The original of the Final Report was issued in the Slovak language.
In case of inconsistency original version in Slovak language is applicable.

MINISTRY
OF TRANSPORT
AND CONSTRUCTION
OF THE SLOVAK REPUBLIC

AVIATION AND MARITIME INVESTIGATION AUTHORITY
Námestie slobody 6, P.O.BOX 100
810 05 Bratislava

FINAL REPORT

on the safety investigation of the air accident

helicopter type **Bell 429**

Registration Mark **OM-ATR**

Reg. No.: SKA2016007

The investigation of occurrence has been conducted pursuant to Art. 18 of the Act No. 143/1998 on Civil Aviation (Civil Aviation Act) and on Amendment of Certain Acts and in accordance with the Regulation (EU) No. 996/2010 of the European Parliament and of the Council on investigation and prevention of civil aviation accidents and incidents, governing the investigation of civil aviation accidents and incidents.

The final report is issued in accordance with the Regulation L 13 that is the application of the provisions of ANNEX 13 Aircraft Accident and Incident Investigation to the Convention on International Civil Aviation.

The exclusive aim of investigation is to establish causes of accident, incident and to prevent their occurrence, but not to refer to any fault or liability of persons.

This final report, its individual parts or other documents related to the investigation of occurrence in question have an informative character and can only be used as recommendation for the implementation of measures to prevent occurrence of other accidents and incidents with similar causes.

Use of abbreviations and acronyms

AGL	Above Ground Level
CVR/FDR	Flight Recorder
FIC	Flight Information Center
FI(H)	Qualification – Flight Instructor/helicopters
ft	Feet (dimensional units)
HEMS	Helicopter Emergency Medical Service
hPa	Hectopascal
CED	Criminology and Expertise Department
kt	Knots
ROC BB	Regional Operational Center Banská Bystrica
LAPL	Light Aircraft Pilot Licence
LZTT	ICAO code for the POPRAD - Tatry airport
NVIS	Night vision imaging systems
NVG	Night Vision Goggles
SANAV	SANJOSE NAVIGATION
SERA. 5005	Visible Flight Rules - for flights under VMC night/implementing Commission Regulation (EU) No. 923/2012 of 26 September 2012
SHI	Slovak Hydrometeorological Institute
UTC	Co-ordinated Universal Time
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
Vs	Vertical speed

A. INTRODUCTION

Operator/Owner:	AIR-TRANSPORT EUROPE spol. s r.o., healthcare provider (hereinafter referred to as “ATE”)
Operation type:	HEMS
Helicopter type:	Bell 429
Registration mark:	OM-ATR

Take-off Site:	cadaster of Strelníky municipality
Flight phase:	after take-off/flight to University Hospital with F.D. polyclinic Roosevelt in Banská Bystrica (hereinafter “healthcare facility”)
Accident Site:	N 48°41´51,80´´ E 19°25´15,50´´
Accident date and time:	07.09.2016, 20:30:34

<u>Note</u>: All time data in this report are in UTC time.

B. INFORMATIVE SUMMARY

On 07.09.2016, the pilot took flight with a Bell 429 helicopter, registration mark OM-ATR (helicopter) from LZTT airport, into the mountainous terrain in the Strelníky cadastral area, to pick up and transport an injured patient to a healthcare facility.

After landing on a marked and illuminated area in the area at 20:10, the pilot shut down the engines to load the patient.

At 20:30, the helicopter pilot started again with the intention of flying to the healthcare facility. After less than a minute after the helicopter took off, the fire brigade and the rescuers present at the take-off area heard echo-like sounds caused by the collision of the helicopter against a tree stand and its subsequent impact on the ground.

At 00:20, 08.09.2017, the helicopter of the Ministry of Interior of the Slovak Republic was at the site of the accident.

Both the helicopter crew and the transported patient suffered fatal injuries in the accident.
The helicopter was destroyed.

A commission was set up to investigate the causes of the accident:

Ing. Zdenko BIELIK	Chairman of the Safety Commission
Ing. Juraj GYENES	Member of the Safety Commission
Lic. Jaroslava MIČEKOVÁ	Member of the Safety Commission

Report to be issued by:

Aviation and Maritime Investigation Authority
of the Ministry of Transport and Construction of the Slovak Republic

C. MAIN PART OF THE REPORT

1. FACTUAL INFORMATION
2. ANALYSiS
3. CONCLUSIONS
4. SAFETY RECOMMENDATIONS

1. FACTUAL INFORMATION

1.1 History of the flight

On 07.09.2016, the pilot performed a helicopter rescue flight according to the ATE Operations Manual, following a call from KOS BB from LZTT Airport because the HEMS crew in Banská Bystrica was not trained to land at night.

The crew of the HEMS helicopter during the night operations consisted of:
helicopter commander, member of the technical crew/rescuer and physician.

Prior to the helicopter's take-off, it was preceded by an agreement between the HEMS dispatcher, KOS BB, the on-site fire brigade, and the pilot who agreed to illuminate the area for landing.

In the next communication, the pilot specified the landing capability with the fire brigade commander, the dimensions and the illumination of the area at the intervention site.

According to the first information provided, an area measuring 100 x 100 meters should have been available at the site of the estimated landing. The pilot decided to perform a flight on this basis.

At 19:24, the pilot performed the take-off himself and continued on to the announced intervention site near the “Ľubietovska bukovina” landmark and at 19:38 he established a connection with “Bratislava INFO” as “Krištof 03”.

At 20:10, the pilot landed in difficult mountain terrain in the dark, moonless night at an agreed area at an altitude of 1,065 meters above sea level, N 48° 41' 39,22'” E 19° 25' 34,07'” and shut down the engines.

At 20:16:35, the attending physician announced to the KOS BB by mobile phone that the estimated landing at the healthcare facility would be in 15 minutes.

After treating the injured party and the administering of medication by the attending physician, at 20:17 the patient was in a vacuum mattress and clamped to the stretcher, loaded onto the helicopter.

At 20:30, the helicopter pilot started again with the intention of flying to the healthcare facility.

After a relatively short time from the helicopter’s take-off, loud sounds were heard due to:
- the helicopter’s impact on the earth, creating a loud sound,
- the explosion of an oxygen tank heated by a fire onboard the helicopter.

In the accident the helicopter crew members and the patient suffered fatal injuries.

The helicopter was destroyed in the air accident.

Time period: Night
Flight rules: VFR

1.2 Injuries to persons

Injury	Crew	Passenger	Other persons
Fatal	3	-	1
Serious	-	-	-
Minor	-	-	-
None	-	-	-

1.3 Damage to the helicopter

The helicopter was destroyed in the air crash due to impact and subsequent fire.

1.4 Other damage

No circumstances have been reported to the Aviation and Maritime Investigation Authority, possibly with other claims for damages against a third party.

1.5 Personnel information

Pilot:

a citizen of the Slovak Republic, 50 years of age,
holder of commercial pilot licence helicopter, issued on 12.08.1991 by the Transport Authority of the Slovak Republic.

First class medical certificate

- single-pilot commercial operations carrying passengers marked valid until 22.01.2017
- other commercial operations marked valid until 22.07.2017

Second class medical certificate	marked valid until 22.07.2017
LAPL class medical certificate	marked valid until 22.01.2018

Qualifications:

AgustaWestland A 109K2	marked valid until 31.05.2017
AgustaWestland AW109E	marked valid until 30.04.2017
Ecureuil AS 355 N	marked valid until 30.04.2017
BELL 429	marked valid until 28.02.2017
FI(H)	marked valid until 30.04.2019

Flight Experience:

total of flight hours	4,649 hours,	03 minutes,	15,066 flights
total flight hours at night	476 hours,	48 minutes,	1,564 flights
from the total in 2016	169 hours,	23 minutes,	682 flights
total on the Bell 429	17 hours,	48 minutes,	102 flights
total on the Bell 429 at night	1 hour,	53 minutes,	12 flights

HEMS crew members:

doctor - a citizen of the Slovak Republic, 46 years of age,
member of the technical crew/paramedic - citizen of the Slovak Republic, 32 years of age.

1.6 Information about the helicopter

Type:	Bell 429		
Registration Mark:	OM-ATR		
Serial number:	57143		
Year of Manufacture:	2013		
Manufacturer:	Bell Helicopter Textron Canada Limited, Canada		
Total Flight Hours:	393 hours, 27 minutes, 1,997 flights		
Right engine:	PW207D1	S/N PCE-BL0296	Total hours: 360 Total flight hours: 320
Left engine:	PW207D1	S/N PCE-BL0295	Total hours: 360 Total flight hours: 320

Special Certificate of Airworthiness No. 1176/01, issued by the Transport Authority of the SR, issued on 26.05.2014.
The airworthiness review certificate was performed on 21.09.2015 and was valid until 24.09.2016.

