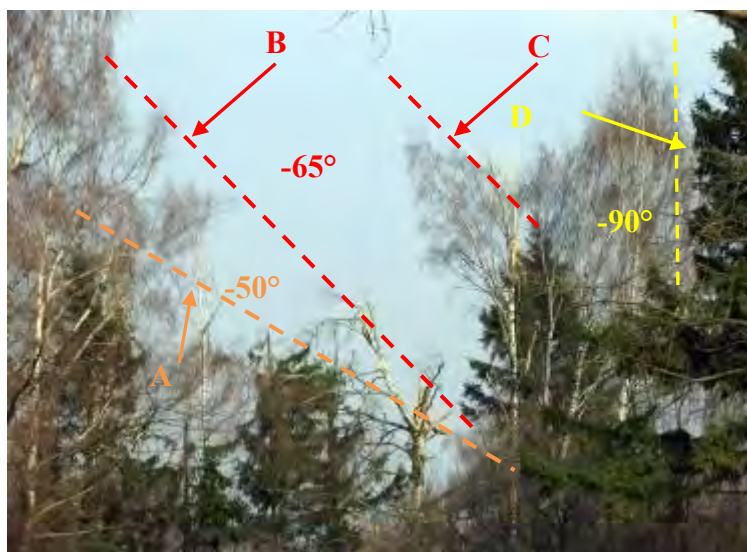


Fig. 10. Trees damaged 150 m away (item 8, 9 and 10 fig. 2)
from the point of separation of the left wing:

- A – shearing line in firs
- B – shearing line in birch (wing);
- C – shearing line caused by elevator;
- D – shearing line in firs caused by left wing edge.

690 m away from the runway threshold, at -90° roll (fig. 10), the plane started veering off to the left while its fuselage was approximately **18 m** above ground.

50 m later, the plane's roll increased to -120° as the fuselage, wings, and tailplane impacted with two tall trees causing their limbs and branches to break. At this moment, the left elevator separated. With a roll reaching -130° , the plane collided with the last group of trees. The fuselage pitch was approx. 16° and started decreasing quickly in the following flight phase. That point is marked as '6' in fig.1 and it corresponds with the point where the ATM-QAR flight record broke off. In the final phase of the flight, the plane travelled with its nose pointing slightly down.



Fig. 11. Damage to the last group of trees before the impact with the ground

Eventually, the plane collided with the ground with the stump of the left wing first with a roll of approximately -150° (fig. 15), small negative pitch of about -6° (fig. 16), on a magnetic course of about 240° (from the moment of the left wing loss, the course deviated by approximately -20° – fig. 17).



Fig. 12. A furrow left by the left elevator

Fig. 13 and 14 show the final flight phase from the inner NDB to the crash site.

