COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-157/CENIPA/2016

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PR-TUN**
MODEL:	**R44 II**
DATE:	**04DEC2016**

NOTICE

According to the Law nº 7565, dated 19 December 1986, the Aeronautical Accident Investigation and Prevention System – SIPAER – is responsible for the planning, guidance, coordination and execution of the activities of investigation and prevention of aeronautical accidents.

The elaboration of this Final Report was conducted taking into account the contributing factors and hypotheses raised. The report is, therefore, a technical document which reflects the result obtained by SIPAER regarding the circumstances that contributed or may have contributed to triggering this occurrence.

The document does not focus on quantifying the degree of contribution of the different factors, including the individual, psychosocial or organizational variables that conditioned the human performance and interacted to create a scenario favorable to the accident.

The exclusive objective of this work is to recommend the study and the adoption of provisions of preventative nature, and the decision as to whether they should be applied belongs to the President, Director, Chief or the one corresponding to the highest level in the hierarchy of the organization to which they are being forwarded.

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with Appendix 2, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

Thus, it is worth highlighting the importance of protecting the persons who provide information regarding an aeronautical accident. The utilization of this report for punitive purposes maculates the principle of "non-self-incrimination" derived from the "right to remain silent" sheltered by the Federal Constitution.

Consequently, the use of this report for any purpose other than that of preventing future accidents, may induce to erroneous interpretations and conclusions.

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Taking into account the nuances of a foreign language, no matter how accurate this translation may be, readers are advised that the original Portuguese version is the work of reference.

SYNOPSIS

This is the Final Report of the 04DEC2016 accident with the R44 II aircraft, registration PR-TUN. The accident was classified as "[LOC-I] Loss of Control in-Flight".

During the displacement between Osasco - SP, and a party house located in the municipality of São Lourenço da Serra - SP, the aircraft crashed into the ground.

The aircraft was destroyed.

The pilot and three passengers perished at the site.

An Accredited Representative of the National Transportation Safety Board (NTSB) - USA, (State where the aircraft was designed) was designated for participation in the investigation.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ACFS	Automatic Control Flight System
CA	Airworthiness Certificate
CAE	Cabin/ Left Front Seat
CATD	Cabin/ Right Rear Seat
CATE	Cabin / Left Rear Seat
CIV	Pilot's Flight Logbook
CMA	Aeronautical Medical Certificate
FAA	Federal Aviation Administration
FPS	Frames Per Second
GPS	Global Positioning System
HMNC	Conventional Single Engine Helicopter Rating
IAG-USP	Astronomy, Geophysics and Atmospheric Sciences Institute of the São Paulo University
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IML	Legal Medical Institute
IPEV	Research and Flight Testing Institute
LTE	Loss of Tail Rotor Effectiveness
MMA	Aeronautics Ministry Manual
METAR	Aviation Routine Weather Report
OGE	Out of Ground Effect
PAX	Passenger
PCH	Commercial Pilot License – Helicopter
PMC	Maximum Continuous Power
PMD	Maximum take-off weight
PPH	Private Pilot License – Helicopter
REDEMET	Aeronautics Command Meteorology Network
SAS	Increasing Stability Systems
SSUB	ICAO Location Designator - Osasco Helipad, SP
TAF	Terminal Aerodrome Forecast
TPP	Registration Category of Private Service - Aircraft
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

1. FACTUAL INFORMATION.

Aircraft	**Model:** R44 II **Registration:** PR-TUN **Manufacturer:** Robinson Helicopter	**Operator:** HELICOP CHART.SERV.BRASIL TAXI AER.LT-ME
Occurrence	**Date/time:** 04DEC2016 - 1830 UTC **Location:** Forest zone **Lat.** 23º52'07"S **Long.** 046º55'49"W **Municipality – State:** São Lourenço da Serra – SP	**Type(s):** [LOC-I] Loss of Control in-Flight **Subtype(s):** NIL

1.1 History of the flight.

The aircraft took off from the Osasco Helipad (SSUB) - SP, to the Recanto Beija-Flor party house, located in the city of São Lourenço da Serra - SP, at about 1800 (UTC), with one pilot and three passengers on board.

