This document is an English translation of the Final Report on the fatal accident involving the L-410UVP-E20 aircraft registered RA-67047 that occurred on November 15, 2017 at Nelkan landing site, Khabarovsk Krai, RF. The translation was done as accurate as a translation may be to facilitate the understanding of the Final Report for non-Russian speaking people. The use of this translation for any purpose other than for the prevention of future accidents could lead to erroneous interpretations. In case of any inconsistence or misunderstanding, the original text in Russian shall be used as the work of reference.

INTERSTATE AVIATION COMMITTEE

AIR ACCIDENT INVESTIGATION COMMISSION

FINAL REPORT
RESULTS OF INVESTIGATION
OF ACCIDENT

Type of accident	Accident
Type of aircraft	L-410UVP-E20, airplane
Registration	RA-67047
Owner	State Transport Leasing Company, Public Company
Operator	Khabarovsk Airlines, RSUE
Aviation Administration	Rosaviatsia Far East ITO
Place of accident	Nelkan landing site, Khabarovsk Krai, RF
	Coordinates: N 57°37'25.5" E 136°09'11.4"
Date and time of accident	15.11.2017, 13:09 local time (03:09 UTC), daytime

In accordance with ICAO Standards and Recommended Practices, it is not the purpose of this report to apportion blame or liability.
The sole objective of the investigation and the Final Report is the prevention of accidents.
Criminal aspects of the accident are tackled within the framework of a separate criminal case.

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LIST OF ABBREVIATIONS

A/C	Aircraft
AAI STSC	Air Accident Investigation Scientific and Technical Support Commission
AAIC	Air Accident Investigation Commission
AFIL	Air Filed Flight Plan
AFM	Aircraft Flight Manual
AGB	Accessories Gear Box
AMC	Aviation Meteorological Center
AOC	Air Operator Certificate
AR IAC	IAC Aviation Register
ARFF	Aircraft Rescue & Fire Fighting
ASL	Above Sea Level
ATC	Air Traffic Control / Controller (depending on context)
ATM	Air Traffic Management
ATPL	Airline Transport Pilot License
ATS	Air Traffic Service
CA	Civil Aviation
CAA	Civil Aviation Authority
CAWS	Civil Aviation Weather Station
CME	Office of the Chief Medical Examiner
CSN	Cycles Since New
CT	Compressor Turbine
CVR	Cockpit Voice Recorder (MC)
DH	Decision Height
E	Eastern Longitude
EMERCOM RF	Ministry of the Russian Federation for Civil Defense, Emergency Management and Natural Disasters Response
F/O	First Officer
FAP	Federal Aviation Rules of RF
FAP-128	*Preparation and Conduct of Flight in Civil Aviation of the Russian Federation*, FAP approved by Order №128 of Ministry of Transport of RF as of July 31, 2009
FAS Russia	Federal Antimonopoly Service of the Russian Federation

FCU	Fuel Control Unit
FGBI	Federal Government Budgetary Institution
FH	Flight Hours
FME	Flight Medical Expertise
GAMC	Main Aviation Meteorological Center
GE AC	General Electric Aviation Czech company
HMS	Hydrometeorological Station
HQC	Higher Qualification Commission
IAC	Interstate Aviation Committee
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ITO	Interregional Territorial Office
JSC	Joint Stock Company
KIAS	Knots Indicated Airspeed
MDA	Minimum Descent Altitude
MED	Medical Unit
METAR	Aerodrome routine meteorological report
MH	Mag Heading
MSN	Manufacturer Serial Number
N	North Latitude
NDB	Non-directional beacon
NGV	Nozzle Guide Vanes
NOSIG	No Significant Change
PF	Pilot Flying
PIC	Pilot-in-Command
PT	Power Turbine
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RF	Russian Federation
RGB	Reduction Gearbox
Rosaviatsia	Federal Air Transport Agency (RF CAA)
RRCC	Regional Rescue Coordination Center
RSUE	Regional State Unitary Enterprise
RWY	Runway
SART ground	Ground-Based Search and Rescue team

TBO	Time between overhauls
TC	Aviation Training Center
TF unit	Task Force Unit
TSLO	Time Since Last Overhaul
TSN	Time Since New
TTSN	Total Time Since New
TWR	ATC tower
UTC	Coordinated Universal Time
ÚZPLN	Air Accident Investigation Institute (Czech: *Ústav Zjišťování Příčin Leteckých Nehod*)
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WS	Winter Season
YNAO	Yamalo-Nenets Autonomous Okrug
ZAO	Russian equivalent for *Limited Liability Company*

Synopsis

On 15.11.2017 at 13:09 local time (03:09 UTC[1]), at daytime, under VMC, during the landing approach to Nelkan landing site with the azimuth of 187°, at the distance of 1400 m from the RWY threshold, L-410UVP-E20 RA-67047 A/C crashed when performing its NI 463 flight on the route Khabarovsk – Chyumican – Nelkan.

There were 2 crew members, 5 passengers (all RF citizens) and 410 kg of cargo onboard. The crew and four passengers were killed; 1 passenger was seriously injured. The A/C obtained significant damage. There were no on-ground damages. There was no fire.

The IAC received the information on the accident at 05:37on 15.11.2017.

The investigation was conducted by the Investigation Team assigned by the IAC Vice-Chairman – Chairman of the AAIC by Order No. 39/852-P of 15.11.2017.

In accordance with Annex 13 to the ICAO Chicago Convention (further "Annex 13"), Notification was sent to AAII of the Czech Republic (the State of Design and the State of Manufacture of the aircraft).

The investigation was started on 15.11.2017.

The investigation was completed on 18.06.2019.

A preliminary criminal investigation was being conducted by the Far East Investigation Directorate of the RF Committee of Inquiry.

[1] Further in this Report the time is given in UTC format. Local time is UTC + 10 h.

1. Factual Information

1.1. Flight history

Fig. 1. An equivalent aircraft

On 14.11.2017, Khabarovsk Airlines' representative submitted the flight request for L-410UVP-E20 RA-67047 A/C flight to Joint ATM System Khabarovsk regional unit; the flight (NI 463) was planned along the route Khabarovsk – Nikolayevsk-on-Amur – Nelkan.

On 14.11.2017 at 22:00 (local time: on 15.11.2017 at 08:00) at Khabarovsk airport, the preflight preparation was started including the medical examination. While the preflight preparation was being performed, new information was received that Nikolayevsk-on-Amur airport was closed due to the RWY snow removal. In coordination with ATC of Nikolayevsk-on-Amur airport, it was decided to change the route as follows: Khabarovsk – Chyumican – Nelkan.

Before coming onboard the crew passed all mandatory preflight procedures as required by the normative documentation.

On 15.11.2017, before the departure, Khabarovsk Airlines' technicians provided the line maintenance check in accordance with the F-A Form (Maintenance Job Card #687). No findings in relation to the aircraft and/or systems' operation were reported. The total amount of fuel on board was 1250 kg.

The flight crew obtained all the necessary weather information (actual and forecast) during of the preflight weather briefing. The actual weather and the weather forecast for the departure aerodrome, on route weather, the weather forecast for the destination and alternate aerodromes – all met the FAP-128 (Russian FAR) requirements stated in items 5.30 and 5.38, and did not preclude the PIC's decision for departure.

There were 2 crew members, 5 passengers and 410 kg of cargo (personal luggage and mail) onboard. The A/C takeoff mass was 6368 kg and the A/C center of gravity was at 25.5% MAC, which was within the AFM limits for the flight.

The takeoff from Khabarovsk airport was performed at 23:33.

The onroute flight was conducted normally (see Fig. 2).

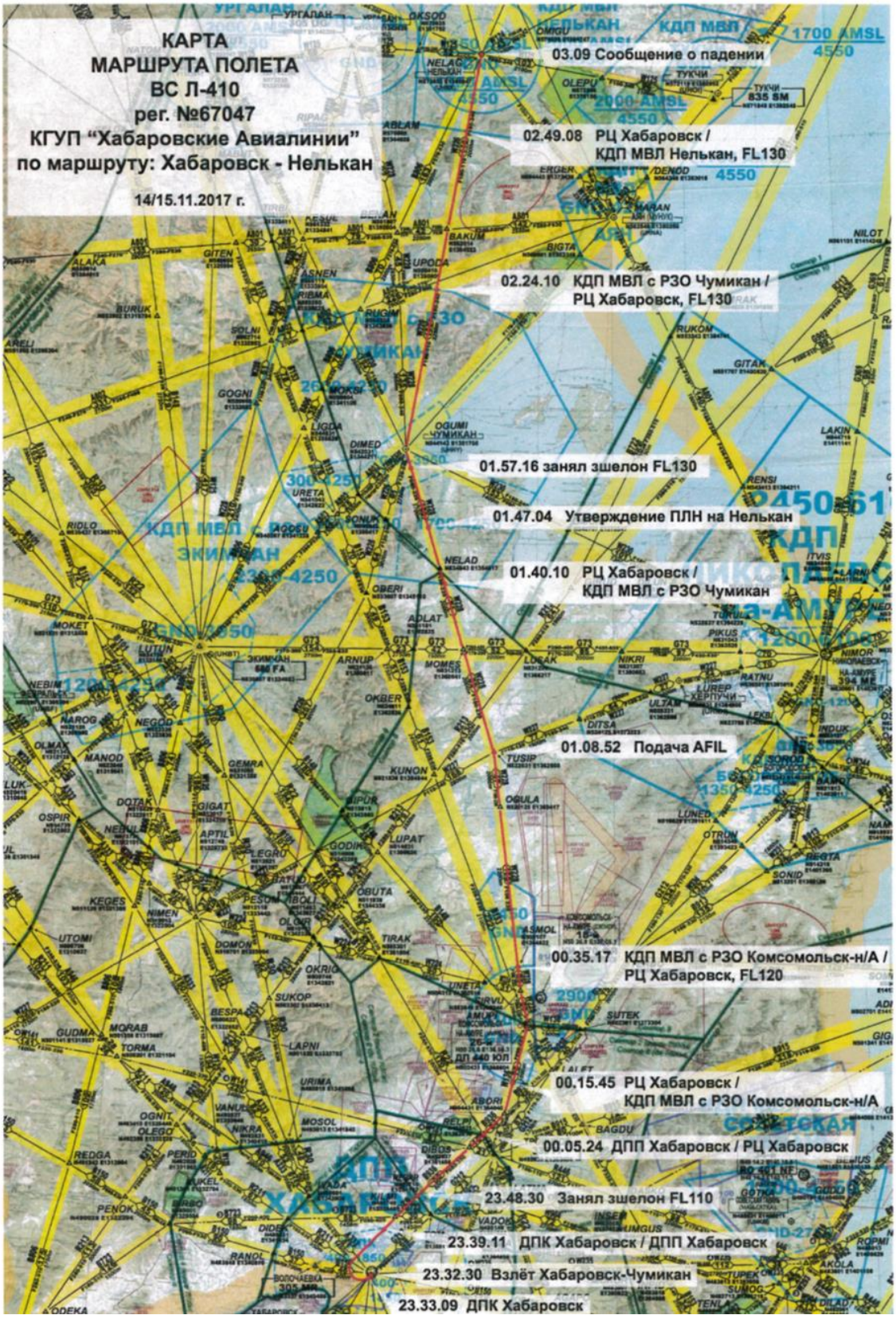

Fig. 2. L410UVP-E20 RA-67047 route

50 minutes before the approach to Chyumikan aerodrome, the flight crew checked the remaining fuel and requested the Khabarovsk ATC controller for the route change (AFIL): after passing of the OGUMI waypoint to follow the B226 airway to Nelkan destination airport without a stop at Chyumikan. According the initial flight plan, the stop at Chyumikan was intended only for refueling.

On 15.11.2017 at 01:47 the Khabarovsk ATC approved the AFIL.

At 02:35 the crew contacted the Nelkan Tower controller and received the approach conditions and the actual weather at the landing site.

During the approach, at the true height of about 100 m and IAS of about 100 knots, developing the aggressive right roll and losing its altitude, the aircraft left the descending glidepath, collided with the ground and was destroyed. The crew and 4 passengers were killed. A 3-and-half year old child was taken to hospital with serious injuries. Nobody was killed on ground and there was no on-ground damage.

The accident area is mountainous, marshy, with broad-leaved and needle-leaved trees. In winter, the area is covered with snow which is about 50-100 cm deep. The accident place ASL elevation is 304 m, the magnetic dip is minus 15°.

1.2. Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	2	4	0
Serious	0	1	0
Minor/None	0/0	0/0	0/0

1.3. Damage to Aircraft

In course of the with-the-ground collision, the fuselage, the engines and the tail assembly were damaged significantly. The cockpit was almost destroyed; the wings show some damage and deformation (see Fig. 3).

Fig. 3. View of A/C after accident

1.4. Other damage

There was no other damage.