Total of flight hours from the helicopter manufacturer: 393 hours, 27 minutes, 1,997 flights.

Mandatory Insurance: CATLIN Insurance Company Limited 20 Gracechurch Street GB-London EC3V 0BG valid from 17.02.2016 to 16.02.2017.

1.7 Meteorological information

On 07.09.2016, a pressure-height with the center over northern Romania interfered with our area. Relatively warm air was flowing towards us from the southeast on its front.

On 07.09.2016, from 18:00 to 20:00 in the cadastral area of Strelníky (Bukovina area) in the ridge position at about 1,000 a.s.l., it was initially cloudy, later even clear, without precipitation. The prevailing type of cloud was Stratocumulus with a lower limit at a height of 2,500 a.s.l. The air temperature slowly dropped from 14 °C to 12 °C, the relative humidity ranging from 70 to 80%. A light to mild southeast to east wind was blowing through.

On 07.09.2016 at 20:26, in the cadastral village of Strelníky (Bukovina area), in the ridge position at the height of about 1,000 a.s.l., it was clear or almost clear. The air temperature was about 12 °C, and there was a relative humidity of around 80%. Total cloud coverage was 0/8 to 1/8. A slight southeast to eastern wind was blowing at a speed of up to 5 m/s at a height of 10 m above the flat terrain without any obstacles. Horizontal visibility was 40 km. During darkness, horizontal visibility is determined on the basis of the visibility of light points.

On that day the sun went down at 17:11. Astronomical night started at 18:59. The moon arriving in the first quarter phase set at 20:09. It follows that at about 20:26 there was absolute darkness in the area.

Airflow in the free atmosphere above the cadastre of Strelníky village on 07.09.2016 around 20:00 was as follows: at a height of 2,000 a.s.l. (level of about 800 hPa) there was a southern flow at a speed of about 8 m/s. In the direction of the earth's surface the wind remained south to southeast, but its strength gradually weakened. At 1,500 a.s.l. the wind speed in the free atmosphere was about 6 m/s. At lower levels the air flow of the surrounding mountain obstacle gradually began to have influence. The wind direction gradually changed to southeastern and eastern, and to about 1,000 a.s.l. it reached a speed of 3 to 5 m/s. The air temperature at the reference level of 1,500 a.s.l. (850 hPa) was 14 °C.

For the meteorological data, measurements from the classical climatological, precipitation and automatic meteorological stations of the SHI observation network from Poľana, the Low Tatras and Pohronie were used. In addition, measurements of SHI distance systems, in particular satellite and radar measurements, as well as radio probe measurements from Gánovce near Poprad and Budapest were used.

1.8 Aids to navigation

Garmin GPS (GNS-430), GPS Garmin 530, GPS Sentinel Moving map, mag. compass KCA0116W, 2 ADAHRS altimeters, 2 speedometers (ADAHRS), 2 variometers (ADAHRS), 3 slip indicators (ADAHRS), 2 artificial horizons (ADHIR), 1 backup artificial horizon (H221FAM) , 2 course indicators (ADAHRS) Honeywell KRA-405B Radar Altimeter, Mode S transponder (Garmin GTX330).

1.9 Communications

The helicopter was equipped with 1 VHF COM1 (GNS530) and 1 VHF COM2GNS430 radio communication devices enabling two-way radio connections at any time with all flight stations and rescue service stations as well as an onboard mobile phone.

1.10 Aerodrome information

Not applicable.

1.11 Flight Recorders

Fire damaged the Samsung K9F1208U0C NAND flash memory from Penny & Gilles CVR/FDR equipment.

Autonomous GPS Tracker with SANAV GS181 S/N1301008000180.

Video recording and photos from a cameraman present on the scene.

1.12 **Wreckage and impact information**

First contact with forest stand
N 48° 41'53,40'" E 19° 25'19,10", 960 a.s.l. + 32 meters of height of forest stand.

Impact
N 48° 41'51.80'" E 19° 25'15.50'", 990 a.s.l.

The helicopter fell into the forested mountainous terrain – the difficult-to-access part of the gorge, the debris scattering from the point of first contact with the trees to the main part of the helicopter fuselage, where the crew's bodies were found. The distance between the first contact with the trees and the debris was 85 meters.

1.13 **Medical and pathological information**

A forensic examination was performed - from the forensic point of view it was a violent death - from traumatic causes - traumatic-hemorrhagic shock from wounds to several important organs and fractures of several bones of the skull, torso and extremities - multiple traumas.

Based on injuries in the area of upper and lower extremities found during the autopsy, it could be assumed that at the time of the helicopter's impact on the ground, it was very likely that both the upper and lower extremities of the pilot were in an active position on the helicopter control components.

The examination of biological materials taken at the autopsy did not reveal the presence of ethyl alcohol, commonly used pain-relieving drugs, drugs for sedating and creating drowsiness (analgesics, antianxiety drugs, barbiturates and benzodiazepines) or other psychoactive substances, or narcotics and drugs which could have affected the thinking and conduct at the time of the accident, possibly contributing to his death.

All the injury changes described were causally related to the air accident.

Even with the external and internal examinations as well as additional laboratory expertise tests of the biological materials collected at the autopsy, there were no acute or chronic disease indications which could have adversely affected the attention and action appointed at the time of accident, or that could have been in a causal link with his death.

1.14 Fire

A fire occurred after the helicopter's impact, which was extinguished after the arrival of the Fire and Rescue Corps members. The fire burned all flammable components.

1.15 Survival aspects

Due to the nature of the injury and the subsequent fire, the crew could not be rescued even in the case of immediate assistance.

1.16 Tests and research

Expert examinations were performed:

<u>CVR/FDR Flight Recorder</u>

The device was sent to the partner investigation office in Great Britain (Air Accidents Investigation Branch, Farnborough House, Berkshire Copse Road, Aldershot) to examine the possibility of recovering data in the chips in the fire-damaged Samsung K9F1208U0C NAND flash memory.

<u>SANAV GPS tracker</u>

The device was sent to the partner investigation office in Taiwan (Associate Engineer AVIATION SAFETY COUNCIL, Beixin Road, Xindian District, New Taipei City 231, Taiwan) – downloading of data from the internal memory.

The SANAV device (if a GSM network is not available) writes the data during the flight to the internal memory at 10 second intervals with the preset parameters.

<u>PW207D1 engines and their accessories</u>

The engines were shipped to Pratt & Whitney Canada (7007, Chemin de la Savane, St Hubert, Quebec, Canada) in Montreal, in sealed wooden boxes.

Between 21.02. and 24.02.2017, a sequential splitting of the engines, drive racks, and fuel pumps was performed to determine the possibility of their possible failure before the air crash.

<u>Data Collective Unit/DCU</u>

They were removed from the engines to find out how to download and analyze the data.

<u>Shafts and flexible couplings</u>

They were handed over to the Criminology and Expertise Institute of the Police Force of the Slovak Republic (PZ SR) for the purpose of the expert assessment of damage to the flexible drive shaft couplings.

1.17 Organizational and management information

ATE operates HEMS in seven operational centers in Slovakia. It has long years of experience with air rescue. The crew of the POPRAD-KRIŠTOF 03 operation center performs most interventions under the challenging conditions of the High, West and Belianske Tatras and the Slovak Paradise.

Flight operations were performed in accordance with aviation regulations valid in the territory of the Slovak Republic and local regulations.

The flight was performed in accordance with the operating procedures and intervention methodology for rescue flights (HEMS flight - VFR at night) approved by the Transport Authority of the Slovak Republic.

The Transport Authority of the Slovak Republic issued an exemption from night visibility rules to the flight operator ATE for operating helicopter flights for medical purposes, under the following conditions of SERA.5005:

- over high terrain or in mountainous areas at a height of at least 300 m (1,000 ft) above the highest obstacle located within 4 km of the intended position of the aircraft,
- anywhere else than above, at a height that is at least 200 m (650 ft) above the highest obstacle within 4 km of the intended position of the aircraft.

HEMS operating area – area selected by the commander for the aircraft to pick up the patient from the area. Primarily selected during the HEMS flight, but in most cases it is not possible to plan ahead.

The dimensions of the area for interventions at night should not be less than:
2 x D (D = 13.11 for the Bell 429) width and 4 x D (D = 13.11 for the Bel l429) length.

1.18 Additional information

Slovak Government Flight Service of the Ministry of Interior of the Slovak Republic, with the participation of the members of the Safety Commission, performed a flight on the same type of helicopter, registration mark OM-BYD, in the airspace for the simulation of a flight prior to an air crash and reconnaissance of terrain, to obtain information on possible flight directions during the flight in question, as well as analyze the possible experiences of the helicopter crew.