After about 30 minutes of flight, there was loss of control in flight and the aircraft collided with the ground.

The aircraft was destroyed. The pilot and the three passengers suffered fatal injuries.

1.2 Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	1	3	-
Serious	-	-	-
Minor	-	-	-
None	-	-	-

1.3 Damage to the aircraft.

The aircraft was destroyed.

1.4 Other damage.

None.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Hours Flown	Pilot
Total	572:06
Total in the last 30 days	17:24
Total in the last 24 hours	Unknown
In this type of aircraft	50:06
In this type in the last 30 days	17:24
In this type in the last 24 hours	Unknown

N.B.: The data related to the flown hours were obtained through the Pilots' Flight Logbook (CIV) registers.

1.5.2 Personnel training.

The pilot took the PPH course at the AGD Aviation - Escola de Aviação Civil Ltd., located in the municipality of São Paulo - SP, in 2011.

1.5.3 Category of licenses and validity of certificates.

The pilot had the PCH License and had valid HMNC Rating.

1.5.4 Qualification and flight experience.

The pilot was qualified and had experience in that kind of flight.

1.5.5 Validity of medical certificate.

The pilot had valid CMA.

1.6 Aircraft information.

The aircraft, serial number 12560, was manufactured by Robinson Helicopter, in 2008 and it was registered in the TPP category.

The aircraft had valid Airworthiness Certificate (CA).

The airframe and engine logbook records were updated.

The last inspection of the aircraft, the "100 hours" type, was performed on 21OCT2016, by the Full Copters Aviation Eireli – EPP Maintenance Organization, in Americana - SP, having flown 44 hours and 24min after the inspection.

1.7 Meteorological information.

The METAR of the Congonhas Aerodrome (SBSP), São Paulo - SP, 21 NM away from the accident site and the Campo de Marte (SBMT), São Paulo - SP, brought the following information:

METAR SBSP 041800Z 19014KT 9999 FEW018 SCT070 25/17 Q1007=

METAR SBSP 041900Z 18016KT 9999 SCT008 BKN013 21/16 Q1007=

METAR SBMT 041800Z 28014KT CAVOK 29/12 Q1005=

METAR SBMT 041900Z 11010KT 9999 SCT035 BKN060 24/18 Q1005=

The quadrilateral in Figures 1 to 4 highlights the area of the accident in the meteorological radar images obtained in the website of the IAG-USP on 04DEC2016, at the 1800 (UTC), 1810 (UTC), 1820 (UTC) and 1830 (UTC).