1.5. Personnel Information

Position	**PIC**
Date of birth; sex	21.10.1975; male
Education	Buguruslan CA Flight School in 1994; qualification – pilot
Pilot license	ATPL #0028740 issued by Rosaviatsia Far East ITO on 25.09.1994. Rating: An-24/26/30, L-410 UVP-E20; pilot-instructor for An-24/26/30, L-410 UVP-E20
Pilot Medical Certificate	№ 013497, issued by ATM State Corporation branch, *Far East Aeronavigation*, FME. Issued on 25.10.2017; valid till 25.10.2018

Weather minimum	IFR 60x800; VFR 200x3000, takeoff 300 m
Total flying experience	12076 FH
Type experience on L-410 UVP-E20	1243 FH
Experience as PIC on L-410 UVP-E20	1243 FH
FHs within the last calendar month	54 h
FHs within the last 3 days	09 h
FHs on the day of accident	03 h 34 min
Breaks in flights within the last calendar year	Annual leave 01.03.2017 – 11.03.2017, 01.06.2017 – 31.07.2017
Last check for piloting and navigation skills	11.08.2017, by pilot-instructor (pilot-examiner), Regional Qualification Commission member; "excellent"
Simulator Training	08.10.2017, Sasovsk CA Flight School
Last recurrent proficiency training	Uralskyi Air Training Center (Yekaterinburg), certificate #7562 issued on 21.11.2016
CRM training	Uralskyi Air Training Center (Yekaterinburg), certificate #7562 issued on 21.11.2016
Level of English language awareness	No English testing was conducted, however according to the available information his English level was zero
Approval for WS operations	Order #26 of 22.09.2017, Khabarovsk Airlines
Preliminary training	22.08.2017, by Khabarovsk Airlines Flight Operations Director Deputy
Pre-flight rest, including sleep	At home
Pre-flight medical examination	Khabarovsk airport MED
Pre-flight briefing	15.11.2017, by himself, Khabarovsk airport
Accidents and incidents in the past	None

Position	**F/O**
Date of birth; sex	12.06.1987; male

Education	Sasovsk CA Flight School in 2007; qualification – pilot
Pilot License	ATPL #0029484 issued by Rosaviatsia Far East ITO on 28.07.2016. Rating: copilot on An-24/26/30, L-410 UVP-E20
Pilot Medical Certificate	#013288, issued by ATM State Corporation branch, *Far East Aeronavigation*, FME. Issued on 26.07.2017; valid till 26.07.2018
Total flying experience	1220 FH
Type experience on L-410 UVP-E20	837 FH
FHs within the last calendar month	80 h
FHs within the last 3 days	09 h
FHs on the day of accident	03 h 34 min
Breaks in flights within the last calendar year	Annual leave 15.02.17 – 18.03.17, 24.03.17 – 02.04.17, 14.08.17 – 12.09.17
Last check for piloting and navigation skills	12.07.2017, by pilot-instructor (pilot-examiner), Regional Qualification Commission member; "excellent"
Simulator Training	08.10.2017, Sasovsk CA Flight School
Last recurrent proficiency training	Far East Training Center (Khabarovsk), certificate #25649 issued on 24.05.2017
CRM training	Certificate #M06-25174 issued on 05.04.2017
Level of English language awareness	No English testing was conducted, however according to the available information his English level was zero.
Approval for WS operations	Order #26 of 22.09.2017, Khabarovsk Airlines
Preliminary training	15.09.2017, Khabarovsk Airlines Flight Operations Director
Pre-flight rest, including sleep	At home

Pre-flight medical examination	Khabarovsk airport MED
Pre-flight briefing	14.11.2017, by PIC, Khabarovsk airport
Accidents and incidents in the past	None

Position	**ATC at Nelkan Tower**
Date of birth; sex	30.01.1978; male
Education	Dal-aerocontrol Training Centre from 15.10.1996 to 12.04.1997 in accordance with the Program: "Initial training for ATC in low-intensity airports"
License	ATC specialist license CD #017509, issued by FAS Russia on 25.02.1998
Check for theoretical and practical skills	23.08.2017, by ATC chief controller, traffic department
Last recurrent training	From 27.03.2017 to 06.04.2017; Institute of Air Navigation, Siberian Office, in accordance with the Program "Air traffic management for ATC staff"
Weather observer training	From 11.04.2008 to 12.04.2008; Institute of Air Navigation, Far East Office, in accordance with the Program "Weather training for observers at unclassed aerodromes and landing sites"
Medical Certificate	Medical unit of ATM State Corporation branch, *Far East Air Navigation*, # PA № 168352, issued on 02.12.2016, valid till 02.12.2020

1.6. Aircraft Information

A/C data

Type of A/C	L 410 UVP-E20
Manufacturer, date of manufacture	17.12.2015, Aircraft Industries, a.s. (Czech Republic)
MSN	3010
Registration	RA-67047
Certificate of Registration	#7991 issued by Department of Inspection on Flight Safety, Rosaviatsia on 03.02.2016
Certificate of Airworthiness	#2032160015 Rosaviatsia Far East ITO on 22.03.2016; valid till 22.03.2018 or when TSN reaches 4800+150 FH
Assigned life (h/landings); assigned life limit	20000 / 20000; no calendar limitation
TSN, CSN	1693 h, 1071 landings
Service life left	18307 h, 18929 landings
Assigned hours and service life till first overhaul	Check to be done at 4800 h or 10 years
Number of overhauls	None

Engines' data

Type of Engine	GE H80-200	
	Left	**Right**
Date of manufacture	19.11.2014	28.11.2014
Manufacturer	GE Aviation Czech (Czech Republic)	GE Aviation Czech (Czech Republic)
Engine MSN	144010	144011
Assigned life; life limit	No calendar limitation	No calendar limitation
TBO (h/cycles); life limit	3600 / 6600; no calendar limitation	3600 / 6600; no calendar limitation
TSN (h/cycles)	1693 / 1028	1693 / 1028
TBO left (h/cycles)	1907 / 5572	1907 / 5572
Engine overhauls	None	None

Propellers

Type of Propeller	AV-725	
	Left	**Right**
Date of manufacture	11.12.2014	04.12.2013
Manufacturer	Avia Propeller (Czech Republic)	Avia Propeller (Czech Republic)
Propeller MSN	140046	130039
Assigned life; life limit	12000 h; no calendar limitation	12000 h; no calendar limitation
TBO; life limit	3600 h, 6 years	3600 h, 6 years
TSN	1693 h	1743 h
Assigned service life left (h/cycles)	1907 h, till 11.12.2020	1857 h, till 04.12.2019
Propeller overhauls	None	None

The L 410 UVP-E20 Airplane Maintenance Program was developed by the Khabarovsk Airlines specialists and on 25.11.2016 was approved by the Head of Rosaviatsia Far East ITO.

The L 410 UVP-E20 Airplane Maintenance Program specifies the mandatory maintenance procedures, their terms and limitations, that have been set by the A/C manufacturer and formalized by the airworthiness directives.

The L 410 UVP-E20 Airplane Maintenance Program is developed and kept current in accordance with the following documents:

– Aircraft Maintenance Manual (AMM), the latest version with supplements and corrections of 15.11.2013;

– APPENDIX of MAINTENANCE SCHEDULE of the L 410 UVP-E 20 Airplane without overhaul (Do-L410-1223.2) for the L 410 UVP-E 20 Airplane with Ser. No. 2913 (Limitation section changes approved under EASA major change approval 10045210 dated 07.06.2013);

– APPENDIX No.59 of MAINTENANCE SCHEDULE of the L 410 UVP-E 20 Airplane without overhaul (Do-L410-1223.2) GE H80-200 Engines and AV-725 Propellers Installation;

– GE H80-200 Maintenance Manual P/N 0983402" (further EMM), Operation and installation Manual AV-725 Document number EN-1320.

The Engine and Propeller Maintenance Program was incorporated into the L 410 UVP-E20 Airplane Maintenance Program. The engine maintenance procedures are provided in accordance with EMM; the propeller maintenance procedures are provided in accordance with Operation and Installation Manual AV-725 Document number EN-1320.

All aircraft and systems technical documentation is kept in English, but is simultaneously translated into Russian, because most of the Khabarovsk Airlines specialists do not understand English.

The F-1 Form base maintenance check for the airframe and Type 2 Form base maintenance check for left and right powerplants were conducted on 05.11.2017 (Maintenance Job Card #570).
The F-A Form line maintenance check (before the first departure) was conducted on 15.11.2017 (Maintenance Job Card #687).
For the date of the accident, the aircraft and engines had the sufficient service life left.

1.6.1. Aircraft structure features of concern

Propeller control system features

The powerplants are equipped with the P-W22-1 centrifugal governors intended to be used with hydraulically controlled constant-speed propellers on the airplanes with turbo-propeller engines. The governors control propeller speed constantly changing the propeller pitch aiming to provide compliance between the current torque of the propeller and the torque generated by the engine.

According to the propeller control system description (see Fig. 4), the propeller governor provides pressurized oil to the propeller servo piston to increase or decrease the propeller blades pitch to maintain preselected propeller speed which is set by the PCL. The rotating pivoted flyweight governor mechanically controls the pilot valve which regulates oil to the propeller servo piston and thus changes (decreases or increases) the propeller blades pitch. The rotating flyweight governor exerts centrifugal force which acts against the speeder spring which is mechanically controlled by the PCL.

Each propeller blade is equipped with the counterweight. The counterweight twisting moment pushes propeller blades towards coarse pitch.

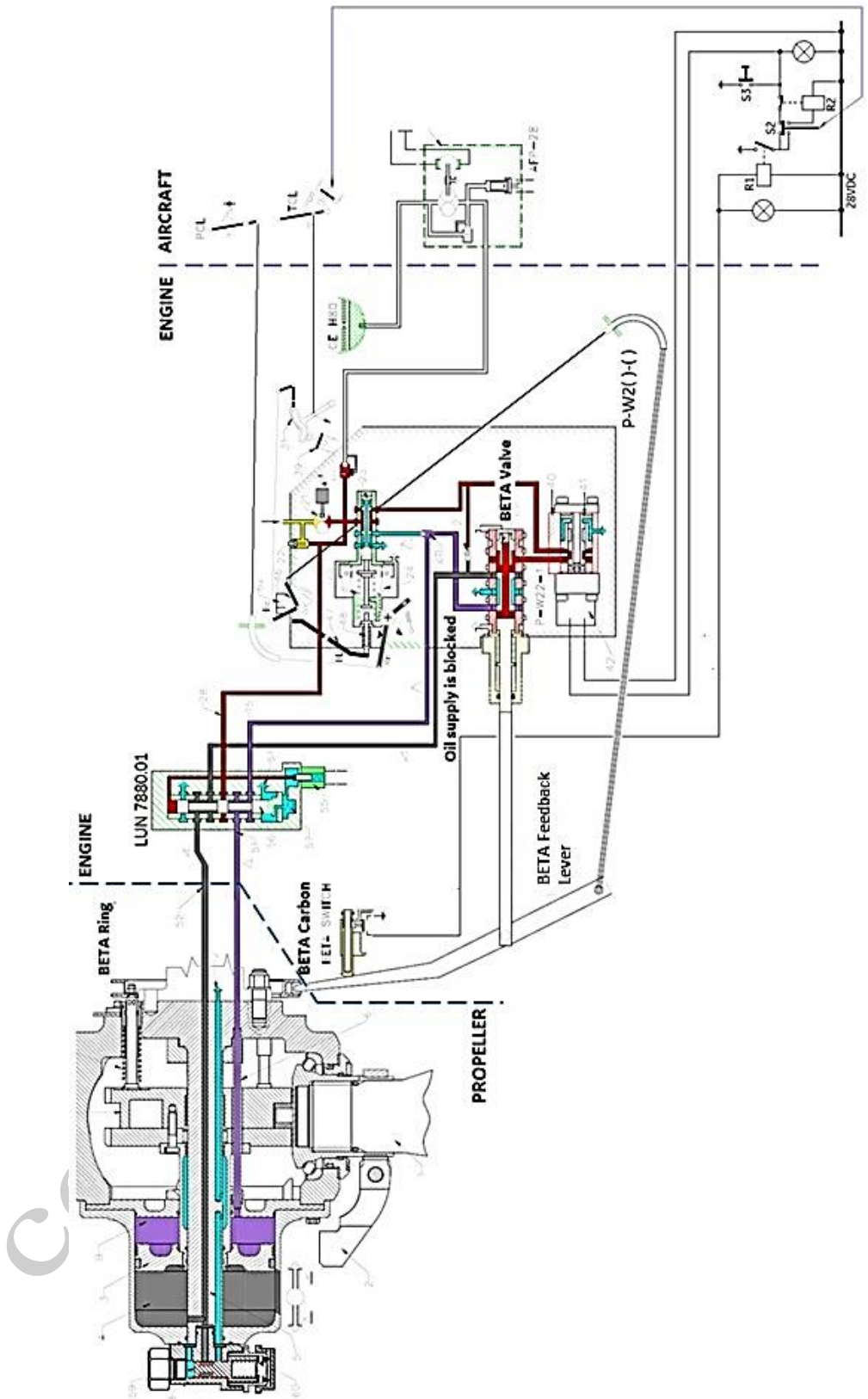

Fig. 4. Propeller system description

In flight, when the pilot moves PCLs into higher propeller speed RPM, the increasing oil pressure turns the propeller blades into the lower blade angle direction. When min flight angle +13.5° is reached (with TCLs set to forward thrust close to the flight idle position), the BETA valve has to stop further blades' pitch decrease by stopping the oil supply to the propeller pitch change mechanism (servo piston).

The BETA Valve is a primary device to set the minimum propeller flight blade angle. The BETA Valve is controlled by the BETA Feedback Lever (a part of BETA control/Feedback system). This BETA Feedback lever is connected with propeller BETA Carbon Block at one end, with the BETA Valve in the center and with BETA Control Mechanical Linkage on the other end (see Fig. 4). The BETA Control Mechanical Linkage enables to manually control propeller blades pitch in BETA/Reverse mode.

To prevent the propeller from going into uncommanded reverse mode, propeller system is equipped with following:

1. Pitch Lock Solenoid Valve

The Pitch Lock Solenoid Valve, mounted on propeller governor casing, hydraulically interconnects the flyweight governor passages and the BETA Valve passages. If it is energized, it hydraulically stops the oil supply to the BETA Valve and further to the propeller servosystem.

2. BETA Switch

The BETA Switch senses position of the propeller BETA Ring and provides annunciation (switch is electrically closed) when the propeller system operates in BETA/Reverse mode.

3. Pitch Lock System

The Pitch Lock System is a backup system and operates both at the aircraft and engine level. In the event of uncommanded movement of the propeller blades towards reverse mode (to the position of the blade angle lower than the minimum flight blade angle), the Pitch Lock System is triggered by the BETA Switch signal, which is up when the propeller blades reach ~+9° and stops the further propeller blades' movement. The Pitch Lock System is armed by moving the TCL in position of forward thrust. Adjustment of BETA Switch is performed at aircraft level during integration of propeller system based on instructions of propeller manufacturer. The TCL quadrant switch and BETA Switch electrically close the Pitch Lock System circuit and electrically enable the Pitch Lock solenoid. If the TCL is moved to the BETA/Reverse position, the TCL switch is electrically opened, and the Pitch lock system is thus disabled.

Note: *BETA mode is a propeller operational mode which is realized when the propeller operates with blades setting in a range of the min flight (13.5°) and max reverse (- 26,1+/ -1°) angles with TCLs setting between the flight idle and max reverse. BETA mode shall be used for decreasing of the propeller power during taxiing and/or for obtaining a negative thrust during the after landing breaking action.*

1.7. Meteorological Information

The meteorological support to the A/C flight along the Khabarovsk – Chyumican – Nelkan route was provided by Aviamettelecom of Rosgidromet FGBI and by Urgalan airport (Khabarovsk Krai) weather team (license # P/2015/2731/100/Л, issued on 11.02.2015 by Federal Service for Hydrometeorology and Environmental Monitoring).