1.19 Useful or effective investigation techniques

Common investigation methods were used.

2. ANALYSIS

Pilot Activity

The crew suffered an extremely high psychological stress in the landing maneuver in an unknown mountainous terrain under the given weather conditions The pilot decided to perform an intervention based on the information that the HEMS operating area was 100 x 100 meters in size, with the actual dimensions of the area being inside the permitted dimensions. Still, the pilot made a landing on the untouched terrain without problems.

After loading the patient, the pilot took the helicopter up from the intervention site at a height of 1,065 a.s.l. with vertical alignment to the height above the tree tops. The take-off was oriented to the east (in the helicopter landing's direction). Above the trees the helicopter began to fly at a prescribed flight speed to climb to 55-60 kt.

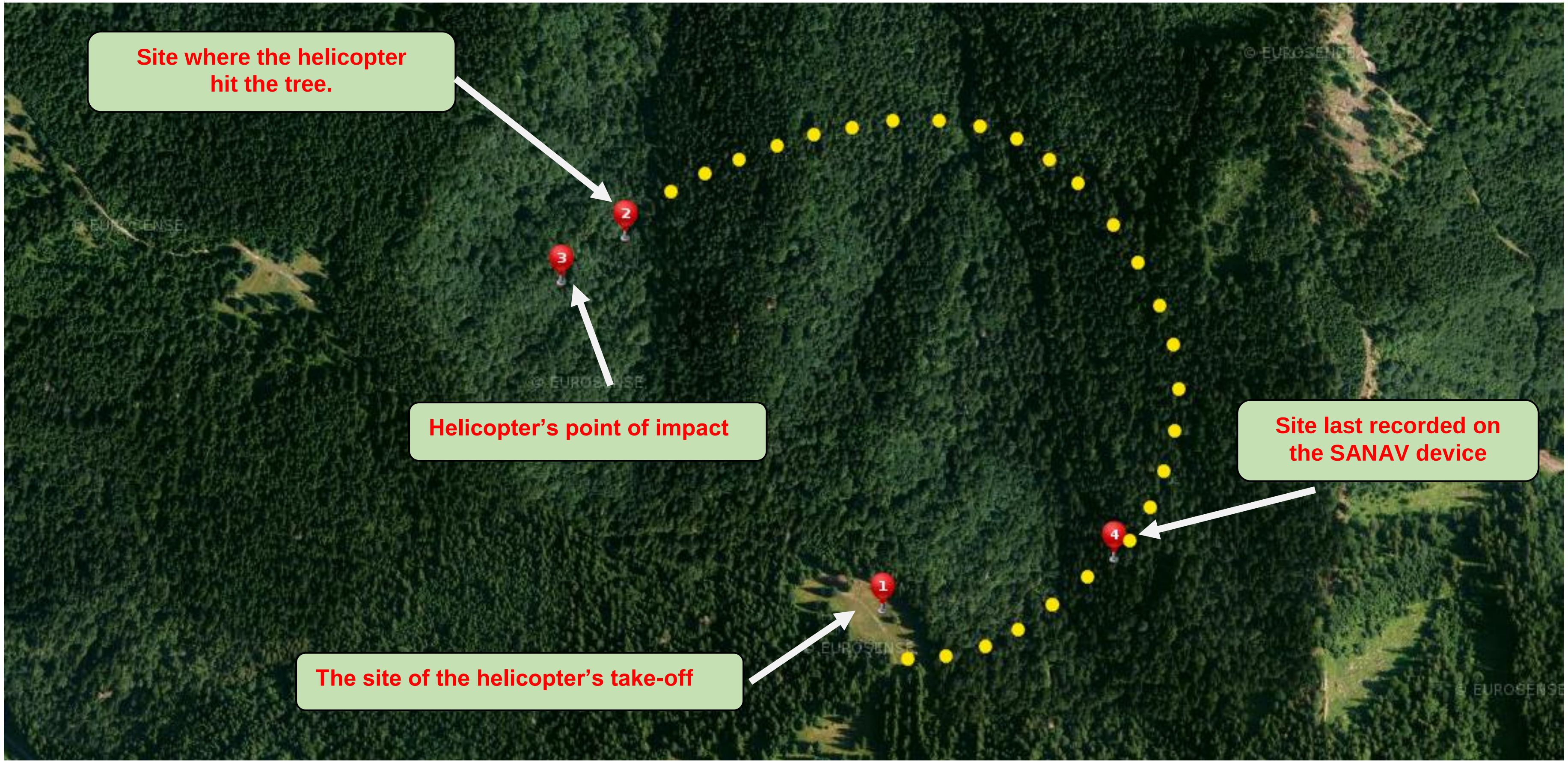
During the helicopter's climb, a technical crew member/rescuer was monitoring obstacles and at this stage should report to the pilot a continuous flight speed and altitude up to V = 100 kt or H 500 ft AGL. The pilot safely performs the torque on the route above the obstacles after reaching a safe height of min. 500 ft AGL.

Before take-off the pilot should set a height of H min = 500 ft or higher on the altimeter to warn of possible approaches to a terrain obstacle below it. After the take-off, he should rise to a safe height and perform an "instrument check" during horizontal flight.

40 seconds after the take-off, the helicopter reached a speed of 76.6 kt according to the data recorded in the SANAV and the undefined height of the flight above the tops of the trees.

From this time the pilot probably did not continue to climb to a safety altitude of 300 meters above the mountainous terrain at night.

On the basis of witness testimonies, it can be assumed that the last phase of the flight continued on a dark moonless night hidden from the view of present witnesses/firefighters and rescuers/behind a high forest stand by a left-hand torque westward toward the town of Banská Bystrica.



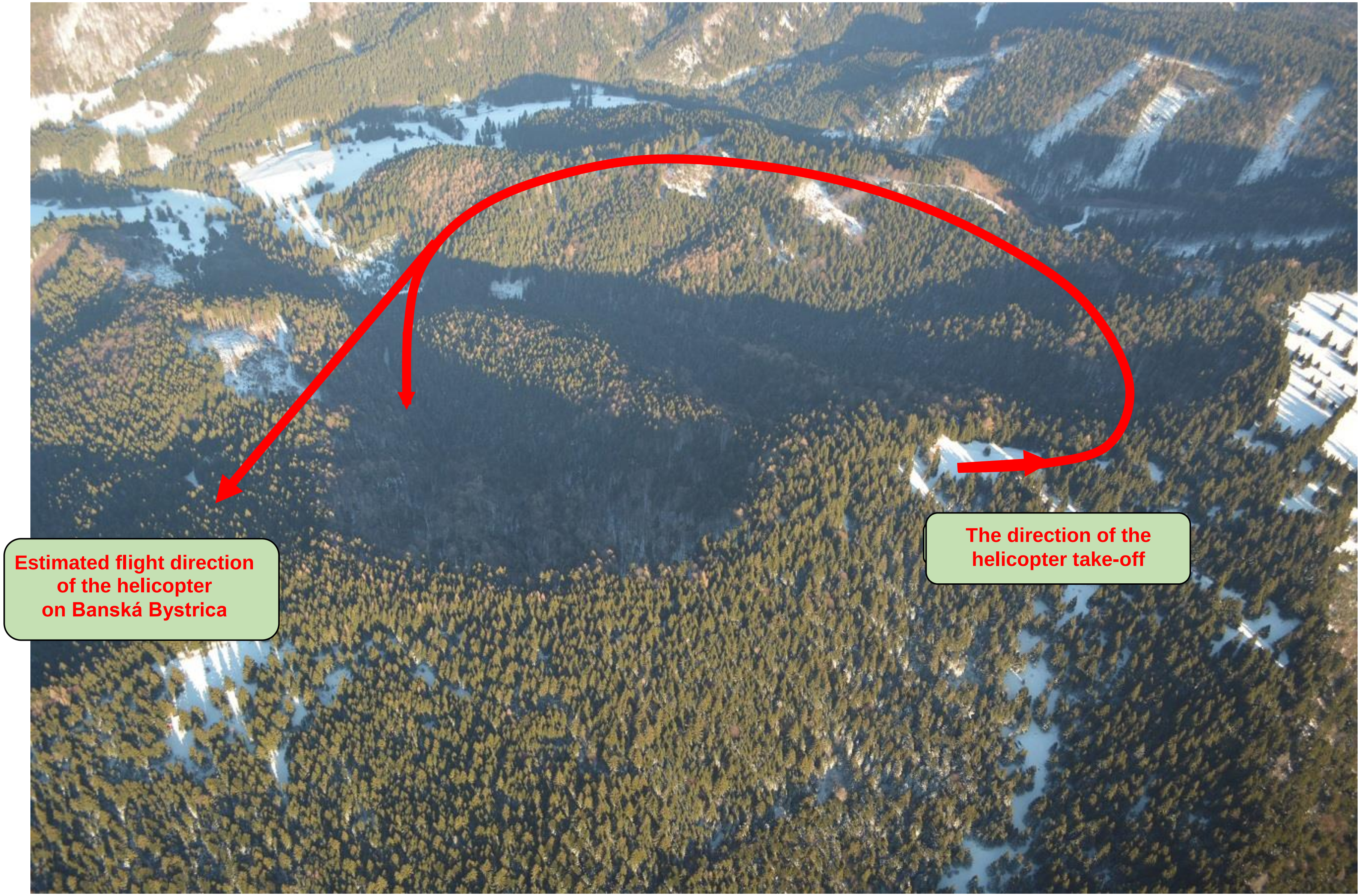
The average steady torque in the horizon at 360° at the estimated 80 kt flight speed was set at 640 meters after the map's recalculation. On the basis of the average, the total circumference of the fictitious torque was set at 1,396 m.