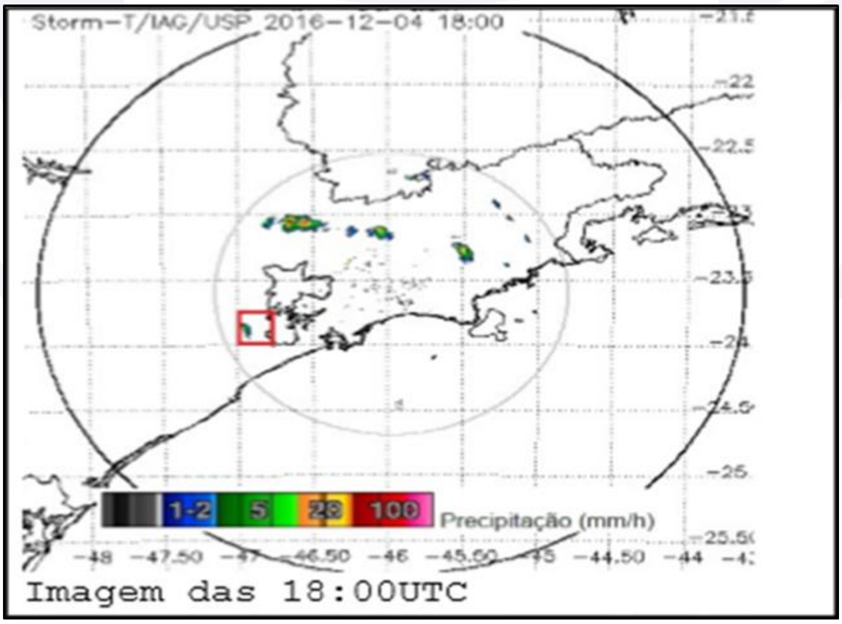


Figure 1 - Image from the meteorological radar at 1800 (UTC) of IAG-USP.

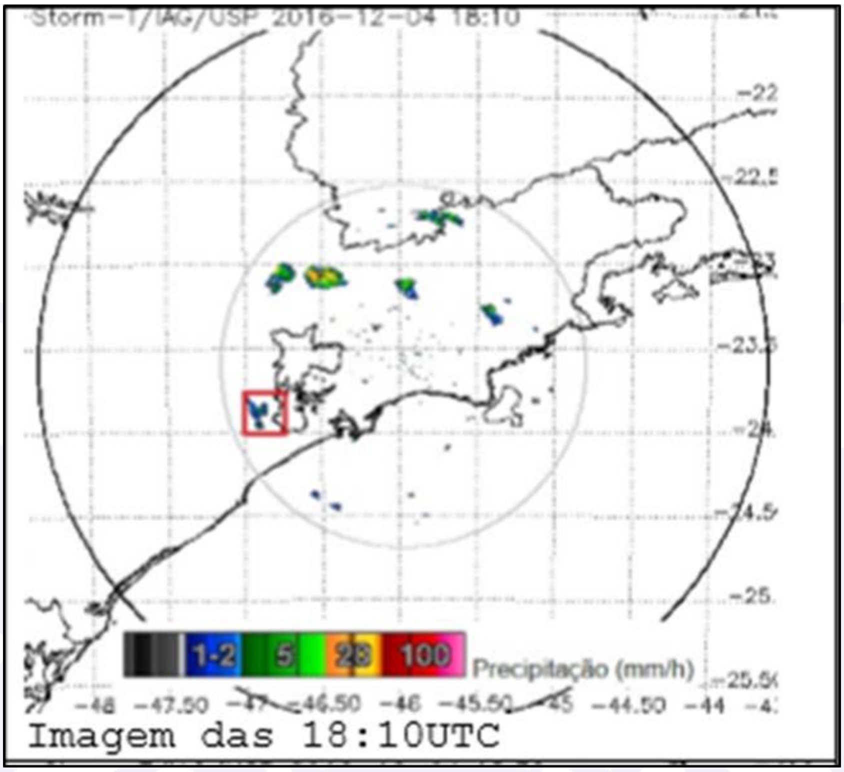


Figure 2 - Image from the meteorological radar at 1810 (UTC) of IAG-USP.