During the preflight weather briefing, the duty forecaster provided the PIC with the Form #106 with the TAF forecast and the METAR weather report made for the departure, destination and alternate aerodromes of Khabarovsk, Chyumican, Nelkan and Komsomolsk-on-Amur; the PIC confirmed the receiving of the Form by his signature at 22:35.

Weather forecast for Nelkan landing site was valid from 22:00 on 14.11.2017 till 03:00 on 15.11.2017: variable surface wind 01 m/s, visibility 10 km, light snow, continuous cloud, ceiling 2100 m.

The actual weather for Nelkan landing site on 14.11.17 at 23:00 was as follows: surface wind – quiet, visibility 10 km, continuous cloud, ceiling 900 m, air temperature minus 29 °C, QNH 1016 hPa, QFE 735/0980; TREND NOSIG.

The actual weather for Nelkan landing site at the accident time as recorded by the Nelkan ATC Tower was as follows: wind 20°, up to 4 m/s, visibility over 10 km, scattered clouds at 900 m, continuous cloud at 2100 m, pressure 733 mm of mercury, temperature minus 25 °C.

1.8. Navigation Aids, Landing Aids and ATC

For the flight along the desired route, the flight crew used the standard onboard Garmin GNS-430 system.

The traffic management at Nelkan landing site is provided by TWR for local flights. At the distance of 950 m from the RWY 04 threshold, the standalone non-directional beacon PAR-10 (operating on the frequency of 380 kHz) is installed. At the distance of 350 m from the RWY 04 threshold and at 100 m to the left from the RWY 04 centerline, the radio direction-finder ARP-80k is installed.

1.9. Communication Means

The Nelkan airfield control Tower is equipped with 2 two-way microwave radio stations Baklan-RN (one primary and one standby), operating within the frequencies from 30 to 300 MHz.

P-600 recorders are used for recording of the ATC-with-crew communications and for recording of the ATC pre-flight briefings.

On the day of accident, the recorder was on, the radio transmitters and receiver operated normally. The communication was steady and intelligible.

1.10. Aerodrome information

Nelkan landing site is located 1.5 km to the south-west of Nelkan township. The coordinates of the reference point are the following: N 57°38′29.5″, E 136°09′39.1″. The RWY is unpaved with the elevation of + 306 m; the magnetic dip is minus 15°. The takeoff and landing magnetic bearings are respectively 41° and 221°. The RWY length is 1522 m.

The landing site minima are: for helicopters 300 x 3000 and for airplanes 360 x 3000 at daytime. No flights are allowed at nighttime from/to Nelkan landing site.

Both VFR and IFR arrivals' and approaches' charts are approved for Nelkan landing site.

Figures 5 and 6 show the arrival and approach patterns that were used by the flight crew for entering the landing site zone and for conducting the approach.

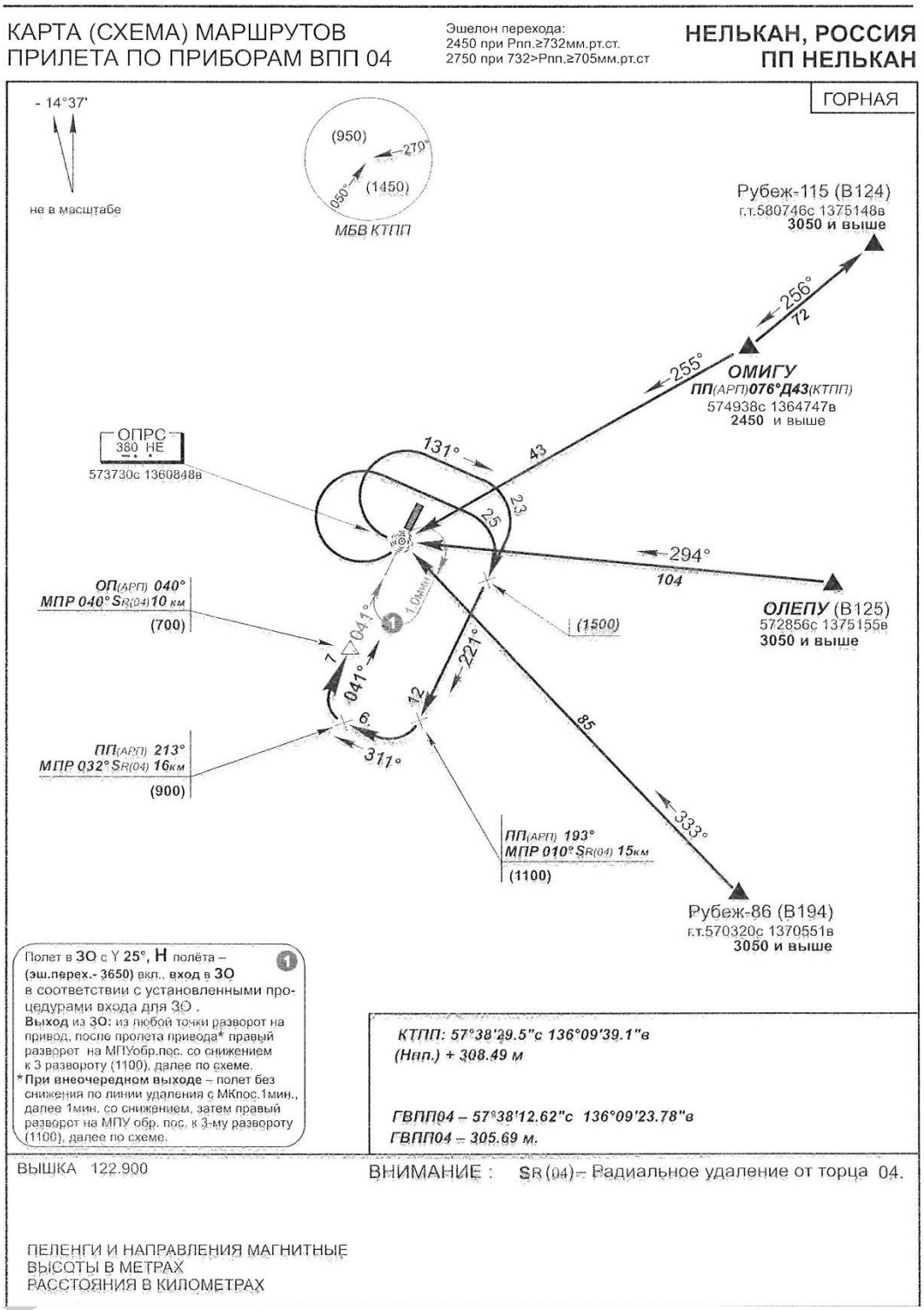

Fig. 5. Nelkan landing site RWY 04 IFR arrival pattern

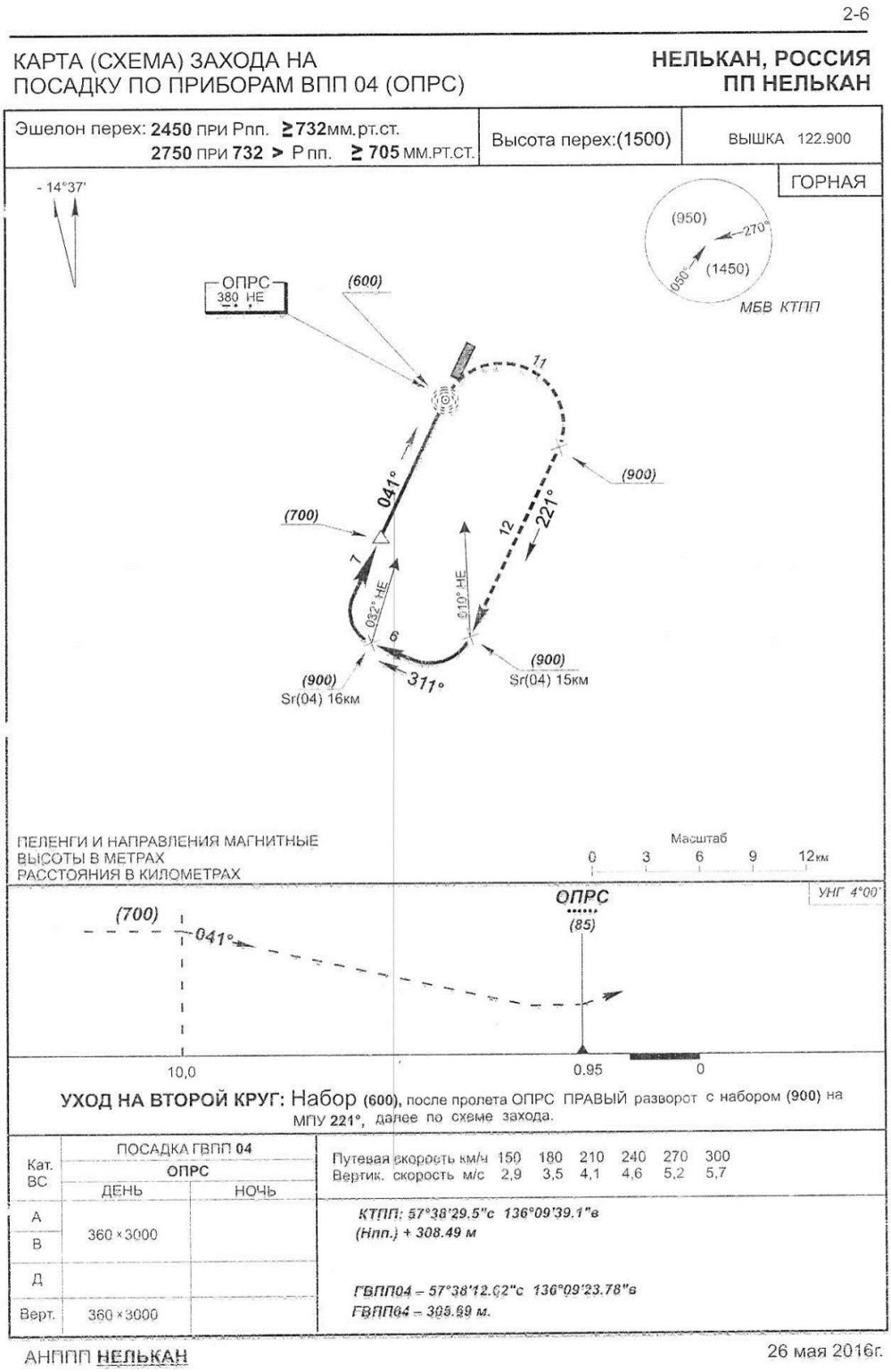

Fig. 6. Nelkan landing site RWY 04 IFR approach pattern

The landing site is owned by Khabarovsk Airlines, RSUE since 01.11.2017.

1.11. On-board recorders

The A/C was equipped with an FA-2200 MADRAS FDR and an FA-2100 CVR. After the accident, the recorders were found in good condition. The onboard recorders' downloaded and

decoded data were used in course of the investigation for establishing the accident circumstances and causes.

The onboard Garmin GNS-430 data were also used in course of the investigation.

1.12. The A/C fragments' condition and location

The A/C came to rest in the forest area; all its parts and fragments laid close together. There were no parts and fragments found along the A/C trajectory up to the accident site. The ground collision occurred when the A/C had a minor left roll and a low forward speed (the distance between the first impact point and the place of the A/C full stop is about 3 m). Some traces of ground touch with LH wing fuel tank and the LH and RH gear legs were found. The tree (birch) was broken by the A/C RH wing; the tree butt diameter was about 15 cm. No traces of the A/C RH wing fuel tank ground touch were found.

The fuselage showed breaks in the areas of frames #7 – 8, #13 – 14 and #24.

The LH engine was found at its normal position attached to the wing, but significantly moved to the left, downward and forward, looking from the aft to the forward. The propeller blades were found at their normal positions but bent; one blade had damaged the cockpit.

The RH engine was found at its normal position attached to the wing; the propeller blades were found at their normal positions; two of blades were found slightly bent.

The plastic nose cone was found separated and laid to the left of the A/C fuselage.

There was no fire at the accident site.

1.13. Medical and Pathological Information

All the crew members had the required medical certificates and were authorized for performing their functions with respect to their professional licenses. Bodies of PIC and FO were sent to Khabarovsk for medical examinations at the forensic laboratory.

According to the forensic examination conclusion, both the PIC's death and the FO's death were caused by the fatal injures obtained in the cockpit during the A/C collision.

There were no traces of ethyl alcohol found during the PIC and FO bodies' forensic examination.

1.14. Survival Aspects

During the accident, there were PIC, FO and 5 passengers aboard. PIC and FO were at their working stations and were secured with the safety belts. The passengers were sitting in the cabin (see Fig. 7) and were also secured with the safety belts.

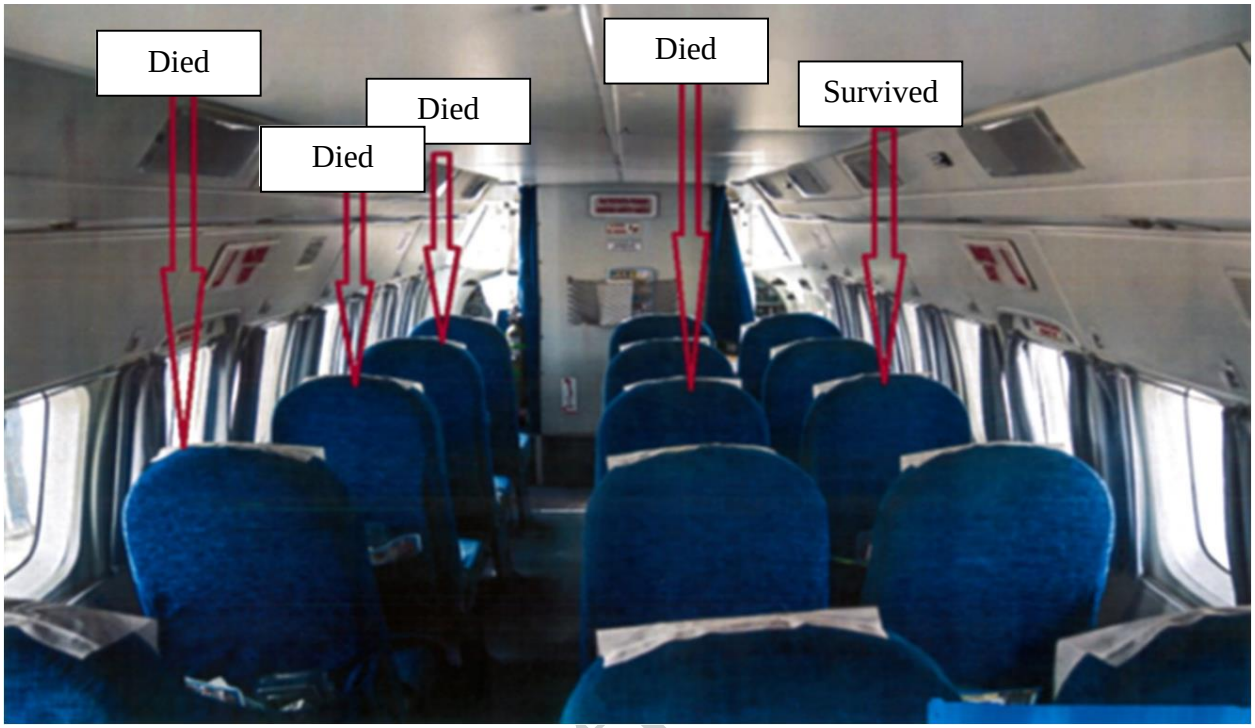

Fig. 7. Passengers' location in the cabin

When the A/C collided with the ground, PIC and FO remained in their seats. All the passengers remained in their seats after the collision.