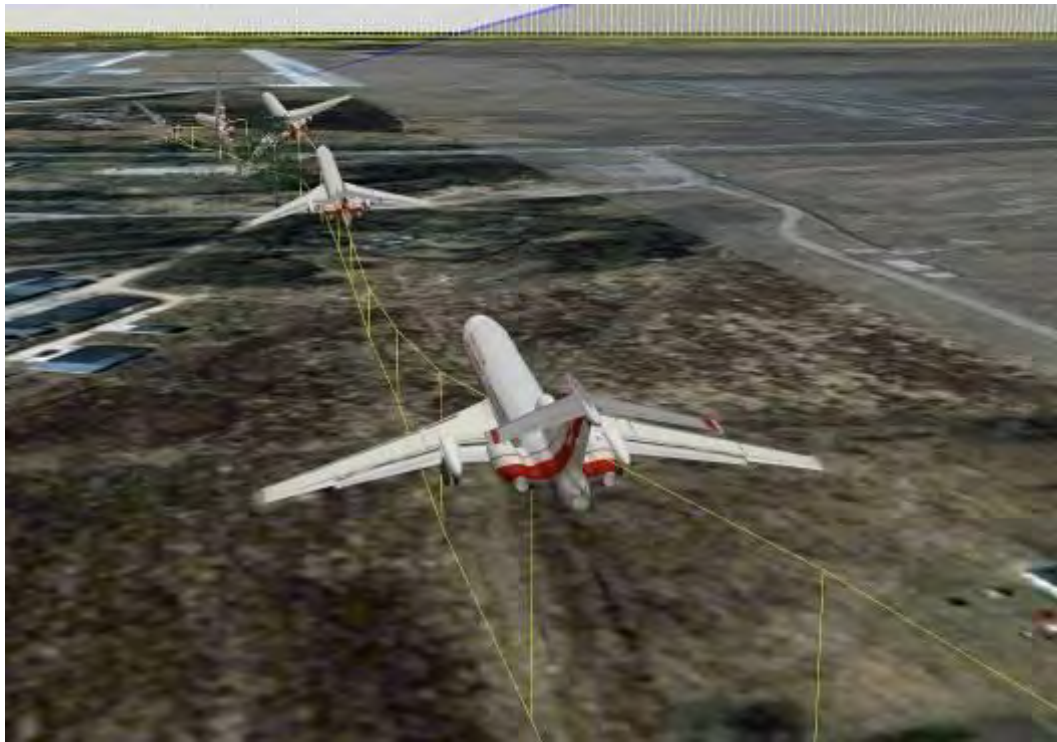


Fig. 13. Graphical presentation of the final flight phase and of the impact with the ground
(as seen from the direction of the approaching plane)

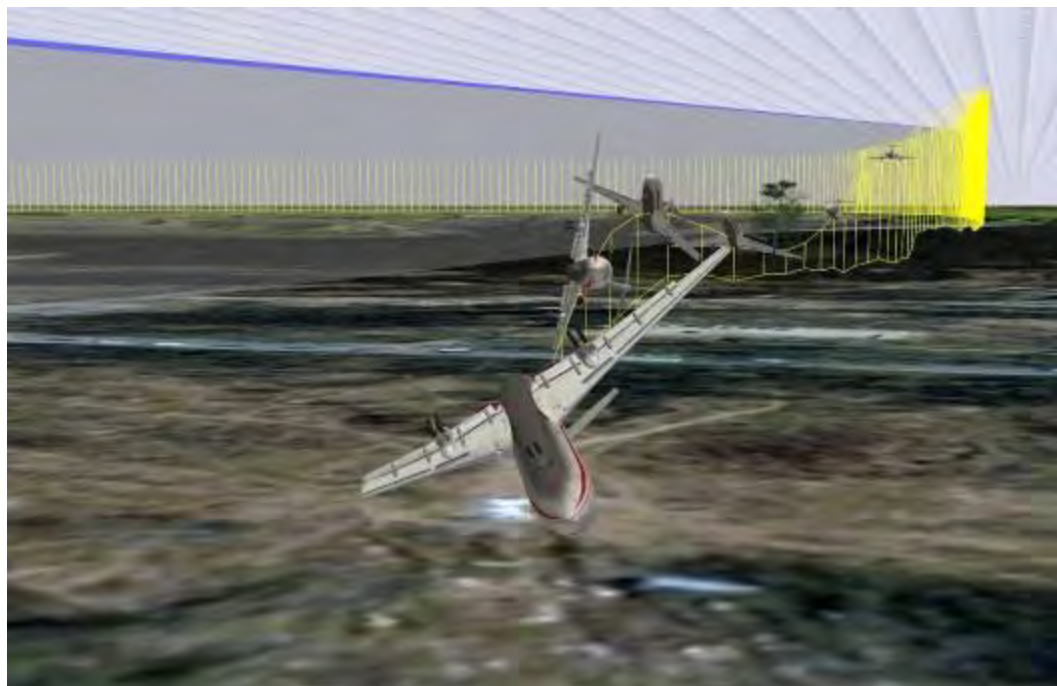


Fig. 14. Graphical presentation of the final flight phase and of the impact with the ground
(as seen from the direction of the crash site)