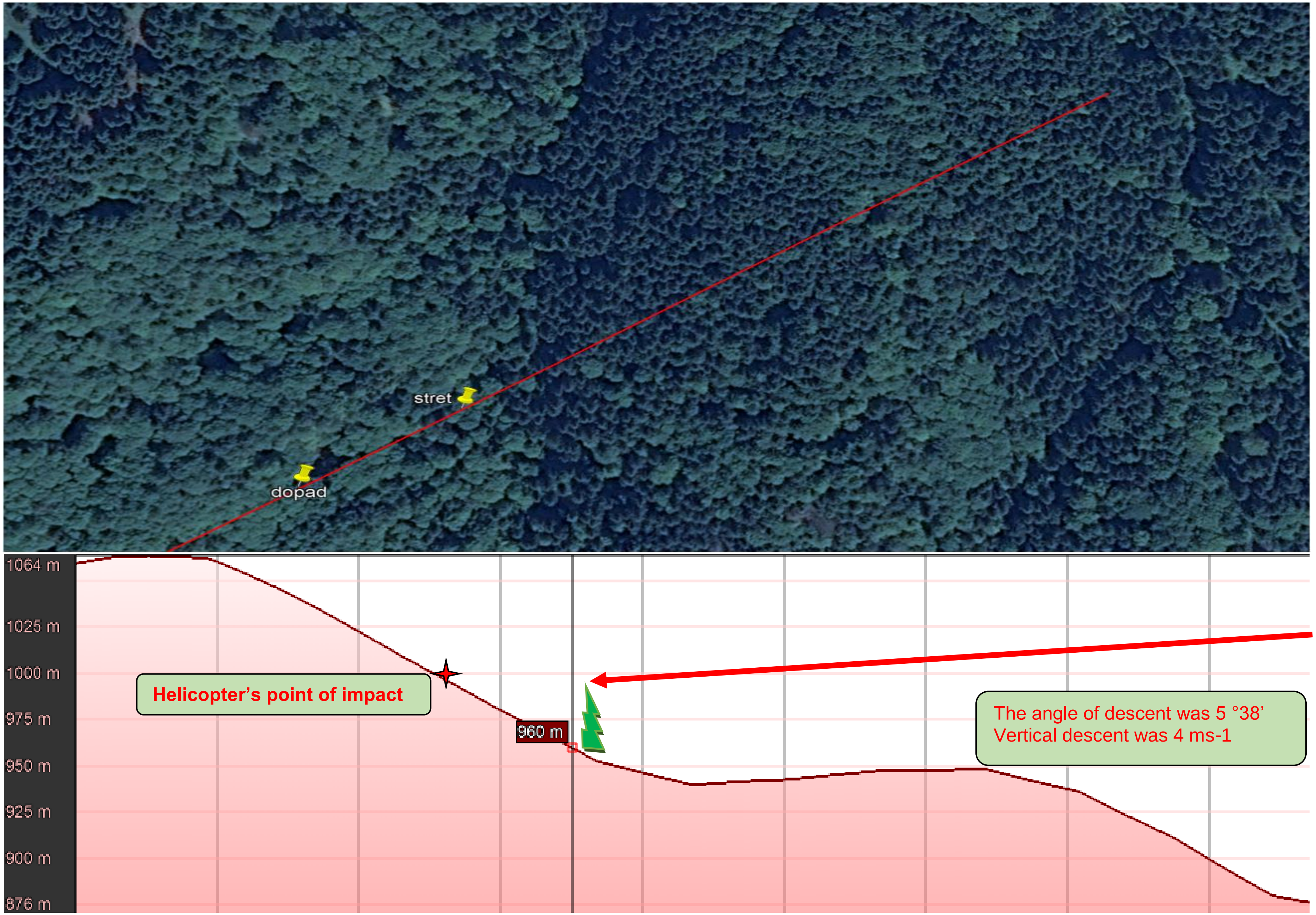
The Commission recalculated the flight time from the point of suspension to the point of the last record on the SANAV device, while using the estimated 50 kt/25 ms^{-1} flight velocity and a 257 m trajectory for the calculation, set for 10 seconds, which is the same as the SANAV device.

The flight time from the last SANAV recording point to the tree-lined trajectory was calculated as ¾ of the estimated flight trajectory of 360° (1,139 m) minus the 244 m flown path at the estimated 80 kt flight speed set for 27 seconds. The total time from the end of the suspension was 37 seconds.

The Commission recalculated the helicopter's tilting angle for a steady horizontal torque at an estimated flight speed of 80 kt at a known radius of 320 m and set at 28° (the tilting angle during flight could be varied by varying flight speed and height).

Based on the estimated tilting angle of 28° and at a distance of 964 m, a speed of 80 kt, and the height difference the helicopter dropped during the torque (95 m), the helicopter's descending angle from the last SANAV recording point to the point of impact with the forest stand was 5°38'. At this descending angle and estimated speed, the vertical descending rate of the helicopter was determined to be 4 ms^{-1}.





stret
dopad
1064 m
1025 m
1000 m
975 m
950 m
925 m
900 m
876 m
Helicopter's point of impact
960 m
The angle of descent was 5 °38'
Vertical descent was 4 ms-1

At this time, the helicopter did not demonstrate any system or engine failure during the flight, and the crew did not report any problems to the FIC.

The probable left turn after take-off and the introduction of the course of the left-hand torque on the route became an available factor for disrupting the crew's routine activity and projected into their next activity. The result was probably a failure in piloting, which led to an inexplicable flight regime change.

The established procedures do not deprive the pilot of responsibility for knowing the actual position and condition of the helicopter at each phase of the flight. When deviating/changing from the agreed procedure, crew members must inform each other.

Transitioning from "with NVG" to "without NVG" must be mutually agreed upon. It is important for the crew that all its members understand the meaning of two-way communication or information when using the NVG. During the flight the pilot must observe the helicopter space outside the NVG at regular intervals.

The monitoring is also performed by a member of the technical crew according to the pilot's instructions.

The probable switching-on of a floodlight on taking-off and climbing, fixed on the obstacles present in the departure sector, caused a short or complete loss of the natural horizon and could have created a short-term illusion in flight.

The pilot's physiological limits during the flight's performance summer in the dark could have had an impact on nighttime operation.

The crew did not pay attention to the radio altimeter during the fall, which had to alert them to the approaching terrain beneath.

The short flight experience of the pilot on a Bell 429 helicopter during night flights (1 hr 53 min) and the associated change of routine/habits gained from years of experience on the Agusta helicopter could have led, during the pilot's fatigue after heavy psychological stress, to his piloting mistakes.

At 20:30, the carrier rotor hit a high spruce trunk in a left tilt.
The trees at a site with a diameter of about 20 cm were torn at an angle of 60°, with the destruction of all four of its boughs, resulting in the impact of the helicopter on the ground in the forested mountainous terrain.