The crew and the 4 passengers were killed in the accident. One passenger (the 3-and-half year old child) survived and was taken to the Khabarovsk hospital.

No other killed persons or damage were found on the ground.

1.15. Search and Rescue Operations

No search operations were conducted as the accident occurred at the aerodrome area and the A/C was within the visual range of the Nelkan Tower controller.

After the accident had occurred, at 03:11:15 on 15.11.2017, the controller announced the alert, then phoned to the ATC senior controller of the Nikolayevsk-on-Amur ATM State Corporation branch of "*Far East Air Navigation*", reported the accident, and asked to transmit the said information to the Khabarovsk Area ATM Center.

During the rescue-and-salvage operations, an ACP-3/6-40 fire-fighting vehicle and the private snowmobile were used, and which left for the accident site immediately after the alert annunciation. The snow was deep, so the fire-fighting vehicle failed to reach the site, so some

rescue team members had to walk to the RWY threshold, others used the snowmobile. The team reached the accident site and evacuated the injured child and the crew and passengers' bodies out of the A/C, and at 05:30 transported them to Nelkan medical unit.

The fire-fighting team members provided the security of the accident site till the arrival of the Investigation team.

1.16. Tests and Research

1.16.1. Fuel and oil samples' analysis

At the GosNII GA laboratory, the analysis of the aviation fuel and oil samples taken from L410UVP-E20 RA-67047 fuel and oil tanks was conducted. The analysis showed the sufficient quality of the said samples. The only exception was the sample from the LH engine fuel filter, where the content of actual tar and contaminating particles was different from the standard values stipulated by GOST 100227-88 (Russian standard). However, as the fuel samples from the RH engine fuel filter showed the contamination level, which met GOST 100227-88 requirements, it can be assumed that the contaminations had been inserted into the LH engine fuel filter during sampling.

1.16.2. RH engine MSN 144011 examination

Examination of the RH engine GE H80-200 MSN 144011 was conducted at the GE AC (the engine manufacturer) facilities in the period from January 15th to 21st, 2018. The examination was performed in presence of the UZPLN (Czech investigation authority), Aircraft Industries (the A/C manufacturer) and Avia Propeller (the propeller manufacturer) representatives and was monitored by the Investigation team.

During the engine teardown, the RGB was examined. It was placed onto the GE AC test bench and was checked for possible leakage of the oil return unit, which connects the hydraulic propeller control channels running from the stator to the drive gear shaft. The leakage test was conducted in the static condition of the drive gear shaft (without rotating it). The leakage test results showed that the gearbox performance meet the operational requirements. Further, the gearbox was dismantled and examined. No findings which might have interfered with its normal operation were found.

During the PT rotor and CT rotor visual examination, it was found that the rotors had been damaged in course of the accident.

Visual examination of the gas generator turbine NGV showed that the vanes were in good condition and that they had been damaged in course of the accident.

The outer liner of the combustion chambers, the main shaft, as well as the compressor rotor were found in good condition.

The AGB showed no external damage.

1.16.3. Results of the RH engine AV 725 SN 130039 propeller examination

The examinations of the propeller system was conducted at the Avia Propeller (the propeller and governor manufacturer) facilities in the period from January 18th to 19th, 2018. The examination was performed in presence of the UZPLN, Aircraft Industries and GE AC representatives and was monitored by the Investigation team. In course of the examinations, it was found that at the moment of the accident, the RH propeller blades' pitch angle was minus 1.8 degrees. According to the designer's documentation, the propeller blades' inflight minimum pitch angle is +13.5 °.

1.16.4. Results of the RH engine P-W22-1 propeller governor SN 14G629B examination

The examination of the propeller governor was conducted at the Avia Propeller (the propeller and governor manufacturer) facilities in the period from January 19th to 21st, 2018 in presence of the UZPLN, Aircraft Industries and GE AC representatives and was monitored by the Investigation team.

As the governor body had received significant damage in course of the accident, it was not possible to check the governor serviceability by placing it onto the test bench.

When examining the propeller control system, the following was found:

- BETA feedback lever (linkage between BETA ring and propeller governor) was not interrupted;
- electrical integrity of Pitch Lock Solenoid Valve and engine harness was not interrupted;
- electrical integrity of BETA Switch and engine harness No. XM601-802.3 was not interrupted.

BETA Valve

The BETA Valve casing deformation was observed, it was assumed that it had been caused by the engine impact. After the BETA Valve disassembly, no internal mechanical damage was found. The electrical integrity of BETA Valve was not interrupted.

It was not determined why the BETA Valve failed to prevent the propeller in flight movement below minimum flight blade angle.

Pitch Lock Solenoid Valve

The initial examination of the Pitch Lock Solenoid Valve serviceability was conducted by using the method of sound assessment of the pilot valve activation when electrically powered. The serviceability of the Pitch Lock Solenoid Valve was assessed during the four full cycles. No sound effects were observed during the first 2 cycles. The sound effects were observed during the 3rd and 4th operating cycles. Further, when the Pitch Lock Solenoid Valve assembly was fully disassembled, no damage of the Pitch Lock Solenoid Valve, sliding spool or sleeve was found.

The absence of the sound effects from the Sliding Spool (solenoid) movement could be possibly caused by presence of oil inside of the Valve which might have acted as a damper during the first 2 cycles. The solenoid functional assessment was performed two months after the accident, and during these two months the sliding spool was not properly preserved, that could also cause its stiction.

It was not determined why the Pitch Lock Solenoid Valve was not activated when the propeller had moved below minimum flight blade angle and BETA status annunciation got on.

Therefore, the examinations, including the propeller governor full disassembly, didn't let to determine the cause of the propeller movement below minimum flight blade angle (+13.5°) and of the Pitch Lock Solenoid Valve failure to be activated when the blades had reached the angle of +9°.

1.16.5. RH powerplant P-W 22-1 propeller governor SN 14G629B

The P-W 22-1 propeller governor limits the maximum speed to 2080 RPM. Due to the propeller governor damage, obtained in course of the accident, it was not possible to conduct the governor functional assessment.

Based on FDR data (Fig. 8), propeller governor limited the propeller speed to higher speed on average 2090-2095 RPM. The propeller governor adjustment is to be done in response of the flight crew reporting some problems of gauge. The cockpit analogue gauge division value is about 50 RPM, therefore it is impossible to see when the gauge is 10-or-15 RPM above.

Most probably, the propeller governor was serviceable and adjusted to higher speed on average 2090-2095 RPM, however it did not implement the outcome of the flight.

It should be also mentioned that during the transition into BETA-mode, the propeller governor (starting from the blades' angle of +5°) is partly disabled and when the system operates in the reverse mode it does not provide governing functions.

1.16.6. RH powerplant flyweight (overspeed) governor

The flyweight (overspeed) governor is located at the propeller hub and is to be activated when propeller speed reaches 2160 RPM (+/-10 RPM).

The flyweight (overspeed) governor was inspected at the test bench. Its serviceability was proved, its performance is shown the accordance with the acceptance test data.

According to the FDR data, when BETA status annunciation got on (see Fig. 8) the propeller speed increased up to 2282 RPM that corresponds to the unloaded propeller condition when the propeller blades are moved close to the flat pitch. It is above the overspeed governor setting (2160±10 RPN), which is abnormal, however, in this situation this observed dynamic behavior of the propeller system is expected. Starting from the blades setting angle of ~+1° the overspeed propeller governor is partly disabled (it is fully disabled at minus 7°) that influence the provided governing.

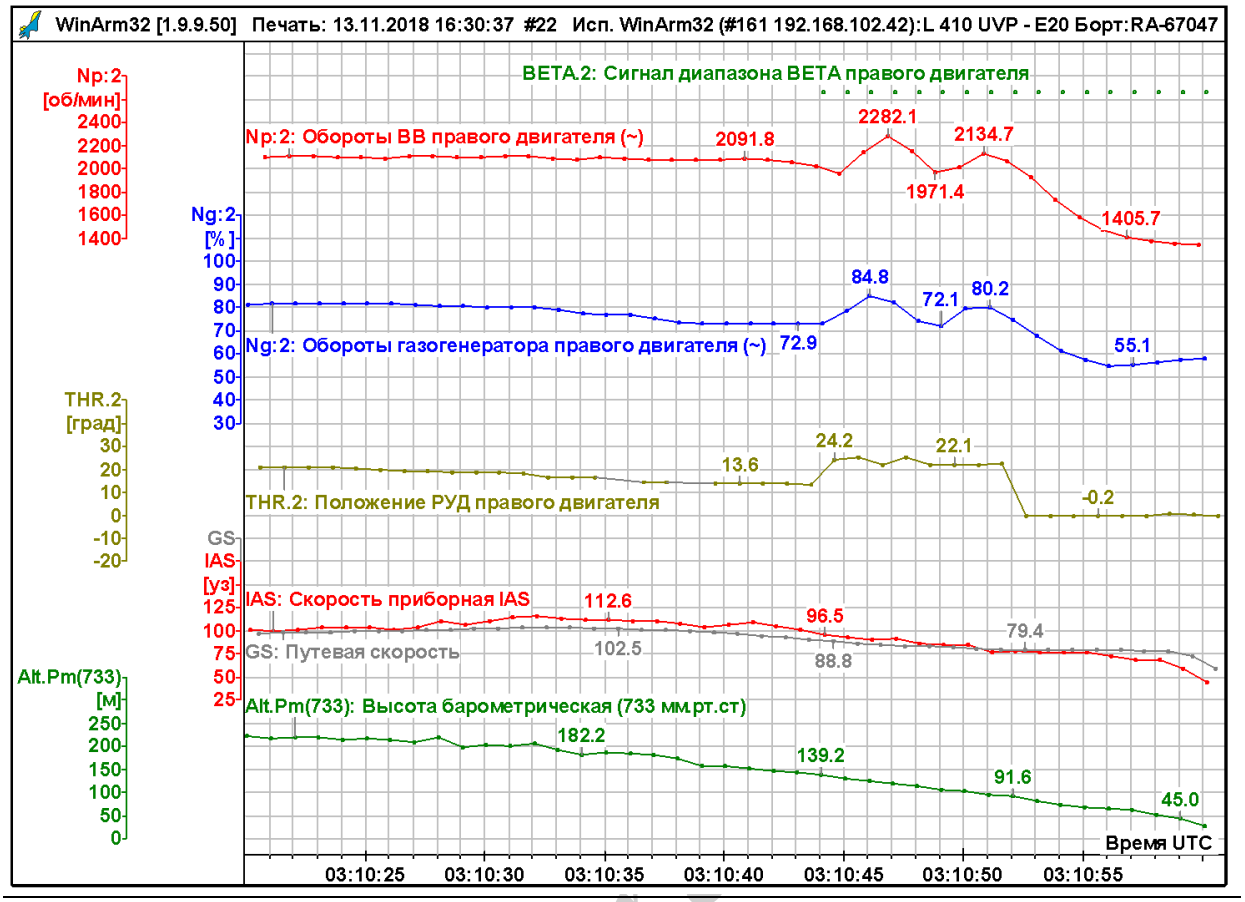

Fig. 8. Record of final stage of flight

1.16.7. RH powerplant SALM (autostart and limiter unit)

The engine overspeed condition (exceeding of NG, NP, TQ, ITT limits (T4) and undesirable ITT gradients) is to be addressed by the SALM unit which together with the FCU provides throttling by means of reducing the fuel supply at engine starting and in BETA mode (or reverse mode) when the propeller rotation speed reaches the value of 1900 (+40) RPM. SALM Unit acts as a back-up system protecting against the power turbine fracture when the primary limiting feature doesn´t work (primary limiting feature: prop speed in reverse mode is limited through the gas generator speed by the FCU fuel schedule). This effect is not instantaneous but there is 1-2 seconds delay.

According the FDR data (see Fig. 8), after BETA status annunciation appeared on and the RH propeller speed increased up to 2282 RPM, when the TCLs were in near constant position, the engine speed went down, which most probably was related to the SALM unit activity. Therefore, in the accident flight, the SALM unit limiter acted in accordance with the intended design.

1.16.8. Examination of P-W22-1 propeller governor SN 15G435C conducted by the Russian Federation Aviaregister[2]

On 11.01.2018, another incident related to BETA status annunciation, occurred with another Khabarovsk Airlines' aircraft. On the L410UVP-E20 RA 67040 aircraft, after the engine starting, when PCLs were moved from the feathering mode to the minimum inflight pitch angle position, the BETA status annunciation got on at RH engine and the Pitch Lock signalization was generated together with the RH engine propeller overshooting up to 1250 – 1280 RPM. When the PCLs were moved into feathering, the BETA status annunciation and the Pitch Lock signalization went out. The said incident was investigated by the Rosaviatsia (RF CAA). The RF Aviaregister specialists together with Avia Propeller (the propeller and governor manufacturer) specialists at the Avia Propeller facilities conducted the examination of P-W22-1 SN 15G435C governor, removed from the RH engine of L410UVP-E20 RA-67040 aircraft.

The following extracts are taken from the Russian Federation Aviaregister Report on the P-W22-1 SN 15G435C governor examination: *"The standard acceptance test performed at the [Avia Propeller] test bench revealed that the governor performance meets the acceptance test's requirements. During the examination of the beta valve serviceability by pushing at the rod some beta valve rod sticking was observed; the beta valve did not return in its intended position (yet it should have done under the return spring influence). After the propeller governor disassembly, some evidences of the broken adjacency of the beta valve rod surface to the mating part were found. The cause of the beta valve push rod sticking was not determined.*

Actually, beta valve sticking may cause propeller uncommanded overspeeding and moving below the min flight blade angle that was pre-set at the governor.