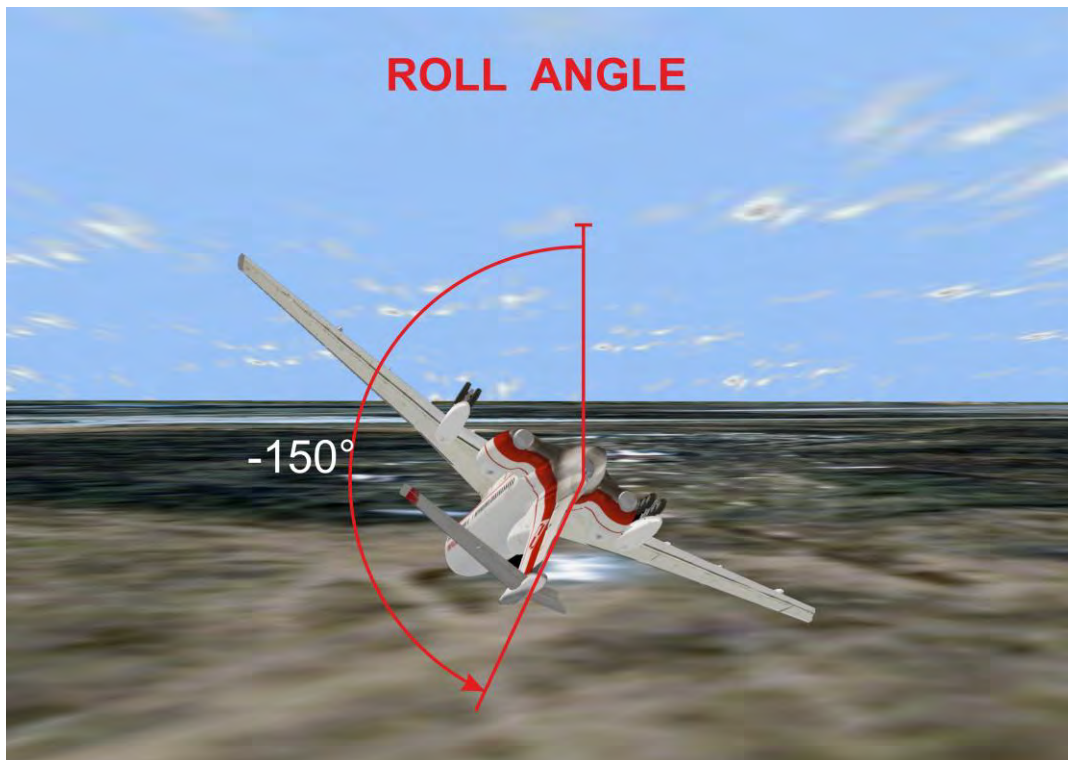


Fig. 15. Roll angle at impact with the ground



Fig. 16. Pitch angle at the impact with the ground

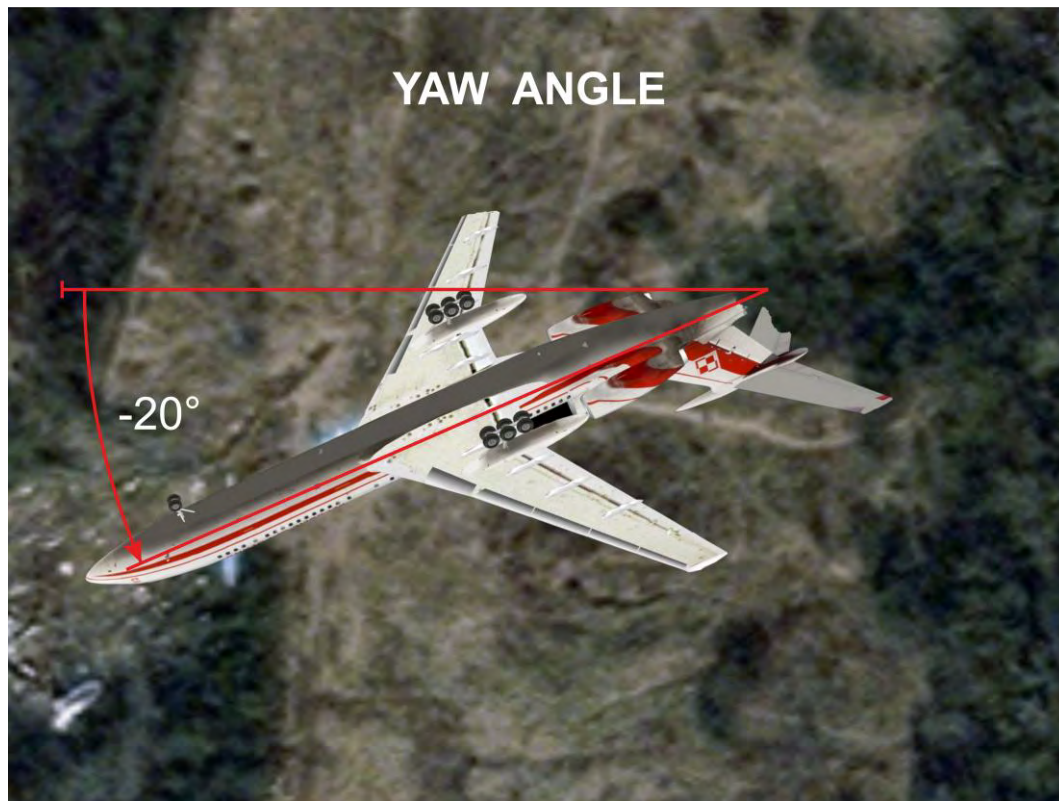


Fig. 17. Yaw angle at impact with the ground

On impact with the ground, the airplane's structure was completely destroyed. First, the remaining part of the left wing, cockpit, and the elevator mechanism fairing were crushed. The impact with the ground increased the roll to full 180° at the same time decreasing pitch.