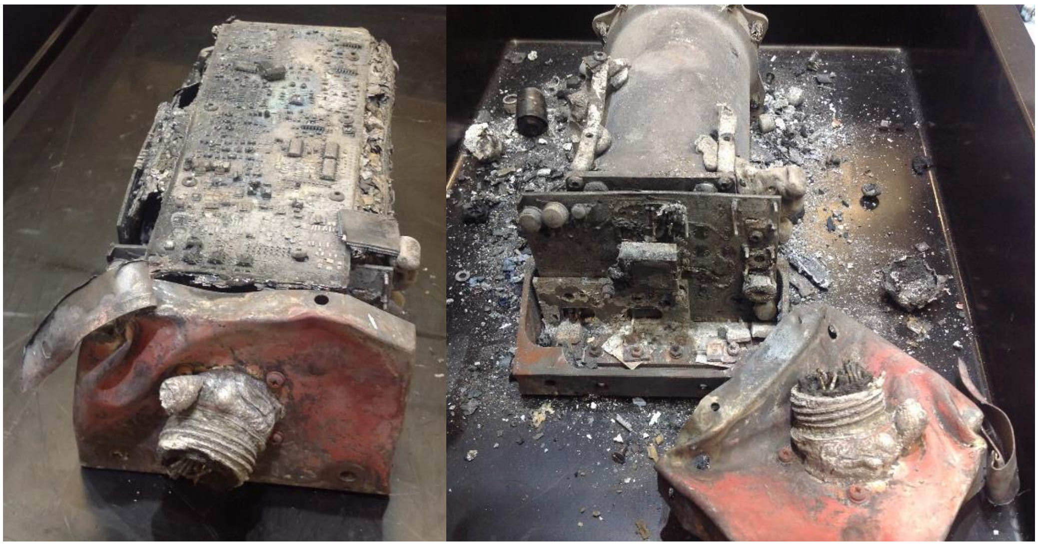
A fire arose following the collision with the terrain, resulting in the helicopter cabin, including the crew (except the pilot who was thrown out of the cabin in the crash), being practically completely burned.

The distance between the point of first contact with the trees from the last record on the SANAV device is 964 m during the estimated flight speed of 80 kt, and after performing a left-hand torque it probably took 37 seconds for the helicopter to hit the tree stand.

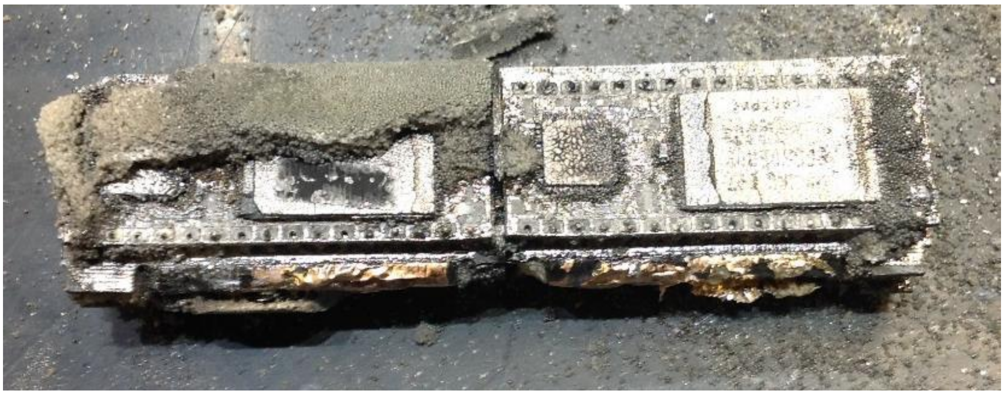
The Commission was unable to prove the reason for the helicopter to fall in the mountainous terrain. If the pilot, for unknown reasons, had not fallen with the helicopter and had remained at the height he had reached after the take-off from the intervention area and would have not risen again, there would have been no crash into the terrain at the given flight course and the mountainous terrain, flying in the direction toward the medical facility.

CVR/FDR

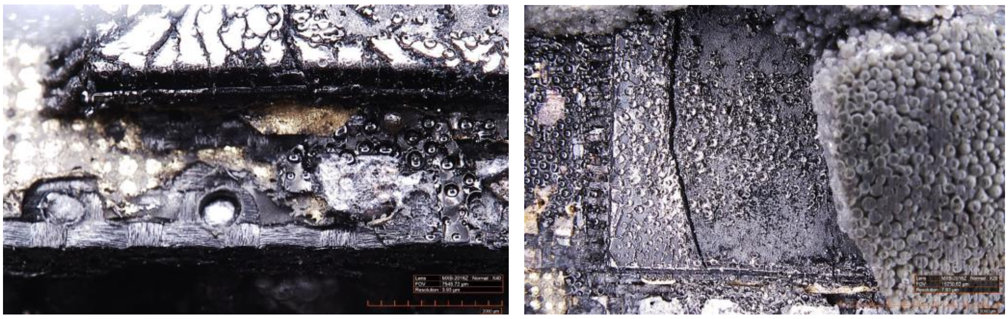
AAIB UK examined the device on behalf of LNVU, which had no identification mark and had clearly suffered mechanical and thermal damage during the fire.



The outer layers were stripped from the device, and four broken memory chips were selected (CVR 1, CVR 2, FDR 1 and FDR 2)



Damaged memory chips CVR 1 and CVR 2



Damaged memory chips FDR 1 and FDR 2

The memory chips were packaged in TSOP-48 plastic packaging coupled to the printed circuit board of the memory module, which showed considerable damage to the packaging of the chips, which began to crumble and crack. Long term exposure to radiant heat would cause disruption to the interfaces of the gold and aluminium wires (Kirkendall Effect). It weakened the wire joints and so it was not possible to re-connect them using conventional ultrasonic methods.

High temperatures caused the solidification of the plastic mixture (due to increased cross-linking), which made removal by conventional means even more difficult. Regardless of whether the data is intact or not, there was no real way of retrieving them.

Due to visible damage to the FDR chip and the fact that the glass filler around the memory modules softened and distorted, it is suspected that the FDR modules were exposed to temperatures of at least 660 °C or even higher. In addition to damage to the physical structure of the device, these temperatures accelerated data loss.

As a result, all the data are unrecoverable.

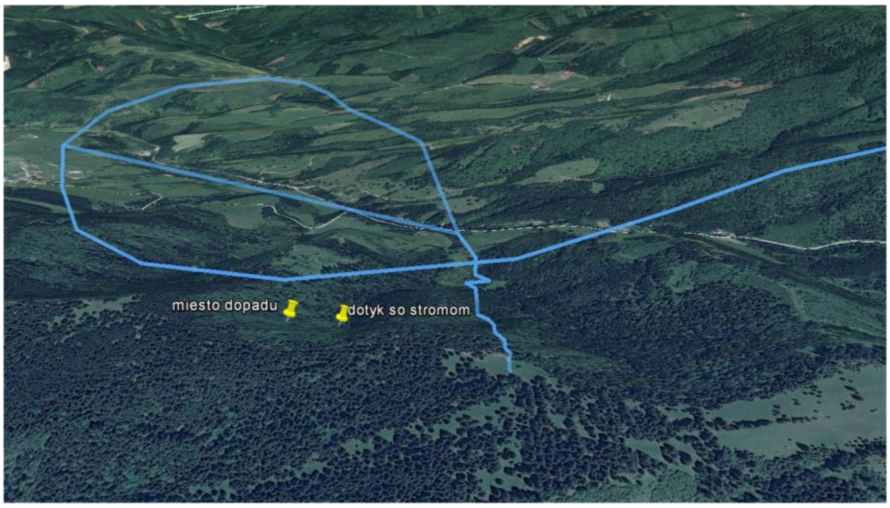
<u>SANAV GPS tracker</u>

The SANAV device, when reaching the GSM network, sends data about the helicopter's position to the ATE company's dispatching.

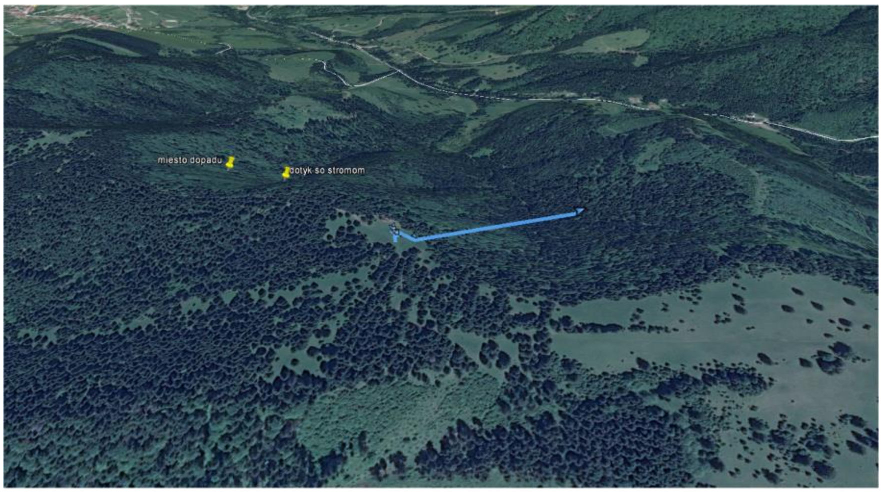
If the helicopter is out of reach of the GSM network (not GSM coverage or helicopter at ground level in a mountainous terrain), the data transfer during flight is suspended and the device sends the data from the internal memory to dispatching after the GSM signal is restored.