Considering that the bench test is unable to fully simulate the propeller governor operation, it was not possible to simulate the failure that had occurred during the actual operation.

As a result of the conducted analysis of the propeller governor operation installed on the propeller engine, FDR data decoding and on-ground inspection, it was found that in case of the beta valve hard seizure during PCLs' movement from the feathering mode to the blade minimum inflight pitch

[2] Within this sub-item, some extracts from the Russian Federation Aviaregister Report issued in course of the L410UVP-E20 RA-67040 accident investigation are quoted. Representatives of A/C, engine and propeller State of design and State of manufacturer did not receive the report from the Russian Federation Aviaregister. Representatives of A/C, engine and propeller State of design and State of manufacturer do not agree with the said Aviaregister Report conclusions and recommendations. They are positive that design of the propeller governor excludes beta valve seizure. The beta valve seizure signs were not observed during propeller governor investigative teardown. The cause of higher resistance of beta valve movement, observed during ground incident, has not been identified. There was no failure, no damage found during governor and beta valve disassembly.
However, at the moment of the L-410UVP-E20 RA-67047 Final Report developing, the investigation of the L410UVP-E20 RA-67040 accident is not completed yet.

angle position (when TCL is at idle), the BC lever departs from the full-stop position and the propeller overspeed occurs. With that, the oil supply channel designed for decreasing the pitch angle remains open. Propeller blades continue to move for pitch decreasing till they are stopped by beta valve (which acts as hydraulic lock). The hydraulic lock's proper work evidences that the P-S-2 № 222-0168 beta valve is in good condition.

Conclusions: the design of the propeller governor and the schematic of its fitting to the engine do not exclude the possibility of beta valve hard seizure which causes the propeller blades' uncommanded movement to the position below the minimum inflight pitch angle, followed by the beta status annunciation and the pitch lock signalization getting on.

Recommendation: In order to ensure the flight safety of L410UVP-E20 airplanes with GE H80-200 engines, AV-725 propellers and P-W22-1 propeller governors, the propeller governor manufacturer should take measures to improve the design to eliminate the beta valve seizure."

1.17. Organizational and Management Information

L410UVP-E20 RA-67047 A/C was purchased at State Leasing Company PLC in the Czech Republic in 2016 and was transferred for further operation to Khabarovsk Airlines, RSUE.

Variant L410UVP-E20 A/C powered by the GE H80-200 engines and AV-725 propellers was approved by the major change approval 10044498, REV.1 to the EASA.A.026 Type Certificate issued on 24.06.2013 and validated by the IAC AR major change approval OGI-13 to the CT302-L 410 UVP-E20 issued on 07.12.2013.

Variant H80-200 EASA.E.070 type certificate issue on 13.12.2011 and validated by IAC AR type certificate СТ334-АМД, 01 from 24.09.2012.

Variant AV-725 EASA.P.031 type certificate issue on 04.07.2011 and validated by IAC AR ST 335-VV (СТ 335-ВВ) issued on 21.11.2012.

The main field of Khabarovsk Airlines, RSUE's activity is passenger and cargo carriage along the regional scheduled and charter routes.

The Khabarovsk Airlines company had got AOC #459 issued on 29.10.2012 by Rosaviatsia Far East ITO. L410UVP-E20 RA-67047 A/C was included into the AOC operations specifications.

The Operator also had licenses for passenger (#PP 0184) and cargo (#PP0185) transportation issued on 05.06.2013 by Rosaviatsia.

The Russian Federal Service of Transport Oversight's Far East Federal District Administration of State Aviation Supervision and Supervision over the Transportation Security monitors the compliance by the legal entities and their executives, individual entrepreneurs and their accredited representatives with the requirements established by the international agreements to which the Russian Federation is a party, federal laws, as well as by the other types of the RF legislation based on the said agreements and laws and applied in field of the Russian civil aviation and transport safety.

1.18. Additional Information

1.18.1. Inflight generation of the BETA status annunciation

In course of the accident investigation, another case of beta status annunciation inflight generation was found. It occurred when L410UVP-E20 RA-67036 aircraft operated by Khabarovsk Airlines was performing an approach at Ayan airport on 03.04.2015.

During the approach, at the height of 260 m and at the speed of 115 knots (see Fig. 9), when PCLs were set to the fine pitch mode, the BETA status annunciation got on at RH engine.

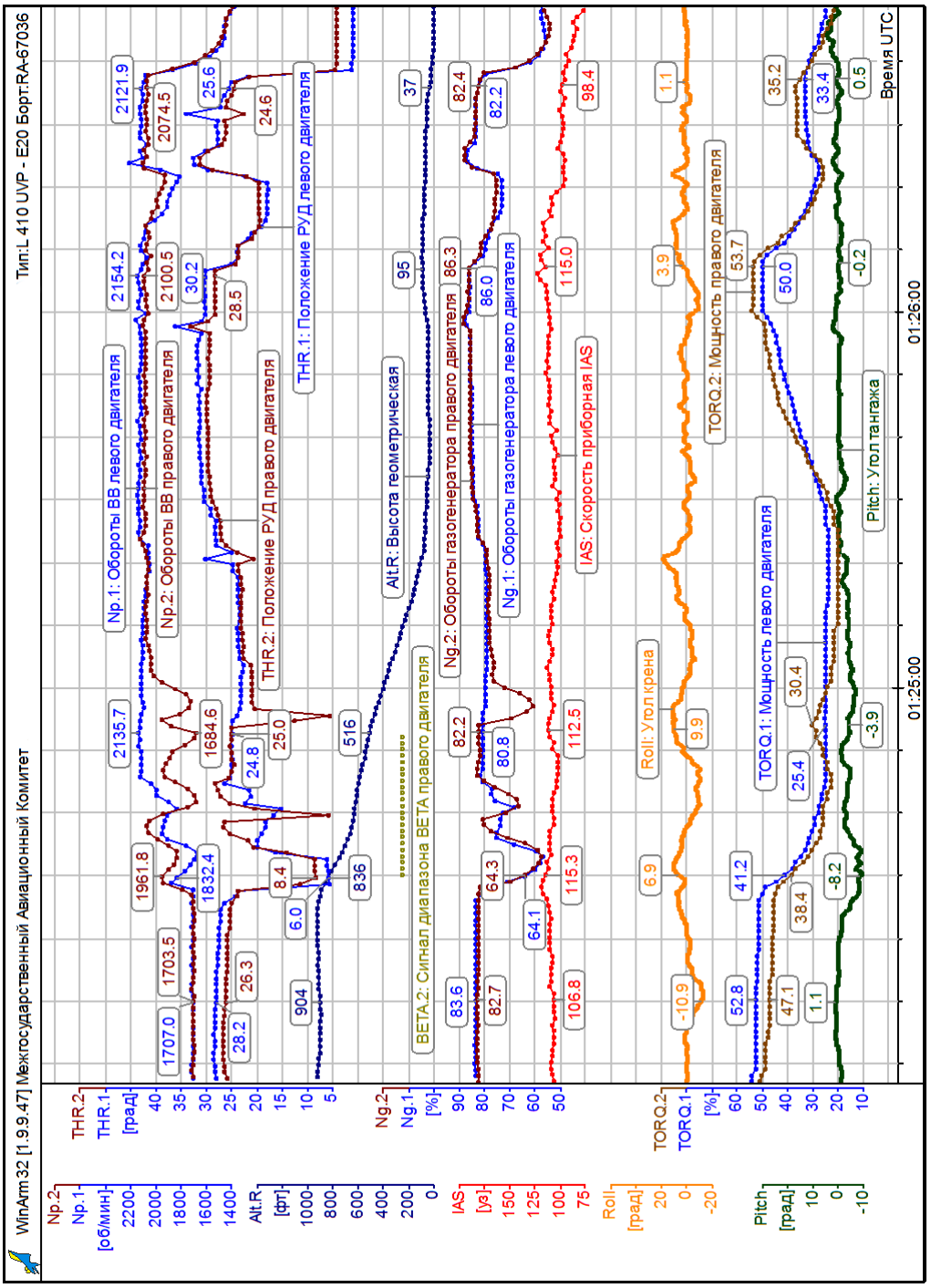

Fig. 9. Record of L410UVP-E20 RA-67036 aircraft landing stage on 03.04.2015 at Ayan airport

After the BETA status annunciation was generated, RH engine continued to operate, the gas-generators' RPMs corresponded to the TCLs positions, the propellers' RPMs corresponded to the PCLs' fine pitch mode. The above case evidences that the Pitch Lock was activated and the propeller blades' inflight uncommanded moving below 9° did not occur.

According to the FO's explanation report, after he had seen the BETA status annunciation going on, he moved RH engine PCL toward the propeller loading, and the BETA status annunciation went off. After the BETA status annunciation went off, the RH engine PCL was set to the fine

pitch mode again. The flight crew made sure that the BETA status annunciation did not come on again and performed a standard twin-engine approach. During the period when the BETA status annunciation was on (approximately ≈ 21 s), the aircraft's height loss was about 110 m; its maximum right roll recorded by the FDR was no more than 10°, further recovered by the crew, which also proves that there was no inflight movement of the RH propeller blades to the pitch angle lower than 9°. During the ground engine testing, performed in all the possible engine modes, but the BETA status annunciation was not activated.

It is important to mention, that the said case was not classified as an incident; therefore, no preventive measures were developed at that time. No information was provided to the A/C, engine and propeller designer/manufacturer. The aircraft remained in operation, no further attempts to determine the cause of the BETA status in flight annunciation.

1.18.2. Immediate actions taken for eliminating of the uncommanded propeller blades' movement to the positions below the minimum inflight pitch angle

After conducting of the examinations at the manufacturers' facilities (in Czech Republic) the A/C, engine and propeller manufacturers carried out the following workpackage on L410UVP-E20 airplanes equipped with H80-200 engines: in accordance with the respective bulletins, the BETA Switches were modified, some components were replaced, and the propeller and governor control systems were respectively adjusted. However, since the A/C operations were resumed on 02.04.2018, the two more cases of abnormal operation of Khabarovsk Airlines' airplanes showed themselves, which were related to the BETA status annunciation and to the Pitch Lock protection mechanism' activation. On 13.04.2018 and on 07.05.2018, after starting the engine on the L410UVP-E20 RA-67035 aircraft, when PCLs were moved into the fine pitch position, the BETA RANGE and the PITCH LOCK annunciation came on, followed by the propeller overshooting. When the PCLs were moved into the feathering mode, the annunciation went off.

Note: *The Note is added based on the requirements of ICAO Annex 13 item 6.3 and here the following comments to the Final Report received from the State of Design are included:*

"Occurrence from April 2018 was related to the incorrect alternative procedure for adjustment of BETA Switch listed in Propeller Operation and Installation Manual E-1707. This incorrect alternative procedure was removed and AVIA Propeller Operation and Installation Manual E-1707 revision 13, was issued on May 21, 2018. Occurrence from May 2018 was related to contamination of BETA Switch. Proper maintenance per instruction in AVIA Propeller Operation and Installation Manual

E-1707 are expected to be performed. As there was observed contamination of BETA Switch prior this occurrence, there have been available Service bulletin SB-H80-200-61-0014 to provide instruction how to clean the BETA Switch with recommended 100 hour time period"

Therefore, the taken actions, probably mitigated the risk of the uncommanded propeller blades' movement to the positions below the minimum inflight pitch angle, but did not fully eliminate the cause of the event. The designers and manufacturers consider the further actions, preventive measures will be taken starting in 2Q 2019.

1.18.3. Shortcomings identified in relation with the documentation use

In course of the investigation, it was found that Khabarovsk Airlines' pilots in course of the L410 UVP-E20-type aircraft operations use the Russian translation of the AFM, provided by the aircraft manufacturer. However, according to the EASA datasheet (EASA.A.026), AFM in English is a part of the type certification (*Do-L410-1218.2 Airplane Flight Manual for the L410UVP-E20 with H80-200 Engines and AV-725 Propellers*). The Investigation team requested the A/C manufacturer; the A/C manufacturer responded that the Russian version of AFM had been provided "for information only".

The Investigation team found that the said airlines' crewmembers operating the L410 UVP-E20 airplanes had not attended any language training courses and did not demonstrate any English language awareness.

1.19. New methods used in course of the investigation

No new methods have been used for the investigation.

2. Analysis

At 02:35 the crew communicated with the Nelkan Tower controller and received the approach and landing conditions and the landing site actual weather. The approach to landing was conducted to RWY 04 (MH_{LAND} 41°) with the standalone NDB (see Fig. 10) by the RH landing pattern (see Fig. 5 and 6).