The impact of the tail fin with the ground caused separation of the right tailplane. The tailplane was arrested by the broken trees having travelled several meters. Then, the tail fin separated from the aft part of the fuselage as did the rests of the tailplane and its actuator mechanism. Before coming to a halt, the tail fin travelled on for about 40 m from the point of its separation from the plane's structure.

As the upper side of the left wing impacted with the ground near the left nacelle of the main landing gear, the left part of the centerwing was torn away from the fuselage. That part of the plane, which consisted of the section between the frames 4 and 15, travelled in the upturned position and came to a halt about 100 m away from its point of separation from the fuselage. The right hand part of the centerwing was torn away together with a part of the left centerwing (between frames 1 and 2) and was propelled forward by about 90 m.

As result of the impact with the ground, the forward part of the fuselage, from the nose to frame #19 was almost completely destroyed. Of the forward part, only underside skin sheets and the forward landing gear strut were left undamaged. The latter came to a halt about 60 m away from the point of impact with the ground.

The forward passenger cabin between frames 21 and 31 continued movement for about 75 m after separation from the fuselage.

The impact of a reinforced component such as the left engine nacelle caused separation of the aft section of the fuselage including the bulkhead. After travelling about 40 m from the point of impact, that relatively well preserved part of the plane came to a stop in a reversed position in relation to the flight direction. Inside, engine 2 was preserved. Engine 1 came to a stop in a close proximity to the same airplane section but it was completely detached. Engine 3 separated earlier and came to a halt about 30 m away from the point of impact.

As result of the impact, the airplane parts became scattered over the area of 130 m by 60 m.

DESCRIPTION OF DAMAGE TO THE AIRCRAFT

At a distance of about 2.7 km from the runway threshold, the aircraft Tu-154M, tail number 101, appeared below the specified glide path and was continuing its descent. About 30 m before the inner NDB, the aircraft was low enough to come into contact with the first ground obstacle (1,099 m from the runway threshold, about 39 m to the left of its centreline). The tip of the left wing hit the top of a birch tree at a height of about 10 m which resulted in cutting off thin branches of about 1 metre in length (Fig. 1). The collision did not inflict damage affecting the aircraft's ability to fly (probably, only local damage to the paint coat occurred on the wing's leading edge).



Fig. 1. A birch tree with cut-off tips

After passing about a 200 metre long distance over a grassy area, the aircraft collided with the following obstacles:

- Two clumps of young birch trees - cropped with the left wing edge;
- A group of young birch, poplar and other trees - branches broken with the aircraft's left wing edge (Fig. 2).



Fig. 2. A group of trees cropped with the left wing

The collisions made characteristic dents in the wing's leading edge and caused deformations and numerous tears both in the lower skin panels of the wings and the displaced flaps (fig. 3). Possibly, this was the moment when wiring harnesses suffered the initial damage.



Fig. 3. Characteristic oval-shaped dents in the wing's leading edge

At a distance of 855 m from the runway threshold, 63 m to the left of its centreline (about 350 m from the site of crash), the aircraft's left wing hit a birch tree with a trunk about 30 cm in diameter. The impact against the birch's branch occurred at a height of 5.1 m (Fig. 4). As a result of the impact, the aircraft lost a part of its left wing about 6.1 metre in length, together with the left aileron and two sections of slats. The part of wing was torn away between frames nos. 27 and 28. Following the loss of such a substantial part of the left wing, the fuel tank no. 3 located in this wing became unsealed.

The collision lead to a simultaneous loss of leaktightness in all three hydraulic systems - the hydraulic pipes supplying the RP-55 control gear of the left aileron were torn apart. The disruption of the hydraulic lines was accompanied by the loss of hydraulic fluid from the systems and the pressure drop in the all of them.



Fig. 4. The birch tree, the collision with which resulted in the tearing away a part of the left wing

After having flown another 200 m, the aircraft collided with tree branches of a diameter up to 20 cm which caused further dents in the leading edges, damaged skin panels, and tore away the left part of the stabilizer together with the left elevator.



Fig. 5. The trees that inflicted further damage to the wing's leading edges and tore away the left tailplane.

At a distance of 525 m from the runway threshold, 105 m to the left of its centreline (54°49'28,09''N, 32°03'7,26''E) the aircraft hit the ground for the first time.

In consequence of the impact, the aircraft was fragmented as shown in Fig. 6.