There were a total of 48 positions in the log after downloading, of which 29 positions were up to the landing time (no final landing time, ending over the terrain) and 19 positions recorded after take-off.

The downloaded data was rendered to a Google Earth underlying map.



Landing - the complete record
(a file from the operator was added to the missing 29 positions from the device log)



Take-off (a set of 19 positions from the device log after startup)

The further course of the flight was not documented by the Safety Commission on the basis of available data.

Engines

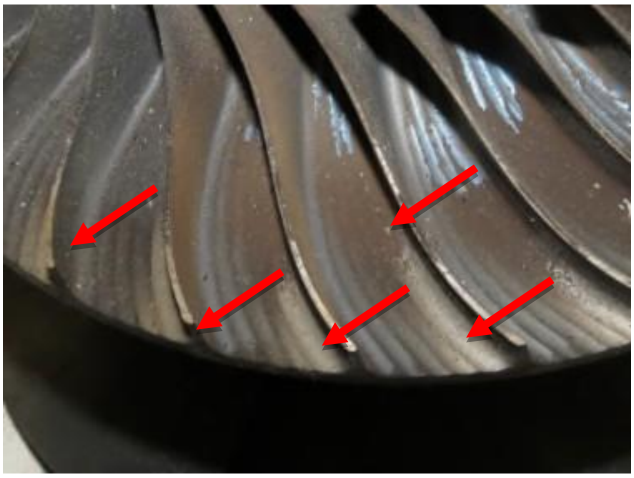
Both engines exhibited friction marks on the peripheral ring of the power turbines (PT), whose contact with the peripheral ring of the PT, the compressor turbine blade tips (CT) had friction traces after contact with the peripheral ring, and the rotor mast had friction marks at its tips as a result of contact with the peripheral ring of the mast. These findings suggest that the engines were performing at the time of impact. The level of performance could not be determined with certainty.

The left S/N BL0295 engine had a broken output shaft, bearing flange No. 8, a turbine speed sensor arm and a grid on the intake. An analysis in the material laboratory revealed that these components were damaged due to tensile overloading as secondary damage due to impact and fire.

Output shaft and bearing No. 8

The left engine S/N BL0295 had two bent blades on the rotor mast. One blade was bent back (counterclockwise) along the entire drainage edge. Another blade was slightly bent. Scanning electron microscopy analyzes showed that the oppositely bent blade exhibited a considerable number of notches and scratches of various sizes, indicating that the front edge of the blade was hit by hard particles of varying sizes. Energy dispersive X-ray spectroscopy (EDS) analyzes were performed on the silicone rubber replica and on the bent blade and adjacent blades. All EDS spectra (non-standard and semi-quantitative), regardless of area, showed significant oxygen content, as well as chemical elements corresponding to minerals/salts from the environment (surface soils and soot) and the base metal of the mast. A metallographic analysis revealed that both blades meet material specifications.

Rotor mast,
bent blades (arrows)



Blades of the rotor mast
with friction marks (arrows)

Ring of the rotor mast against
the direction of the current,
clay deposits (arrows)

Ring of the rotor mast in the direction
of the current, with friction marks (arrows)

The dimensional control of the rotor mast for both engines confirmed that all the blades meet requirements according to the drawings, with the exception of two full blades deformed by the impact of the BL0295 engine.

The mechanical components of both engines showed no signs of defects or overloading before the crash.
The left BL0295 engine exhibited severe deformations of the shell at the 9 o'clock position (in a clockwise direction from the pilot's seat), and the output shaft broke due to shear overload. The damage observed at the rear of the bent blade of the rotor mast revealed scratches and deformations due to contact with a number of small hard particles. It is clear that in the collision a lump of clay and stones caused the puncturing of the grid on the intake. The lump was sucked in, striking and deforming one blade of the rotor mast. The lump was then transformed into dust detritus that was found in various places on the engine. These findings are indicative of the large amount of clay sucked in by the engine during the crash.
Summary:
both engines demonstrated performance at the time of the crash. The level of performance could not be determined with certainty.
There were no signs of any mechanical anomalies or defects before the crash, which would have hindered normal engine operation.

Assessment by the Regulators and Accessories for Both Engines

The investigation of the accessories included the dismantling of the fuel modules (FMM) from both engines, the testing of nozzles from both engines, checking of the data collection unit (DCU) from engine No. 1, checking of the three-function switches, AC generators, N1 and N2 sensors from both engines, checking of the torque moment sensor from Engine No. 1.

All components were found damaged in the fire.

DCU Engine No. 1 was damaged by fire on the cover, case and printed circuit boards.

Fuel Nozzle No. 6 (input) from both engines was not delivered.

The internal seals of both FMM modules were damaged by fire and a blue color was observed on the steel components. The cam lever to control the performance of the FMM No. 1 was at maximum flow at the stop. The cam lever to control the performance of the FMM No. 2 was close to maximum flow at the stop. The casting of cam FMM No. 2 was deformed due to the action of the bulb and this caused the cam not to touch the stops.

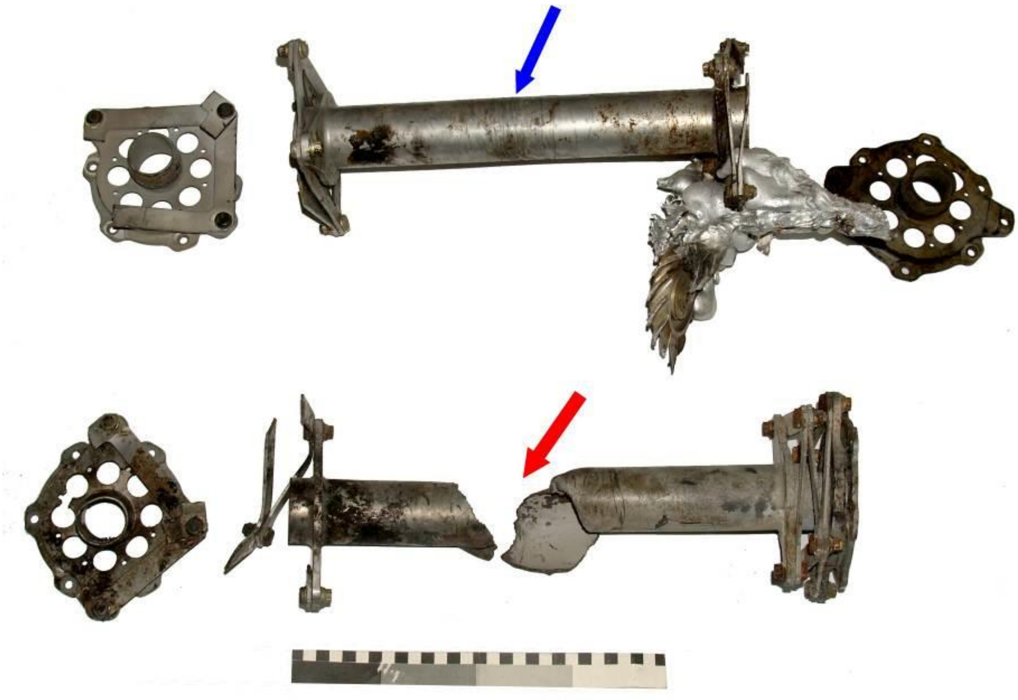
The two pistons of the FMM were ejected. Thus, the metering valves turned to a position with the closed metering apertures. The additional spring of FMM No. 1's metering valve did not touch the metering valve's lever. The additional spring of FMM No. 2's metering valve touched the lever of the metering valve, but there was a gap between the metering valve's lever and the piston. This means that the springs of the piston expanded due to heat and after cooling contracted slightly.

The tip of the N2 engine speed sensor No. 1 was missing with a part of the casting mass (the tip was found in the N2 ring).

Due to damage to the accessories after the accident, it was not possible to determine whether the accessory was one of the causes of the accident.

The Conclusions of the CED

The drive shafts were examined to discover the facts of the damage to the flexible coupling shafts of the helicopter.



The left drive shaft was broken in two. The shaft fracture has an angle close to 45° with respect to the longitudinal axis of the shaft. It is clear from this fact that, at the time of damage, the shaft was subjected to a significant torque, i.e. the left helicopter engine was operational at the time of the helicopter crash or active. The flexible coupling in front of the shaft was not significantly damaged. The flexible coupling for shaft was broken in two. Due to the nature of the shaft damage and the presence of significant torque on the shaft, it was not necessary in this case to perform a detailed examination of the fractures on the individual damaged couplings, since at the time of the fracturing on the shaft, both flexible couplings had to be (also in front and behind the shaft) clearly able to transfer the torque damaged the shaft, i.e. they had to be functional.