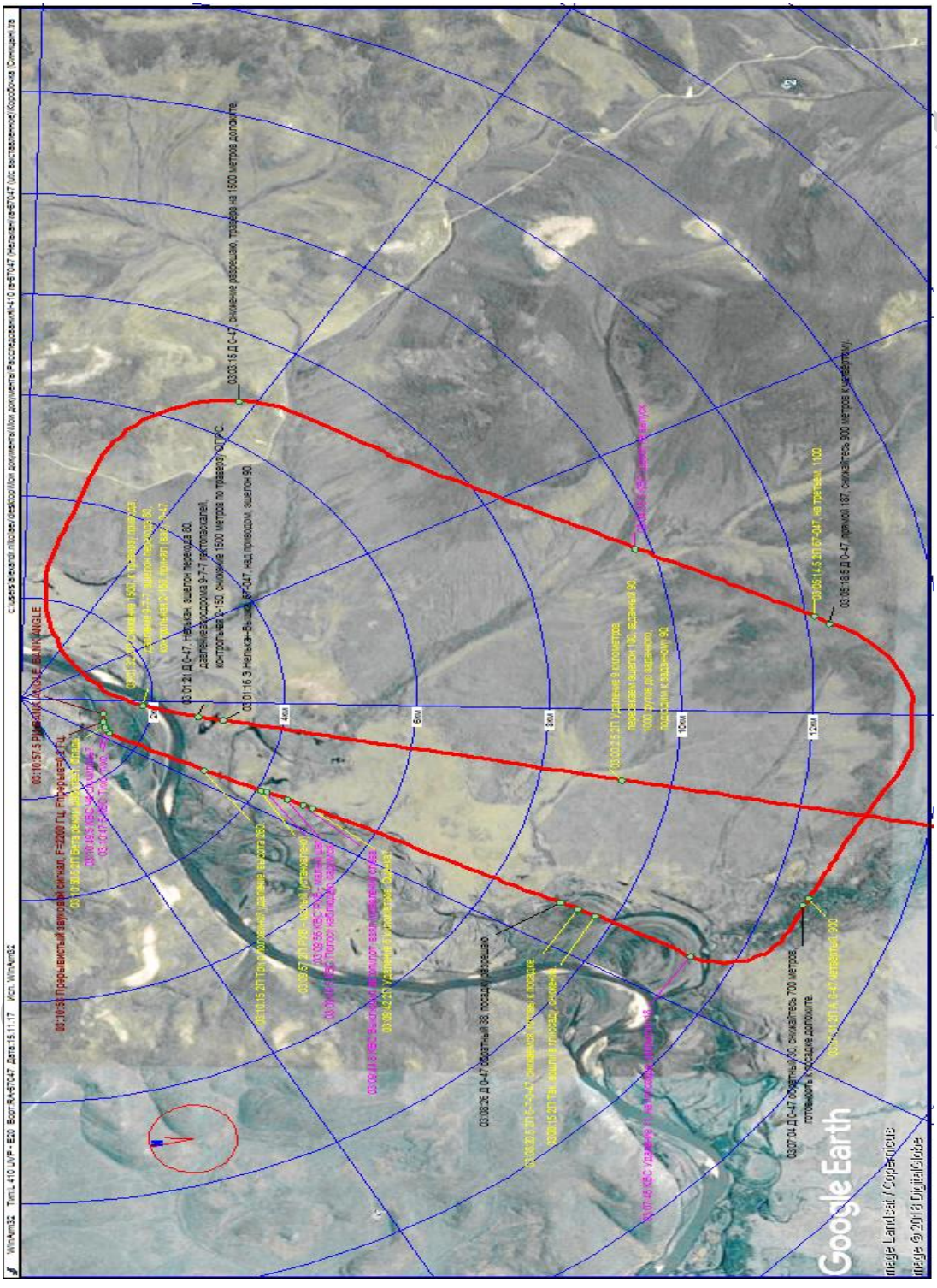

Fig. 10. Trajectory of L410UVP-E20 RA-67047 aircraft approach

For this kind of approach, the weather operating minima are 360 x 3000 m. The actual weather were appropriate for conducting of the approach.

The approach was conducted with the flaps at 18°and the landing gear in the down position. After the crew started to perform the final approach, they reported the readiness for landing and received the respective clearance from the controller. The PIC acted as PF. In course of the final approach, at distance of about 5 km and at height[3] of 400 m, the autopilot was disengaged, and the PIC having the RWY in sight decided to continue the landing.

After the autopilot disengagement, both PCLs were set to the fine pitch mode; then the crew performed the landing checklist. The final approach was conducted within the speed range of 100 to 115 KIAS (see Fig. 11). The airplane landing weight was about 5300 kg. In accordance with AFM, page 5-127, the V_{REF} speed must be about 80 knots considering the airplane actual landing weight and flaps' position. According the L-410UVP-E20 AFM, the approach for landing from the heights that is 100 ft. (30 m) above DH is recommended with flaps at 18°. For crosswind gusts up to 20 kts, the recommended airspeed is 90 kts, that provides the sufficient speed margin for all landing weights. At the DH, when the decision for landing is taken, the V_{REF} speed shall be adjusted with consideration of the aircraft landing weight and flaps' position.

[3] Here and further all heights are shown above the RWY level.

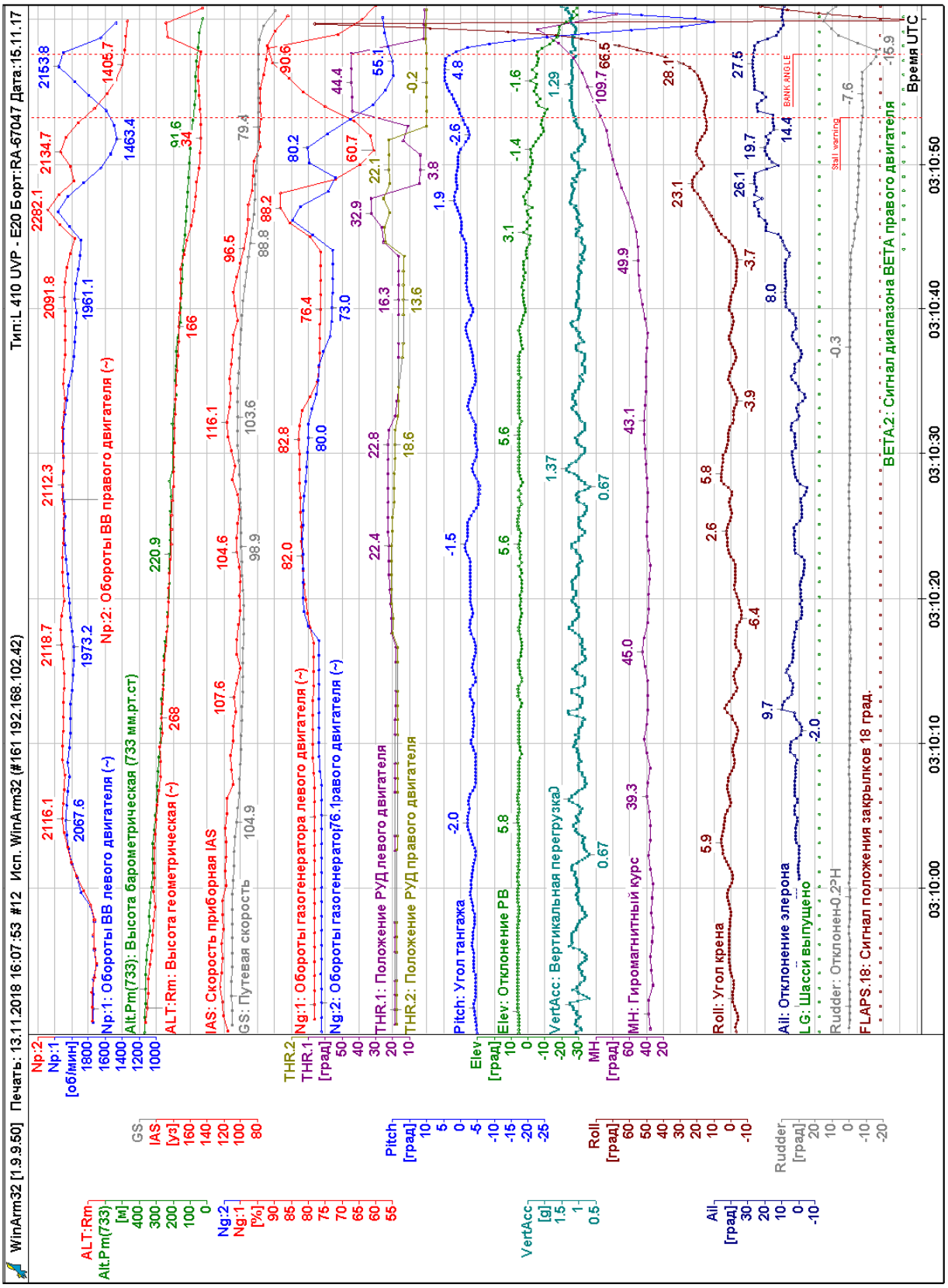

Fig. 11. Record of the final stage of the flight

When the crew had set the PCLs to the fine pitch mode (while the TCLs' positions remained unchanged), the RH propeller rotation speed increased up to 2118 RPM, while the LH propeller rotation speed was within the range of 1970 to 1960 RPM. When the propeller speed is above

2080 RPM, the propeller governor shall response. As per sub-item 1.16.5 of the current Report, the propeller governor was actually adjusted to 2090-2095 RPM and was serviceable.

The abnormal situation started to develop at 03:10:38 at height of approximately ~170 m, when the speed was 108 kts. With the pedals' position remained unchanged and with zero roll, the magnetic heading was changed by 10° (to the right) within 5 s, then at 03:10:44 when both TCLs were set to forward thrust, FDR started to record the single event of the BETA RANGE[4] on the RH engine. The recording of the said single event is seen up to the end of the whole FDR recording (up to the accident).

Almost at the same moment (03:10:44), the right roll started to develop, and after 4 to 5 s it reached about 20 – 25°. During the next 7 to 8 s, the right roll was being changing within the range of 15 to 25°, while the crew was applying the pedals (for about ½ the travel range) and ailerons (up to the maximum deflection) in order to compensate for the roll change.

According to the CVR records, the crew realized the cause of the abnormal situation: the PIC at 03:10:48: "Hush, hush! What is going on?" The F/O at 03:10:51.5: "It is the BETA RANGE on".

The situation had been further deteriorating within about the next 9 s. The A/C continued to descend and to lose its speed vigorously. The crew's control actions aimed to recover the aircraft by applying the TCL of the LH engine normally operating, as well as the controls for the ailerons, elevators and rudder, failed. The crew did not feather the RH propeller; the RH engine was operating till the end of the FDR recording.

At 03:10:53 at the height of 100 m, with the speed of 76 kts and the vertical G of about 1.15 g, the CVR recorded the stall warning annunciation. After the next 3 – 4 s, at the height of 80 m, with the speed of 72 kts and the vertical G of about 1.2 to 1.25 g, the A/C started to develop an aggressive right roll. Considering the FDR readout and the A/C wreckage position after the accident, it could be concluded that, at its final, the A/C performed a full-circle rotation around its longitudinal axis (barrel-roll).

In consequence of the conducted examination, it was found that the emergency situation had been caused by the uncommanded inflight RH engine propeller blades' turn to the angle minus 1.8° (which was significantly below the minimum inflight pitch angle of 13.5°).

[4] According to the AFM (page 7 – 9), when BETA RANGE cell comes ON, it means that the "propeller pitch is set to angle below angle for flight idle". The aircraft manufacturer explained that the said mode inflight setting is prohibited.

It is necessary to add that there was no information on the crew actions in case of BETA RANGE cell comes ON inflight in the L410UVP-E-20 AFM at the moment of the accident. In respond to the Investigation team request (why such information had not been provided in the AFM), the A/C manufacturer/designer answered that probability evaluation, done during the certification procedure, had shown that the probability of a propeller uncommanded setting into the BETA range is 10^{-14} (the Investigation team comment: *that is significantly lower than the extreme improbability of* 10^{-9}).

Therefore, the lack of the recommendations in the L410UVP-E20 AFM on the crew actions in case of BETA status inflight annunciation and, as a consequence, of the propeller blades' uncommanded movement to the pitch below minimum inflight pitch angle, was caused by the lack of relevant training, and resulted in the lack of crewmembers' preparedness to the said situation.

Note: *The Note is added based on the requirements of ICAO Annex 13 item 6.3 and here the following comments to the Final Report received from the State of Design are included:*

"The Aircraft Industries position is, that during the type certification process of L 410 UVP-E20 aircraft with H80-200 engines and AV-725 propellers the event of uncommanded movement of propeller blades to the pitch below minimum inflight angle was classified as highly improbable, which was the reason, why non instructions for flight crew for this event were introduced into L 410UVP-E20 aircraft AFM."

Following the accident (15.11.2017), the A/C manufacturer/designer issued an EASA-approved Documentation Bulletin on 15.12.2017; in which it is stated that: *"on final approach when the amber beta range cell… comes on"* the crew must perform *"the following procedures on the affected engine"*: to put TCL in idle, to push manual feather push-button, and to put PCL into feather. Then to: *"complete flight with one engine inoperative."*

It is necessary to add that the A/C manufacturer/designer was unable to perform a math (dynamic) simulation of the accident flight. The A/C manufacturer/designer reported that was not able to provide the simulation of the airplane dynamic behavior due to the lack of the initial aerodynamic data (such as the negative thrust influence to the airplane flight performance), and also because the situation that was developed in the accident flight had been defined as a very improbable one during the aircraft certification.

Therefore, it was not possible to determine the cause of the uncommand aircraft roll: was it caused by the aircraft exceeding the stalling angle or by the deficiency (while the speed decreasing) of ailerons control moment needed for counteracting of the existing aerodynamic disturbances.

The propeller manufacturer explained, that the value of the negative thrust, which had been generated by the propeller in course of the accident flight was calculated, but negative thrust itself without other aerodynamic data was not sufficient for simulation of aircraft dynamic behavior during this event. So, according to the propeller manufacturer was the reason why the Investigation team received no answer to the question about the aircraft uncommanded roll possible causes.

Note: *The Note is added based on the requirements of ICAO Annex 13 item 6.3 and here the following comments to the Final Report received from the State of Design are included:*

"The A/C manufacturer/designer opinion concerning the uncontrolled roll in latest second of the accident is, that this roll was caused by increase of the power on left engine by the flight crew, which lead to increase of yawing moment (left power unit generating positive thrust, right power unit generating negative thrust) and with conjunction of effects of low airspeed and application by the crew only small rudder deflection, also to large sideslip. Through the increased blowing of the part of the wing behind the left propeller the increased rolling moment was generated, which was further supplemented by the rolling moment generated by the sideslip. Resulting rolling moment, which in latest phase would be further strengthened by nonsymmetrical airflow separation on the right and left wing, could not be compensated by even full deflection of ailerons."

Based on the propeller system description (see item 1.6.1), it may be concluded that for the propeller uncommanded setting to the negative angles of attack, the following three conditions should be met: the availability of the governing signal for the propeller blades' pitch decreasing, the BETA feedback system failure (which probability is 10^{-7} for 1 flight hour according to the Avia Propeller certification report E-1723, Table 9) aiming to prevent the propeller blades' setting to the angle lower than of 13.5°, and the Pitch Lock Valve solenoid failure (which probability is 10^{-6} for 1 flight hour according to the Avia Propeller certification report E-1723, Table 9) starting to operate after the BETA Valve loss and aiming to prevent the propeller blades' setting to the angle lower than of 9°. Therefore, it may be concluded that at least two systems (BETA Feedback system and pitch lock system) failed in the same (accident) flight.

No malfunctions were found in course of the BETA valve examination. The schematic analysis shows that under the normal operations (usually at the landing approach[5]) the BETA valve moves from the position that is corresponding to Pick Up Angle to the position that is corresponding to min flight pitch. By that the BETA lever should rotate against the governor BETA feedback lever.