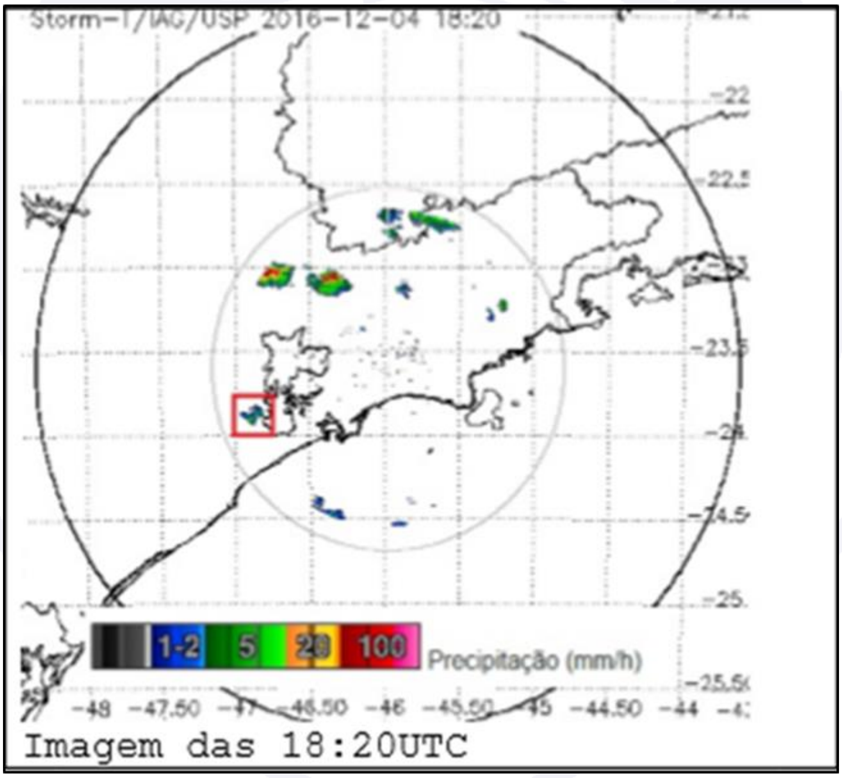


Figure 3 - Image from the meteorological radar at 1820 (UTC) of IAG-USP.

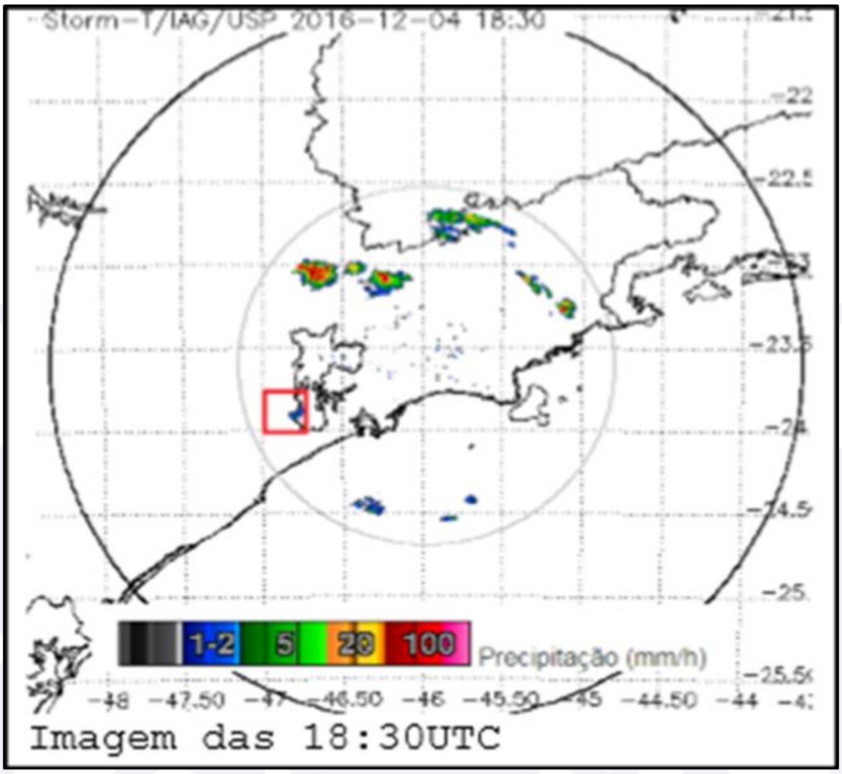


Figure 4 - Image from the meteorological radar at 1830 (UTC) of IAG-USP.

Following the schedule, a meteorological system detected with precipitable water over the region, that is light to moderate rain clouds, is visible.

The meteorological radar of the REDEMET allows a greater approximation of the point of impact. The star (Figures 5 and 6) indicates the location of the accident and shows the passing of the same cloud system with light to moderate precipitation over the region.