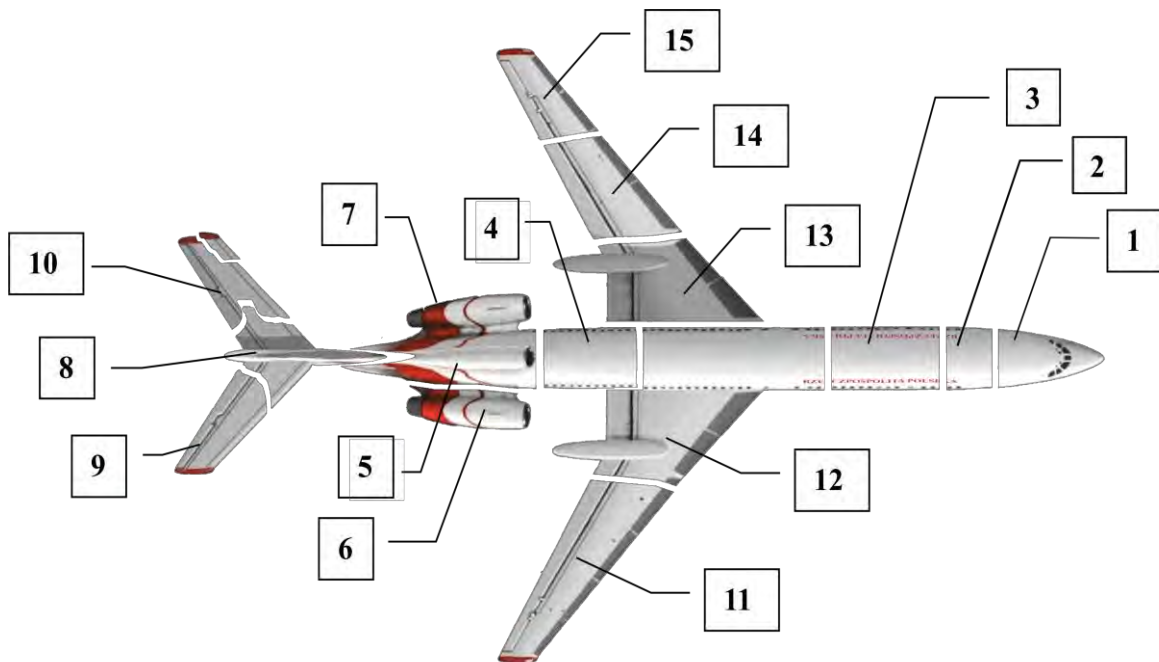


Fig 6. Graphics presenting the preserved fragments of the aircraft

The biggest preserved fragments are:

- 1 - the crushed front part of the fuselage from the nose to frame 7;
- 2 - the front part of the fuselage with the nose gear strut;

- 3 - the lower fuselage section from frame 21 to frame 31 with remnants of the left aircraft's side;
- 4 - the deck and left aircraft's side of the rear fuselage section (passenger compartment area);
- 5 - the tail part of the fuselage from the airtight frame to the tip of the fuselage with engine 2 and ripped apart engine 1 cowl;
- 6 - engine 1 separated from the cowl;
- 7 - engine 3 with remnants of its cowl;
- 8 - the fin with the rudder and the tailplane control gear;
- 9 - the right section of the tailplane with the elevator;
- 10 - the left section of the tailplane with remnants of the elevator
- 11 - the right wing from rib 20 to rib 44 (from frame 20 to the tip);
- 12 - the right section of the middle wing from frame 2 of the left wing to rib 17 of the right wing with the right main landing gear;
- 13 - the left section of the middle wing with the left main landing gear;
- 14 - the fragment of the left wing from frame 18 to frame 24;
- 15 - the fragment of the left wing from rib 28 to the tip with the left aileron.

On impacting the ground, the plane was in an inverted position with a bank angle of about -150° and a pitch angle of -6° (aircraft's nose was slightly lowered). Immediately before the impact the aircraft followed a trajectory inclined towards the ground by $10-12^\circ$ and its course was about 240° . The aircraft's sideslip angle was about 20° . This type of crash is classified as a low energy low angle impact. The swampy ground and shrubbery suppressed energy of the impact and limited the extent of fire that broke out on the scene of accident. The character and extent of the damage suffered by the structure was mainly the result of the aircraft's position in the final stage of the flight.

The first to contact the ground were the remaining part of the left wing and the fin. After hitting the ground, the right tailplane with the right elevator were torn off, followed by the fin and rudder. At the same time, the left wing was being damaged. Subsequently the aircraft's fuselage hit the ground. As the aircraft's bank angle was about -150° , the first to contact the ground was the upper and weakest section of the structure. The skin sections and structural elements in the upper part of the fuselage were torn apart and crushed already on the first impact on the ground. Then, those elements were additionally pressed down by the deck of the passenger compartment and middle wing components with the

landing gear joints of the highest strength and thus of a relatively high weight. The middle wing housed fuel tank 4 with 6,000 kg of fuel and fuel tank 1, also with fuel in a quantity exceeding 3,000 kg. Being at the bottom, the cockpit was crushed by fuselage parts moving over it.