[5] The BETA valve as per the designer explanation acts for the propeller blades' movement to the flight pitch decreasing under the normal operations almost every flight.

The analysis done by the propeller designer/manufacturer shows that the BETA Valve can develop higher resistance/friction against BETA Valve movement. The higher resistance/friction of the BETA Valve causes that the BETA Valve does not stop the flow of pressurized oil to the propeller servo piston at the moment when propeller minimum flight BETA angle is achieved, the propeller piston continues to decrease the propeller blade angle developing through BETA Ring and BETA Feedback Lever the force acting on of propeller control system mechanical linkage. This force then causes the propeller control mechanical linkage movement, that in its turn will result in BETA Feedback system abnormal operation similar to the case when a reverse mode is applied by a pilot.

It was not possible to identify exactly the cause why the resistance of the BETA Valve increases. There can be the following contributors:

- the hydraulic lock caused by insufficient drainage from the BETA Valve casing cavities, or by hydraulic pressure picks occurred during the propeller governor functioning;
- lack of some BETA Valve components' cylindrical surfaces' centering. The cross section of BETA Valve shows that several components are not aligned (center-to-center). This effect combined with thermal distortion (caused by the operation of propeller governor) could cause increased friction during the BETA Valve transition;
- oil contamination, which results in higher resistance against movement (friction) of the BETA Valve.

In course of the Pitch Lock Solenoid Valve examination some difficulties in the Sliding Spool movement during the first 2 cycles were found (see sub-item 1.16.4). There were no such problems during the next cycles. When the Pitch Lock Valve assembly was fully disassembled, no damage of the Pitch Lock Valve, Sliding Spool or Sleeve was found. The Avia Propeller (the BETA Valve designer/manufacturer) believes that the difficulties in the Sliding Spool movement during the first 2 cycles can be caused by the pressurized oil kept in small cavities and acted as a damper. The root cause of the Pitch Lock system malfunction has not been clearly identified.

In the course of analyzing the possible causes of the system failure, the system schematic was reviewed and it shows that the Pitch Lock system is structured into subsystems (both related to power plant and to aircraft) as follows below.

At engine level:

- BETA Switch;
- Engine harness;
- Propeller Governor Pitch Lock Valve & Spool.

At aircraft level:

- Airframe harness;
- Power input;
- TCL Quadrant Switch.

Based upon the analyses, the following subsystems can be ruled out:

1. Pitch Lock system – Engine Level:

a) BETA Switch; b) Engine harness; c) Pitch Lock Valve – Solenoid.

However, the following contributors could cause the malfunction of the Pitch Lock system:

2. Pitch Lock System – Engine Level:

– Pitch Lock Valve – Spool,

as well as some components at the aircraft level.

As was already shown in the sub-items 1.16.8, 1.18.1 and 1.18.2, the BETA Feedback system faults were registered for the different airplanes (power plants) on numerous occasions. The faults were repeated ones (but also intermittent ones); the causes of the said faults were not recognized for sure (as they were intermittent ones); and the measures taken by the propeller designer/manufacturer were ineffective. Therefore, the real-life operations does not prove the declared probability of failure (10^{-7} for 1 flight hour).

Moreover, in all abovementioned cases of the BETA Feedback system faults (excluding the accident flight in question), the Pitch Lock system had operated and its operation prevented the propeller blades' setting to the negative angles of attack.

It is necessary to add that according the L410UVP-E20 AFM item 4.2, *SYSTEM CHECKS AND OPERATION – PROPELLERS, PROPELLER PITCH LOCK TEST*, the crew after the engine start have to conduct the PITCH LOCK TEST. Also the said requirement is included in the Airlines' FOM.

Note: *L410UVP-E20 AFM, item 4.2, PROPELLER PITCH LOCK TEST:*

"Perform it before the first flight of the day.

Test must be performed during propeller unfeathering.

TCL.....IDLE

PCL.....move from FEATHER

to FINE PITCH position

PROPELLER PITCH LOCK TEST button.....press and hold at propeller speed about 700 RPM

Propeller speed must stop rising and both PROPELLER PITCH LOCK amber cells on the instrument panel cover must light when button is pressed.

PROPELLER PITCH LOCK TEST button .....release

Propeller speed must start to rise up to 920 ± 60 RPM and both PROPELLER PITCH LOCK amber cells on the instrument panel cover must light off."

See below the Propeller Pitch Lock system Test at the FDR readout graph at Fig. 12:

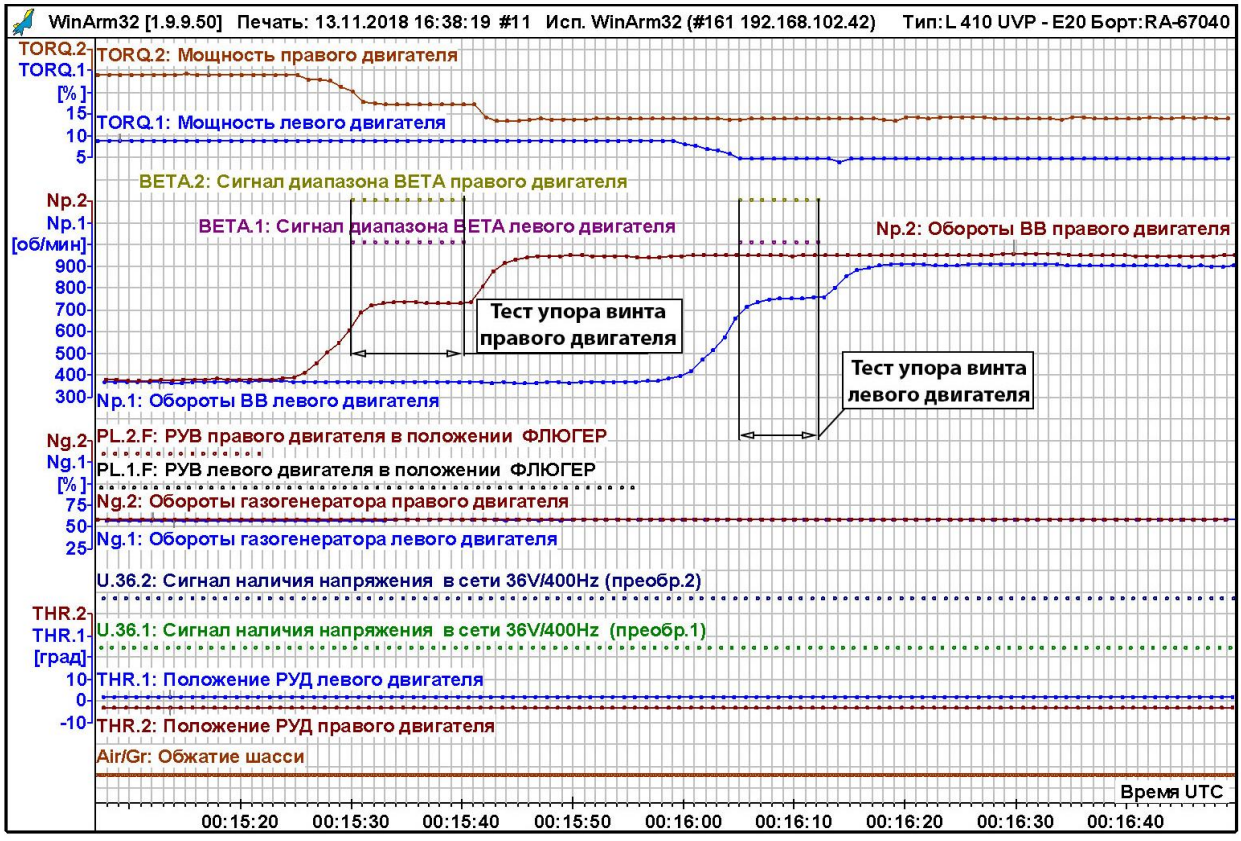

Fig. 12. An example of Propeller Pitch Lock Test for LH and RH engines check.

Note: *A BETA status annunciation is generated (and the single event is recorded by FDR) during conducting of the Propeller Pitch Lock Test at L410UVP E20 airplanes after their modification following the accident (see Fig. 12). As for the airplane in question no recording of the said single events was provided,*

therefore, the only evidence that the flight crew really did conduct the test can be stopping of the propeller speed increase.

It is not possible to be positive if the crew did or did not conduct the Propeller Pitch Lock system test because there are no indicative constant horizontal portions on the propeller speed plot. However, the analysis shows that the crew ***could have conducted*** the said test at about 22:54:45 – 22:54:55.

Three following figures (Fig. 13-15) show the overlay of the plot of L410UVP-E20 RA-67047 LH and RH engines' propeller speed (taken before the accident flight) onto the plot of L410UVP-E20 RA-67036 LH and RH engines' propeller speed (taken during the examinations). During the examinations, the propeller blades were recovering out from feathering by three different ways: without pressing of the PROPELLER PITCH LOCK TEST button, with pressing it during 1 s and during 2 s. Parameters' timing was done by the disappearance of single commands "TCLs to FEATHER position" with consideration of the rate of these commands' sampling frequency.