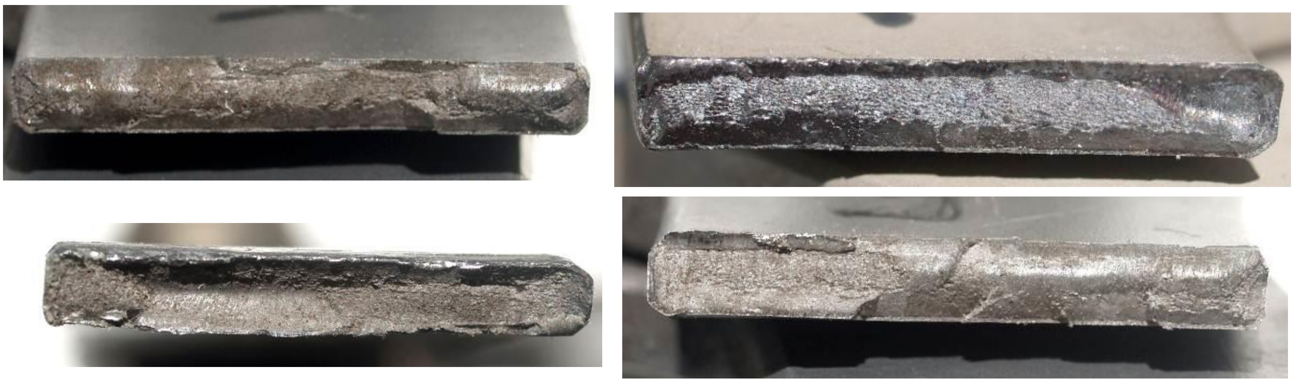
Half detail of the fraction on the left-hand drive haft

The right drive shaft was not broken. Both of its flexible couplings were split. In the central part of the shaft there were clear traces, surface scratches after contact with the rotating shaft with the edges of the respective circular hole in the metal partition between the engine and the main rotor driving gear.

Circumferential scratching showing shaft rotation at the time of the emergency

On the flexible coupling behind the shaft, 5 fractures were examined on flexible blade rectangles. From fractures 1 to 3, both fracture areas of fractures 4 and 5 were examined only after one fracture area.

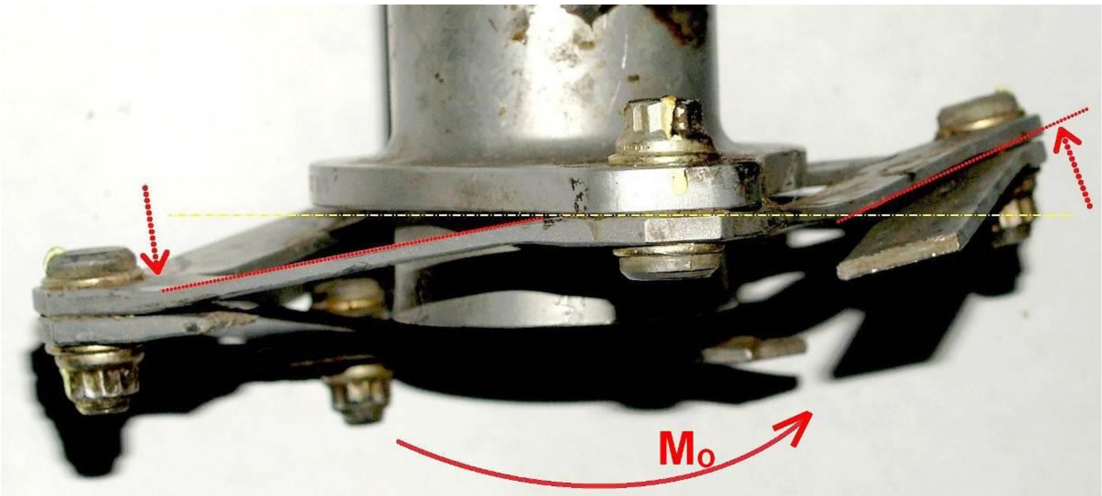
All the fracture areas present on the submitted parts of the couplings were microscopically examined, and the basic characteristics of the fatigue mechanism of the material damage (the initiation site, the clear area of the processing and relaxation belts and the visible area of the final material degradation) were not found on them.



The fractures on the blades of the output flexible coupling of the right-hand drive shaft – no trace of the fatigue mechanism of material damage

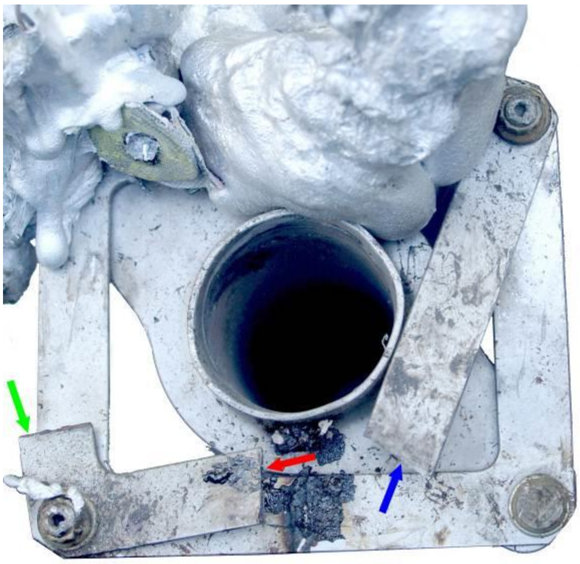
From the investigated fractures, only a fracture marked with a number 4 *on the output flexible coupling of the right-hand drive shaft*, whose surface fracture was secondarily degraded, was not examined.

The first blade rectangle of the output flexible coupling of the right-hand drive shaft directly attached to the shaft flange was clearly deformed by the flexural load M_o. It is clear that at the time of this deformation the remaining part of the coupling had to be compact and functional to be able to transfer this bending load. Thus, it can be clearly stated that damage to this flexible coupling occurred only when the helicopter crashed.



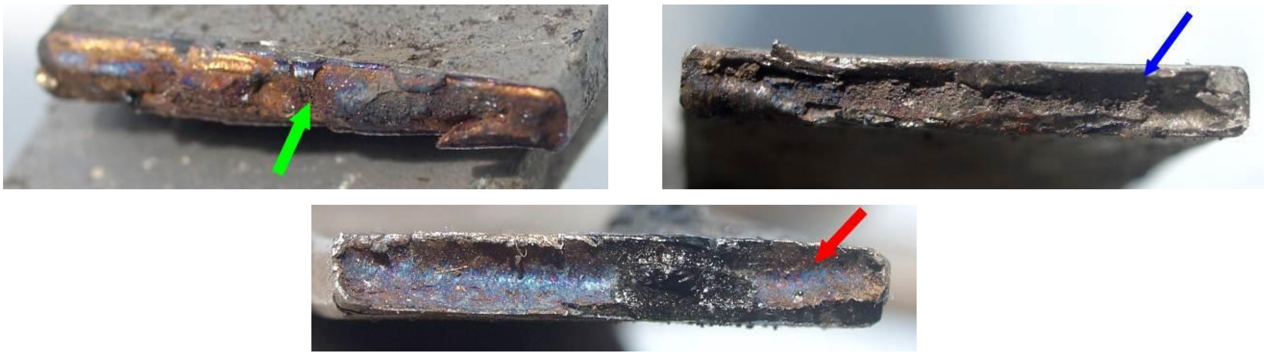
Bending deformation of the first blade square of the output flexible coupling of the right-hand drive shaft

At the input flexible coupling of the right-hand drive shaft, the intermediate blade rectangle was broken (see fractures marked with arrows). The resulting fracture areas were significantly secondarily damaged by the effects of high temperature.



Part of the input flexible coupling of the right-hand drive shaft

However, the macroscopic fracture morphology remains legible, and it can be concluded that the basic features of fatigue damage to the material were not found on the fracture surfaces – the arrow color corresponds to the arrow colors.