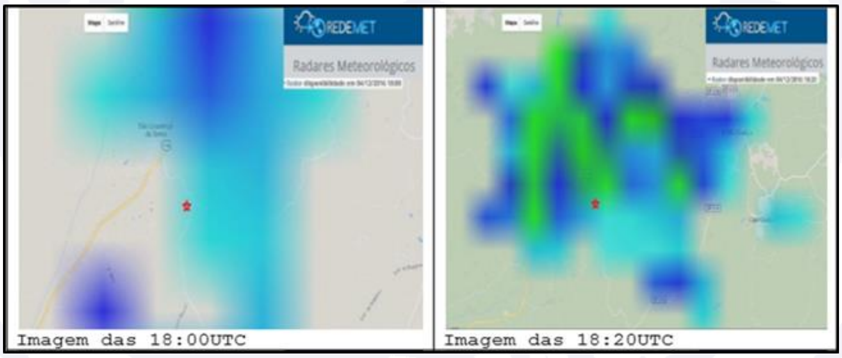


Figure 5 - Radar images from 1800 (UTC) and 1820 (UTC) from REDEMET.

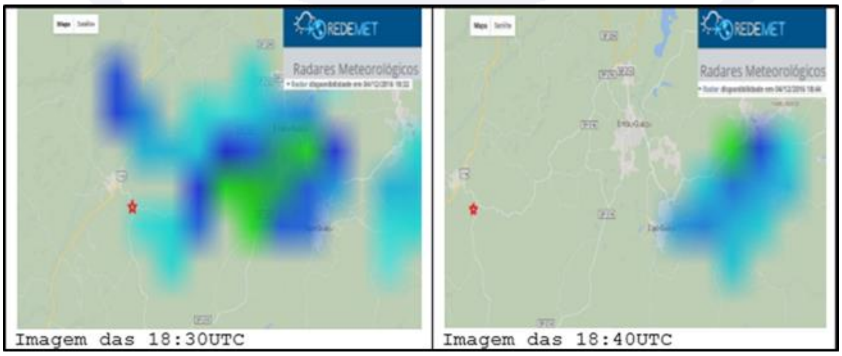


Figure 6 - Radar images from 1830 (UTC) and 1840 (UTC) from REDEMET.

1.8 Aids to navigation.

Nil.

1.9 Communications.

No contacts with Air Traffic control bodies were registered.

1.10 Aerodrome information.

The occurrence took place outside the Aerodrome.

1.11 Flight recorders.

Neither required nor installed.

However, one of the passengers had a GOPRO camera and was able to record practically the whole flight until the moment of the occurrence.

From the recordings, the data of the flight were obtained in order to reconstitute the instants that preceded the accident.

The videos were complete and up-to-date. They were recorded at 1920x1440 resolution and 23.98 FPS (Frames per second).

1.12 Wreckage and impact information.

The impact occurred outside the aerodrome, at 2.382ft of altitude, at approximately 25 NM away from the take-off location (SSUB) and 2.5 NM away from the intended landing site.

The aircraft crashed into the ground without shifting forward or sideways in a wooded area.

The wreckage became concentrated, with few scattered parts, distributed in a circular way in relation to the point of impact. Part of the tail rotor was not found.

There was no fire.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

According to the last health inspection, held on 24NOV2016, the pilot was able for air activity.

According to reports of people close to the pilot, he made a flight in the early morning of 04DEC2016, between 02:00 (local) and 03:00 (local), and between 05:00 (local) and 05:50 (local), taking an interval of approximately two hours between these flights. It was the coverage of a show at the Anhembi Sambadrome.

Analyzing the last 48 hours of the pilot routine, it was observed that these missions were not included in the last logbook of the aircraft. The last flight records prior to these missions were at 13:30 (local) on 02DEC2016 and at 08:00 (local) on 04DEC2016.

Based on the final records of the logbook, the pilot conducted a flight between 08:00 (local time) and 08:55 (local) on 04DEC2016 and then another flight between 12:05 (local) and 12:30 am (local), the latter in the condition of passenger. At 16:00 (local), he would take the flight that resulted in the accident.