The remnants of the aircraft were scattered over an area about 60 m wide and 130 m long.

Fuselage

Crushed and torn into small fragments. The bigger preserved elements are as follows:

- a) The crushed front lower section from the nose to frame 13 (fig. 7). The whole front section of the aircraft, including the radar cover, cockpit and equipment found in this section of the fuselage were crushed and torn into small fragments. Casings and glass elements of onboard instruments found in the cockpit were extensively dented and broken. Most of them remained attached to the crushed fragments of instrument panels.



Fig. 7. The remnants of the aircraft's front section

- b) A fragment of the lower section from frame 14 to frame 19 with the nose gear leg and some connecting elements thereof (fig. 8). The preserved fragment includes the lower fuselage section in the fixing area of the nose gear leg. The whole upper fuselage section from this area was torn into small pieces;



Fig. 8. A fuselage fragment at the fixing point of the nose gear strut

- c) The fragment of the lower section, deck and right aircraft's side from frame 21 to frame 31. (Fig. 9). The preserved elements are the deck with torn off equipment fixings, lower skin panels of the fuselage, and a fragment of the outer skin panel from the right aircraft's side.



Fig. 9. Front fuselage section - the first lounge

- d) Lower part of the middle section from fuselage frame 41 to frame 49 with the torn middle wing. The middle wing was torn asymmetrically. Together with its right part extending up to 17th wing frame (beyond the fixing of the detachable section) two

frames in the left part of the middle wing were torn off (fig. 10). The torn fuel tanks 1 and 4 in the middle wing contained remains of aircraft fuel.



Fig. 10. The middle fuselage section in the middle wing area

- e) The lower portion of the rear section with a crushed left aircraft's side from frame 52 to frame 62 (fig. 11). This fragment included the bent deck from the passenger compartment, lower fuselage skin panels, and fragments of the left aircraft's side skin panels. The right aircraft's side was torn away from the remaining part of this fuselage fragment at the level of the passenger compartment deck;



Fig. 11. The tail part of the fuselage - passenger compartment

- f) The tail part from the airtight partition (frame 66) to the fuselage rear tip with the built-in engine 2 (fig. 12). The fin was torn away at its root from the fuselage tail part. The

engine 1 cowl was torn away at its root from the fuselage. The engine 3 cowl was torn apart - its upper section remained with the tail part of the fuselage.



Fig. 12. The tail part of the fuselage

Except for the tail section of the fuselage, upper skin panels in other sections were completely fragmented. The preserved elements consist of crushed fragments of the deck and lower skin panels. Remains of aircraft's sides can be seen on two sections.

No passenger seats remained attached to the aircraft's structure (remains of the deck) - all of them were torn away from their fixings.

Wing

The preserved bigger fragments are as follows:

- a) The right outer part from rib 20 to rib 44 (fig. 33). Numerous oval dents can be seen on the leading edge and extended slats. Broken slat jack screws. Numerous tears in the skin panels.



Fig. 13. The right part of the wing

- b) The right part with the middle wing from frame 2 (left aerofoil) to frame 17 (right aerofoil) (Fig. 14 and 15) - the middle wing was torn asymmetrically. The slats were torn away from the wing structure. The dents and tears on skin sections at the wing leading edge extended to the front spar;



Fig. 14. The leading edge at the root section of the right wing



Fig. 15. The trailing edge of the right wing and the right main landing gear

- c) The left wing from rib 4 in the middle wing to rib 16 in the detachable section (fig. 16 and 17). The skin panels are torn at the leading edge. Skin panels are bent out rearwards. Large sections of the upper wing skin panels are torn off. The damage to the left wing aerofoil was significantly heavier than that found on the right one;



Fig. 16. The torn leading edge of the left wing



Fig. 17. The trailing edge of the left wing and the left main landing gear

- d) The left part from rib 18 to rib 24 (fig. 18). The fragment is significantly distorted (twisted spars, torn skin panels). All slat jack screws are torn off;



Fig 18. The middle section of the left wing

- e) The outer section of the left wing from rib 28 to the wing tip (fig. 19) - the fragment was torn off on impacting a large birch tree. Relatively well preserved fragment of the

wing. Small oval dents can be seen on the leading edge (slat). The front section of the wing tip fairing was torn off.



Fig. 19. The left wing tip

Tailplane

The right section of the tailplane was torn off at a distance of 1 m from its fasteners on the fin. Numerous dents on the leading edge and twisted structure of the tailplane (fig. 20).