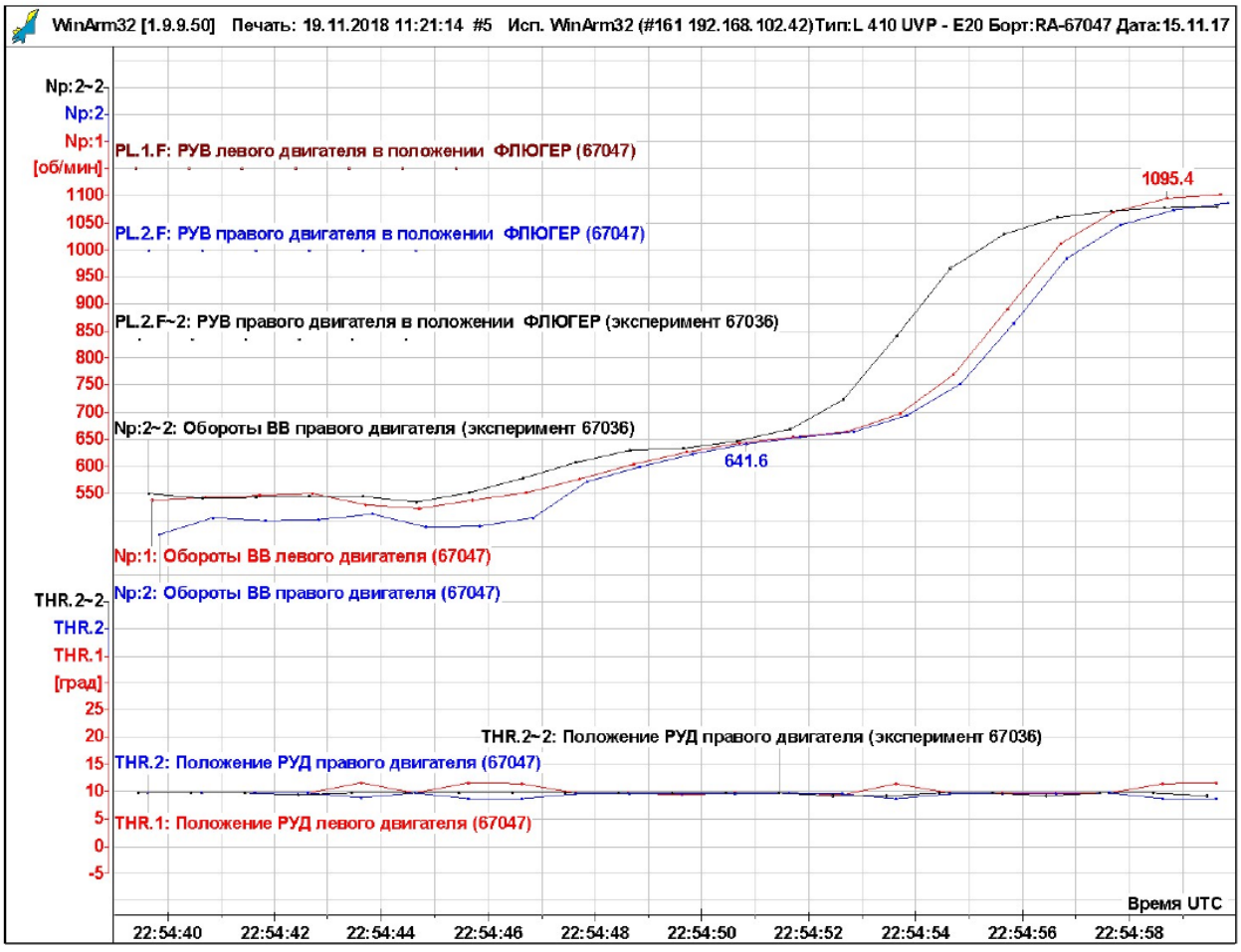

Fig. 13. Without pressing of the PROPELLER PITCH LOCK TEST button

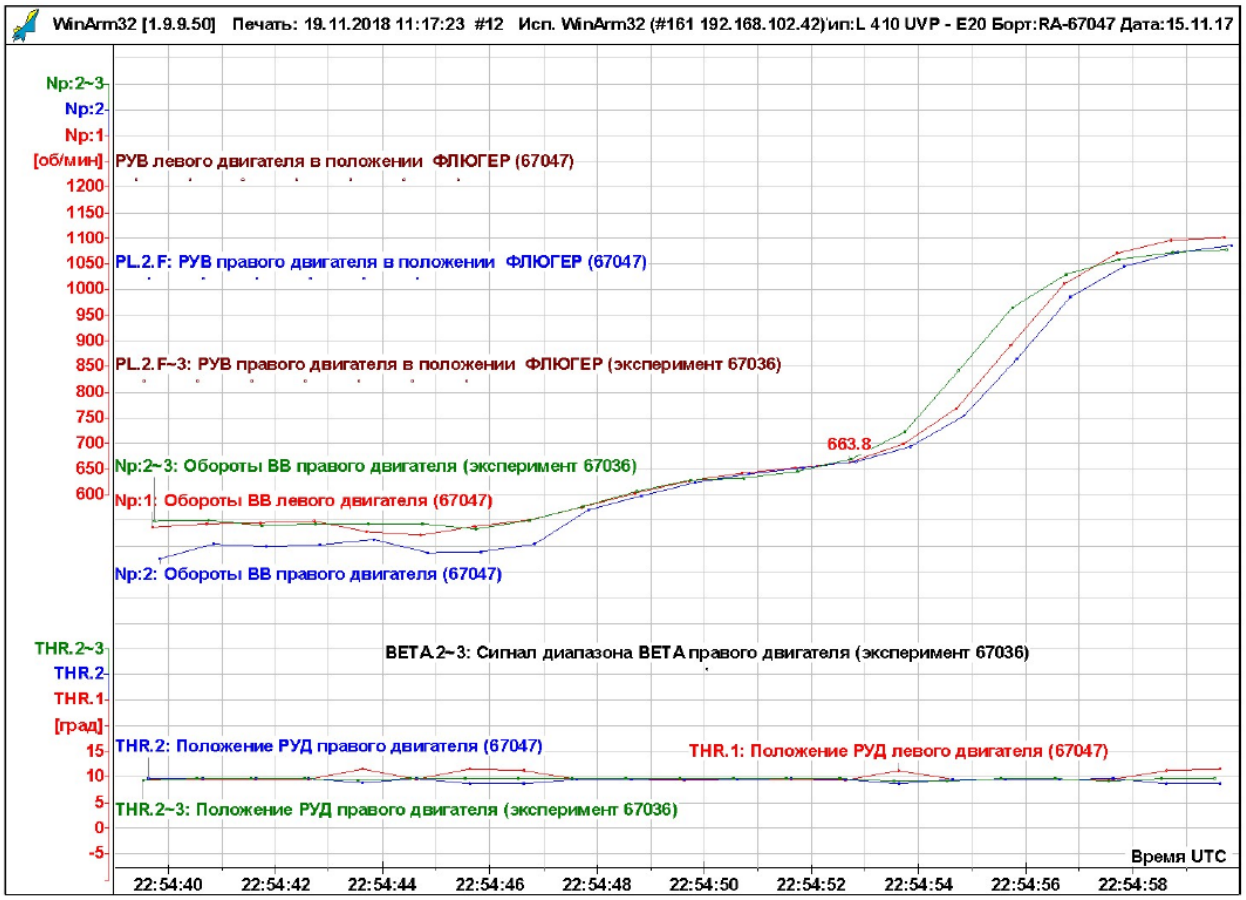

Fig. 14. Pressing during 1 s

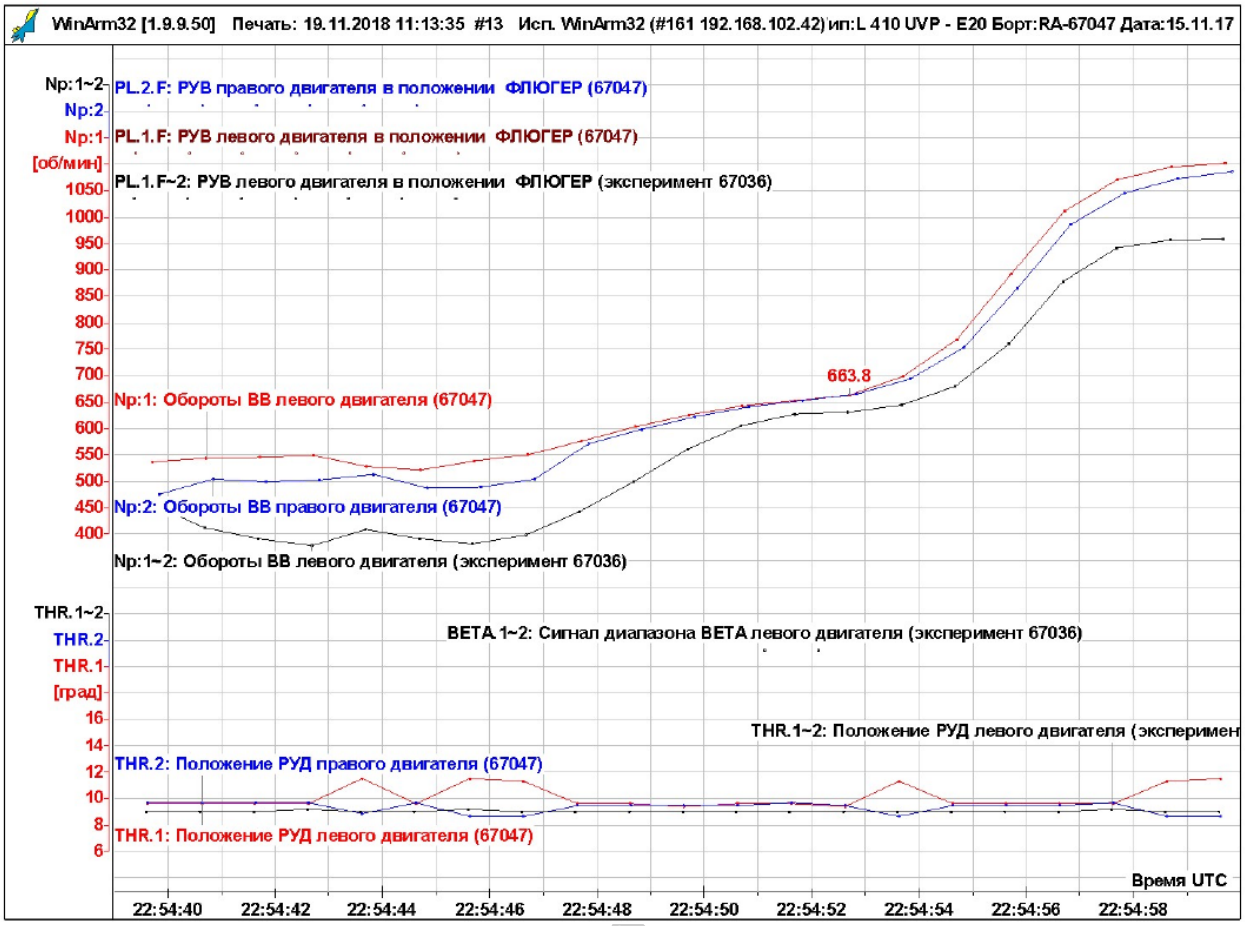

Fig. 15. Pressing during 2 s

The record traces at figures 13-15 are the evidence that most probably the crew performed the PROPELLER PITCH LOCK TEST by short-time pressing the button (during 1-or-2 s).

According to the airplane designer/manufacturer, the evidence of the normal propeller Pitch Lock operation ***is that the propeller speed must stop rising*** when button is pressed during the test; this is stated in AFM. Both PROPELLER PITCH LOCK amber cells on the instrument panel cover light when the Pitch Lock Solenoid is energized. Therefore, the availability of the amber cells lights is not the evidence that the Pitch Lock system operates. When the pilot performs the test he/she shall wait till the propeller speed will be stabilized demonstrating that the propeller Pitch Lock system operates properly. However, it is not possible to realize if the system operates properly with the short-time pressing. Analyzing of preceding flights shows that most of the pilots did not perform the PROPELLER PITCH LOCK button long-time pressing (when the propeller speed stops to rise).

It should be added, that the algorithm of PITCH LOCK TEST included the check of the solenoid electrical circuit operation at the engine level only (based on expertise by A/C designer the fact that Pitch Lock Solenoid is the least reliable component per their data and operation records of the Pitch Lock system), but not of the system in whole, the check at the airframe (airplane) level was not included[6]. This means that even if the solenoid was serviceable the system might have been unserviceable. Therefore, as in course of the investigation it was found that the Propeller Pitch Lock system components (that are to be tested during the PITCH LOCK TEST) most probably did not contribute to the system malfunction, then it is very improbable that the crews' deviation of the PITCH LOCK TEST procedure could make any difference in the detection of the said system malfunction before the flight.

[6] The A/C manufacturer Mandatory Bulletin (MB) L410UVP-E/143a Revision 2, issued on 07.03.2018, introduced changes into electrical circuit of Pitch Lock system testing.

3. Conclusion

The direct cause of the L410UVP-E20 RA-67047 A/C accident was the uncommanded inflight RH engine propeller blades setting to the angle of minus 1.8° which is significantly below the minimum inflight pitch angle (13.5°) with TCLs set to forward thrust. It caused the significant rolling and turning moments, the A/C loss of speed and controllability, and the subsequent with the ground collision[7].

The propeller blades' setting to the negative angles was caused by the failures of two systems: the BETA Feedback system and the Pitch Lock system. As the Propeller Pitch Lock system components that are to be tested during the PITCH LOCK TEST most probably did not contribute to the system malfunction, then it is unlikely that the crews' deviation of the PITCH LOCK TEST procedure could have make any difference in the detection of the said system malfunction before the flight.

The said situation had been classified as extremely improbable during the aircraft type certification, so, there was no required crew actions in AFM for such situations, and the respective crew training was not required.

[7] The foot-note is added based on the requirements of ICAO Annex 13 item 6.3 and on the comments to the Final Report received from the State of Design. The State of Design requests to word this para as follows: *"The negative thrust and increased power on LH ENG without using higher deflection of rudder to eliminated high yawing moment resulted in significant sideslip angle, rolling and turning moment. The A/C loss of speed and controllability and the subsequent with the ground collision."*

4. Other shortcomings revealed in the investigation

4.1. In the L410UVP-E20 AFM, there is no information about the exact time after takeoff when TCLs' red stop is set to the BETA/reverse mode preventing position.

5. Flight Safety Measures taken and Recommendations

Measures taken upon the Investigation team recommendations:

5.1. Russian CAA have made one-time inspection for correct BETA range and propeller control system settings on the GE H80-200 engines.

5.2. On 04.12.2017, the A/C designer/manufacturer issued the Information Bulletin (IB No.: L410UVP-E/492b Revision 1) on engines and propellers control check for the L410 UVP-E20 aircraft starting from MSN 2904.

5.3. On 15.12.2017, EASA issued the Safety Information Bulletin (SIB No.: 2017-21) which recommends the owners and operators to accomplish the actions as specified in IB No.: L410UVP-E/492b Revision 1.

5.4. On 15.12.2017, the A/C designer/manufacturer issued the EASA-approved Documentation Bulletin (DB No.: L410UVP-E/247d) which introduces the required crew actions in case of the BETA range cell comes on during various phases of the flight.

5.5. On 07.03.2018 the A/C manufacturer issued the Mandatory Bulletin (MB) L410UVP-E/143a Revision 2, by which there were implemented changes into electrical circuit of Pitch lock system testing.

5.6. On 07.03.2018 the A/C manufacturer issued the Documentation Bulletin (DB) L410UVP-E/259d, introducing into AFM instructions for Pitch lock functional testing before each flight instead of Pitch lock testing before each flight day and adjusting the execution of the test.

5.7. On 14.03.2018 EASA issued the Airworthiness Directive AD No. 2018-0057 ordering the mandatory execution of bulletins L410UVP-E/143a Revision 2 and L410UVP-E/247d and DB L410UVP-E/259d.

5.8. On 29.03.2018 the engine designer/manufacturer issued the Service Bulletin (SB) SB-H80-76-00-00-0036 Revision 02 ordering a "one-time" inspection and adjustment of engine push-pull control of p/n M601-76.3, as well as installation of the new BETA switch P-S-2A.

5.9. On 19.04.2018 EASA issued the Airworthiness Directive AD No. 2018-0075 ordering the mandatory execution of GEAC SB-H80-76-00-00-0036 Revision 02.

5.10. On 16.11.2018 the engine designer/manufacturer issued the Service Bulletin SB-H80-76-00-00-0045 ordering the inspection of engine push-pull control of p/n M601-76.3, as well as of the new BETA switch P-S-2A, before and during the winter season.

5.11. On 12.04.2019, the engine designer/manufacturer issued SB-H80-76-00-00-0048 and SB-H85-76-00-00-0015 Revision 01 (single document) ordering the inspection and adjustment of engine push-pull control of p/n M601-76.3 "after any maintenance, repair, or modification

action on the engine, on the propeller, or on the airplane, that can affect the settings of the Push-Pull Control".

5.12. On 25.04.2019 EASA issued the Airworthiness Directive AD No. 2019-0089. This AD supersedes EASA AD 2018-0075 and order the mandatory execution of GEAC SB-H80-76-00-00-0048 and SB-H85-76-00-00-0015 Revision 01 (single document). Effective date is 09.05.2019.

Safety Recommendations

To Russian CAA

5.13. To analyze the circumstances and causes of the accident in question during the purposely arranged discussions with the management, command and flight personnel, maintenance personnel, and the ATC staff.

5.14. With consideration of the already taken measures, to consider the potential risks of the use of L410UVP-E-20 airplanes equipped with H80-200 engines before the propeller governor designer/manufacturer will take additional measures for the elimination of the propeller governor operational reliability

5.15. To assess risks related to the fact that aircraft operators use the Russian translation of the L410UVP-E20 AFM, which is not part of the type design certification documentation and was provided by the manufacturer "for information only". Based on this assessment, to take corrective actions. To analyze the applicability of this recommendation to other types of foreign made aircraft.

5.16. To develop and implement the English language awareness qualification requirements for the flight crews which operate aircraft with documentation provided in English, as well as for the maintenance staff which perform maintenance for the said aircraft. This Recommendation is provided repeatedly.

To A/C, Engine and Propeller Designers/Manufacturers

5.17. To Propeller designer – to consider the need of re-assessment of the reliability of the propeller P-W22-1 governor and components of propeller control system.

5.18. To Engine designer – at the engine level to consider the need of re-assessment of the reliability of the propeller control system, which includes the P-W22-1 governor and other components.

5.19. To A/C designer – at the A/C level to consider the need of re-assessment of the reliability of the propeller control system, which includes the P-W22-1 governor and other components.

5.20. To A/C designer in association with the engine and the propeller designers – to consider the need of the implementation of modifications into the propeller control system design and/or its settings in order to eliminate the possibility of the uncommanded propeller blades' inflight setting to positions below the minimum inflight pitch angle.

5.21. To A/C designer – to implement the additional information into the AFM aimed to describe more specific the procedure of the PITCH LOCK TEST execution.

To Rosaviatsia, AR IAC, EASA and other certification authorities

5.22. To consider the suitability of modifying of certification rules for aircraft and/or systems' designers in part of the introduction of requirements to ensure all necessary support to the accident investigation including the provision of the flight math/dynamic simulations.

To Khabarovsk Airlines and other operators of the L410UVP-E20 aircraft

5.23. To conduct the crew training on the pitch lock before flight testing. Consider the FDR recording the crews' regular execution of the PITCH LOCK TEST.

5.24. To assess the risks related to the use by pilots of the L410UVP-E20 AFM in Russian, which is not a part of the type design certification, and was provided by the aircraft manufacturer "for information only". Based on the said assessment to take the appropriate actions.