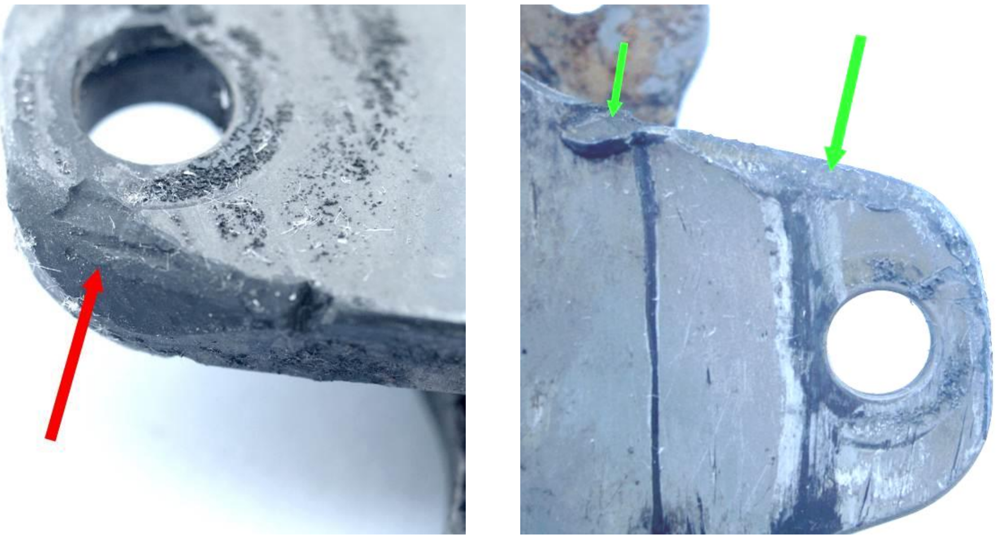


Detail of the fractures on input flexible coupling of the right-hand drive shaft

The remaining parts of this blade coupling, the first blade rectangle and the fractured parts of the central blade rectangle, were not found between the marks submitted for examination, i.e., it was not possible to examine all the fractures that arose on this flexible coupling. There were no rotation surface scratches found on the submitted planes of the coupling part, nor on the coupling joint screws, which would have occurred if the coupling had broken down during the helicopter flight. In this case, the input part of the coupling would need to rotate at (higher) speeds than the output part of the coupling, and the separate part of the coupling would have to repeatedly collide against the planes, or with sharp edges at the edge of their fractures, with visible rotating scratches occurring on the surface of the contact planes. The absence of such scratches demonstrates in essence that damage to the coupling occurred at a time when the engine was stopped or when the engine was stationary.

At the edges of the input flange of this flexible coupling, marks (significant compression of the material) after the impact of the elastic coupling were found in the fixed obstacle. The above-mentioned obstacle could have been some part of the helicopter engine space and the flange coming into contact with it until the helicopter was destroyed. From the range of these burns and from the very high strength of the flange material, it can be assumed that a large torque was applied at the time of the occurrence of these impacts; thus, at the time of the helicopter crash its right engine was operating or active.

Input flange of the input flexible coupling of the right-hand drive shaft – the arrows indicate the edges damaged by the impact of the flange into the fixed obstacle



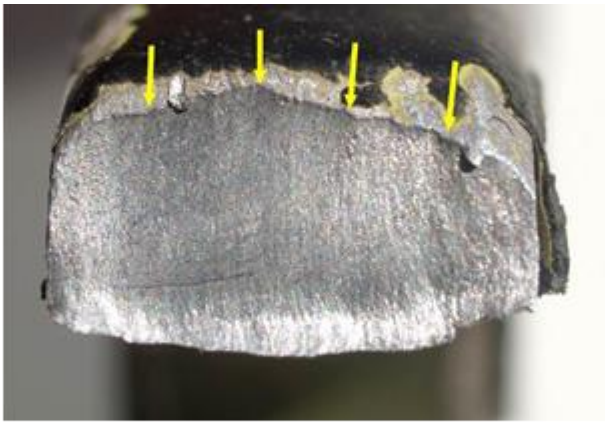
Significant deformation of the material at the edges of the input flange of the input flexible coupling of the right-hand drive caused by the impact of the rotating flange into the fixed obstacle

By examining the submitted drive shafts and the submitted flexible couplings at their inputs and outlets, it was found that before the helicopter's crash both engines were active, and all four flexible couplings were also operating in front and behind the drive shafts.

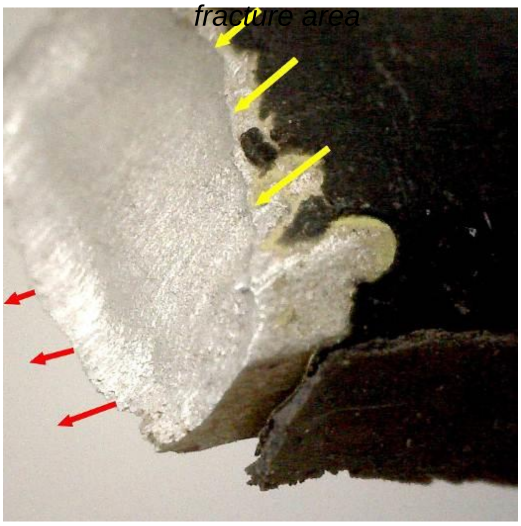
Furthermore, a damaged rod of the rear rotor blade mechanism was submitted for examination. One of the rod's bearing lugs was broken.

Damaged rod of the rear rotor blade mechanism

By examining the fracture surfaces on the lug of the rod, it was found that this fracture originated, or it proceeded from the outer side of the eye to the bearing, with obvious traces of a foreign object entering the mesh material (also some of the damaged helicopter with a quasi-sharp edge). The penetration of the foreign object into the lug material demonstrated the compression of the lug wall near the fracture, as well as the outer edge of the fracture area facing the bottom into the fracture area (see the edge indicated by the yellow arrows). In the bottom part of the fracture area (on the bearing side), the lug material was clearly stretched in a tangential direction (see the stretching of the material in the direction of the red arrows), which fully corresponded with the stretching thrust of the entire lug when it was damaged.



Traces of the foreign object's penetration of the bottom into the lug at the peripheral edge of the fracture area



Traces of the foreign object's penetration of the lug wall and traces along the accompanying stretching deformation of the material in the bottom part of the fracture

Final thrust of the lug by the stretching strain

Damage to the stretched lug occurred when a foreign object entered the lug in a radial direction from the outside in conjunction with the extreme tensile pulling load. Both of these lug loads as well as their damage occurred during the helicopter crash.

- In examining the submitted drive shafts and the adjacent flexible couplings at their inputs and outputs, it was found that before the helicopter's crash all four flexible couplings were functional and that all three damaged couplings were damaged during their extreme strain when the helicopter crashed.
- Damage to the stretched lug occurred when a foreign object entered the lug in a radial direction from the outside in conjunction with the extreme tensile pulling load. Both of these lug loads as well as their damage occurred during the helicopter crash.
- The nature of damage to the left-hand drive shaft and damage to the fixing flange at the input of the flexible joint of the right-hand drive shaft implies that both helicopter engines were operational at the time of their crash or active.

3. CONCLUSIONS/Cause of the air accident

3.1 Findings

Crew

- the pilot and crew members had valid qualifications to perform the flight in question according to the presented documentation for the performance of rescue flights,
- the pilot, on the basis of medical records, did not suffer any health changes that might have been causal to the aviation event in question.

Helicopter

- the aircraft had valid documentation and did not demonstrate any malfunction before take-off and during the flight,
- prior to the critical flight, it had fulfilled the conditions of airworthiness,
- the CVR/FDR device was exposed to large fire and radiant heat, which seriously damaged the memory chips,
- The SANAV device did not record the whole record after take-off - it does not include the entire route from take-off to the moment of the crash, but only about 40 seconds of flight, and the Safety Commission could not assess the next course of the flight before the helicopter fell,
- there was no evidence that any mechanical anomalies or defects were present on the engine components before the crash,
- the expert examination of the CED suggests that the technical condition of the helicopter before the accident and during the flight was not the cause of the occurrence of the flight incident. Both engines demonstrated normal operation until the incident.

3.2 Causes of the air accident

- the helicopter's crash into a tree stand during the flight at a downward curve at a ground level,
- the pilot did not have a safe height above the surrounding terrain after taking off.

3.3 Co-acting Causes

Performing a rescue flight in challenging mountainous terrain under specific conditions (astronomical night).

4. SAFETY RECOMMENDATIONS

Based on the safety investigation of the causes of the air accident

helicopter type **Bell 429**
Registration Mark **OM-ATR**
which occurred on **07.09.2016**

We recommend taking measures for:

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- in the course of the investigation the operator determined an increase of the HEMS landing areas at night above the dimensions required by Commission Regulation (EU) No. 965/2012 of 5 October 2012,
- perform additional pilot training to address emergency situations at night in a specialized workplace designed to simulate changes in global and weather conditions for flights without NVG and with NVG.

In Bratislava, 18.08.2017