Fig. 20. The right section of the tailplane with the elevator

The left section of the tail plane was torn off at a distance of 1,5 m from its fasteners on the fin. A fragment (outer corner piece) was torn off, leaving a ragged tear edge. Numerous oval dents can be seen on the leading edge (fig. 21). The left stabilizer had already separated from the plane before the aircraft crashed into the ground.



Fig. 21. The left section of the tailplane with the elevator

Fin

The fin was torn away at its root from the fuselage tail part. The front part of the fairing of the tailplane control mechanism was crushed. The tailplane control mechanism was heavily soiled with mud. The displacement of the mechanism shaft corresponds to the tailplane's position at -3° . The skin panels torn away from the leading edge of the fin. The rudder is still fastened to the fin and displaced to the left by an angle of about 20° (fig. 22).



Fig. 22. The fin

Power unit

Engine 1 (left) torn away from the aircraft's structure. The low pressure compressor disks separated from the engine. The rotor blades bent in the direction opposite to that of the rotation (fig. 23).



Fig. 23. The left engine

Engine 2 (middle) remains in the rear tip section of the fuselage. The rotor blades are bent in the direction opposite to that of the rotation.

Engine 3 (right) torn off the aircraft's structure and heavily soiled with mud (fig. 24). The rotor blades bent in the direction opposite to that of the rotation.



Fig. 24. The right engine

Controls

Fragments of control wheels and distorted pedals together with the gear located under the cockpit deck were preserved. The elevator, aileron and rudder control rods have numerous tears both at the riveting joints with the tip elements, and on the straight sections (fig. 25 and 26). Control cables torn apart.



Fig. 25. The control rods of the aircraft



Fig. 26. The remains of the aircraft's controls - the elements installed in the cockpit and under the cockpit deck.

Landing gear

The nose gear leg with impact traces is still attached to a fragment of the nose part of the fuselage. The angle brace of the undercarriage strut is slightly bent. The main landing gear legs bear slight impact traces left by tree branches, especially on the strut fairing. The landing gear is in the extended position and locked. No visible traces of damage have been found on the nose and main landing gear wheels (fig. 27-29).



Fig. 27 The nose landing gear



Fig. 28 The left main landing gear



Fig. 29 The right main landing gear

Electrical system

Wiring harnesses are torn apart. The control boxes are deformed. Switch levers are bent and torn off (fig. 30). The housings of the onboard batteries are deformed. Some cells became unsealed.



Fig. 30. The control boxes of the electrical system

Equipment of the passenger compartment

The passenger seats have been torn away from their mountings and fragmented into pieces. The inner wall covering panels in the passenger compartment broken into small pieces (fig. 31). Safety belts have been scattered at the aircraft crash site.



Fig. 31. The remnants of the passenger compartment equipment

Fixed oxygen system

The aircraft Tu-154M, tail number 101, was equipped with a fixed oxygen system. The system was designed for supplying crew members (pilot-in-command, co-pilot, navigator, senior flight engineer and additional crew member) with oxygen. The system was installed in the cockpit.

The system comprised of:

- 5 fixed breathing oxygen respirators БКО-5 for the above-mentioned crew members with containers БУ-1 with individual oxygen masks КМ-114 and smoke protection goggles ДЗО-1Л, separately put on the masks.
- single oxygen bottle УБШ-25/150М with a capacity of 25 l;
- oxygen flow control valve УЗР-1;
- oxygen lines, delivering oxygen to the above-mentioned fixed oxygen respirators.

At the scene of accident only УБШ-25/150М bottle, no. 1100477, was found; the bottle was not disrupted but torn away (together with a part of the mount to which it was attached) when the aircraft's structure was being damaged.



Fig. 32. УБШ-25/150М bottle with a part of its mount and oxygen lines

The bottle was fitted with a cylinder top with a manometer and inlet and outlet connections. There is a longer section of the oxygen line attached to the inlet connection of the bottle; the outlet oxygen line was torn away at the very connection. The bottle bore neither traces of fire, nor any deformations caused by other elements of the aircraft.

The remaining elements of the fixed oxygen system have not been identified at the scene of crash or the wreckage deposition site.

Mobile oxygen equipment

The aircraft Tu-154M was equipped with mobile oxygen equipment. The equipment consisted of 16 portable bottles БКП-2-2-210 with oxygen. Each bottle was fitted with a cylinder top featuring two connections for masks stored in the packaging. Each connection could accept the МКП-ИТ oxygen mask or the ДКМ-1М smoke-mask. The bottle pressure was controlled with the manometer on the cylinder top. 14 bottles were designed for supplying oxygen to passengers and two (in sets containing only smoke-mask) were treated as backup equipment for the crew's fixed oxygen system.