It was analyzed the Necroscopic Report No. 443782/2016-GDL, made on 05DEC2016, at 01:04 (local) issued by the IML of São Paulo. By the analysis of the findings, both external and internal examination, it was concluded that all the injuries were produced due to poly traumatism because of the impact of the aircraft’s fall.

Also, toxicological and alcoholic dosage tests were performed. According to the results presented, no use of toxic agents and ethanol was found in the toxicological test of the pilot.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

At the last health inspection, held on 24NOV2016, the pilot was considered able, according to the result issued by the São Paulo Air Force Hospital, where he performed his evaluation.

As far as his psychological evaluation was concerned, the pilot presented satisfactory conditions in relation to the cognitive functions evaluated, and no limitations were identified that impeded professional practice in aviation.

As reported by people of his acquaintance, the pilot had begun his activities with the PR-TUN aircraft through an informal working relationship. Even after his actual hiring, the pilot's routine remained variable and the communication between him and the company was informal.

In this sense, sometimes a previously established schedule or agreement was altered in an untimely manner, and in other situations, the pilot had already been called at the time of the flight.

The pilot’s routine in the hours prior to the accident involved the accomplishment of flights to serve several purposes, according to the reports obtained. It was not possible to determine the planning time available to the pilot in such circumstances.

1.14 Fire.

There was no fire.

1.15 Survival aspects.

There were no survivors.

1.16 Tests and research.

Part of the tail of the aircraft has undergone examinations.

Overload damage was observed in the region where the tail rotor was separated from its fixation in the aircraft’s tail cone (Figures 7 and 8). There was no evidence of fatigue or impact at the fracture place.

Figure 7 - Part of the tail of the aircraft.

Figure 8 - Surface of fracture with aspect of overload.

The engine had major breakdowns due to the collision with the ground. One of the consequences was the loss of the nameplate. Its identification was performed through the engine Logbook opening Sheet (Figure 9).

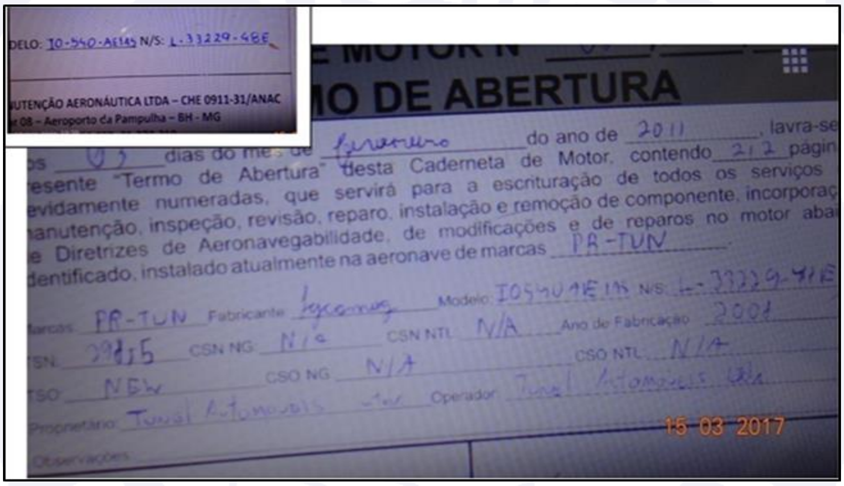


Figure 9 - Identification of the Lycoming IO-540-AE145 engine, S/N 33229-48E.

Figure 10 shows the engine magnetos. It was observed that they were damaged, which prevented bench tests.