At the scene of crash at least several oxygen bottles and isolated broken masks were found. All the bottles accessible to the technical subcommittee were filled with oxygen. As there was a risk of uncontrolled discharge (or even an explosion), the bottles were removed from the scene of accident immediately after they had been found.

Almost all the masks were destroyed. Only the above-mentioned isolated masks or fragments thereof were identified on the scene of accident and at the wreckage deposition site.

Inert gas system

The aircraft Tu-154M, tail number 101, was equipped with an inert gas system. The system was designed for supplying inert gas to fuel tanks 4 and 1 in the event of belly landing.

The system comprised of:

- 3 bottles OCY-5II-0;
- pipelines;
- spraying lines;

At the scene of accident one bottle OCY-5II-01 no. 08056 was found; the bottle was not disrupted but torn away when the aircraft's structure was being damaged (fig. 33).



Fig. 33. OCY-5II-01 bottle

The bottle was fitted with a cylinder top with inlet and outlet connections. The bottle bore neither traces of fire, nor any deformations caused by other elements of the aircraft.

The remaining two bottles and other elements of the inert gas system have not been identified at the scene of crash or the wreckage deposition site.

Aircraft's radioelectronic equipment and accessories

The units, flight and navigational instruments and other indicators installed in the cockpit were heavily damaged. Most of the instruments remained attached to bent elements of instrument panel. From among the instruments and units found at the scene of accident, the following were submitted to laboratory tests:

- From the ARK-15 M ADF set:
 - Receiver, no. E 9905;
 - Receiver, no. I 349;
 - Control panel, no. E 9905;
 - Radiomagnetic indicator RMI-2B, no. 480638;
 - Radiomagnetic indicator RMI-2B (only indicating element without a number was found);
- height indicators A-034-4, no. 71941 (part of the radio altimeter set);
- height indicators A-034-4, no. 71948 (part of the radio altimeter set);
- barometric altimeter WM-15 PB, no. 1188008 from the SWS-PN-15 set for the Pilot-in-Command.
- altitude indicator UWO-15 M1B, no. 1196652 (for the Co-pilot);
- indicator scale of one VBE-SVS instrument (no number);
- BSKA-E unit, no. 1190100946.

The equipment installed in the bays under the deck survived the crash in a better condition. However, most of the unit's casings were heavily deformed (Fig. 34). Some electronic blocks' casings were torn apart while modules with electronic units were broken and destroyed. In spite of the substantial damage, data was read out from the TAWS memory and UNS-1D system that was installed on the Co-pilot's side (one of the two installed on the aircraft).



Fig. 34. Navigational and communication equipment units

The units carried in the luggage compartment (spare parts in so called “technical emergency kit”) survived the crash in the best condition (fig. 35).



Fig. 35. Spare parts carried in the luggage compartment

Flight data recorders

The protective casing of MLP-14-5 with the flight data recorder MSRP-64M-5 was torn off the aircraft’s structure. It was found in the area where the aircraft hit the ground for the first time. Quick access recorders KBN-1-1 and ATM-QAR as well as the protective casing 70A-10M of the cockpit voice recorder MARS-BM were found among fragments of

the aircraft's fuselage. The data from all the above-mentioned recorders were read out. The K3-63 recorder has not been found.

Emergency radios

Installed during the last overhaul, the ARM-406AC1 (no. 7523242494) and ARM-406 (no. 7524241208) radios and their antenna systems became damaged in the crash to the extent of inoperability.



Fig. 36. Emergency radio stations ARM-406AC1 (left) and ARM-406P (right)

The ARM-406P radio station (automatically enabled with a G-load switch): the antenna and power cables torn away, the radio station casing crushed. The ARM-406AC1 radio station: slight damage to the casing (in order to use the radio station, the crew has to wire up the antenna and switch on the device).

Arrangement of the wreckage in the aircraft outline

The remnants of the destroyed aircraft were arranged within its outline on a hard surface on the premises of SMOLENSK “SEVERNY” aerodrome. Elements of individual systems were sorted into separate groups and laid out in the vicinity of the wreckage (fig. 25, 26, 30, 34, 35, 36). A general view of the wreckage is shown in figure 37.



Fig. 37. Parts of the aircraft as arranged on the ground

Summary and conclusions

Examination of the aircraft's wreckage has not revealed any traces of explosives or aircraft fuel detonation.

The small fire affected only few elements of the wreckage and was initiated on the aircraft hitting the ground or immediately after the crash. No traces specific to an in-flight fire have been identified.