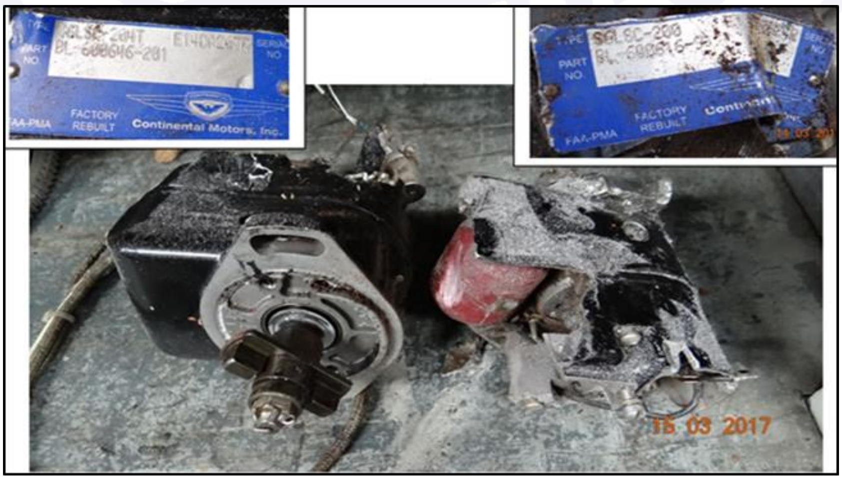


Figure 10 - View of the engine magnetos with their respective identifications.

Control valves, hydraulic tappets, lubrication system and other internal engine components were inspected. It was found that the spark plugs presented evidence of normal operation (Figure 11).

Figure 11 - Spark plugs with normal operating color.

The injector nozzles were unobstructed (Figure 12).

Figure 12 - View of the nozzles. Highlights the clearing.

Figure 13 shows the fuel distributor and its components.

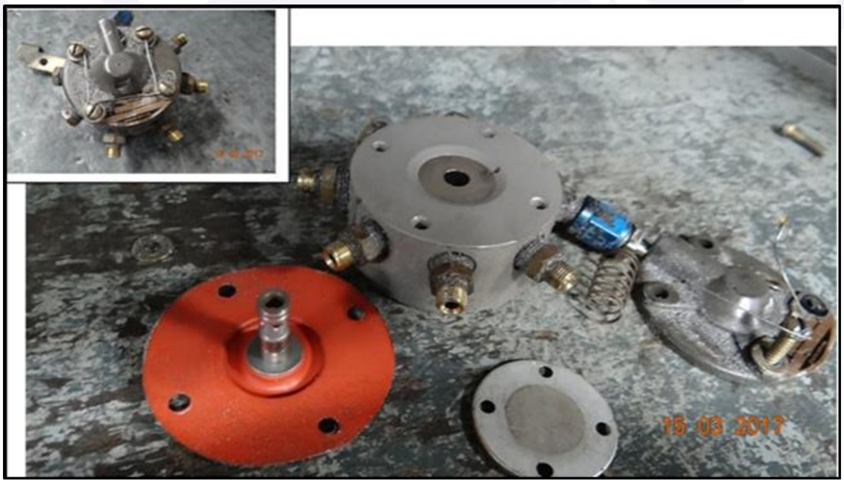


Figure 13 - Disassembled distributor view. Highlighted the distributor assembled.

Figure 14 shows the servo fuel injector. This unit had serious faults as a result of the accident and was with dirt.

Figure 14 - Overview of the servo fuel injector. The highlights show their identification and the damages resulting from the accident.

The fuel inlet filter was inspected (Figure 15). It was clean and uncontaminated, as it could be observed.

Figure 15 - View of the fuel filter at the inlet of the servo injector, with no contaminants.

Figures 16 to 18 show the fuel pump. It was found fractured due to impact. In its internal components, no anomalies that showed a malfunction were found.

Figure 16 - Fuel pump view.

Figure 17 - View of the interior of the fuel pump, showing its valves.

Figure 18 - Clean fuel pump diaphragm view.

Figure 19 shows the filter element of the oil filter, without the presence of filings. The filter before its opening is shown in the highlight of the same figure.

Figure 19 – Oil Filtering element with no filings. Highlighted the oil filter before opening.

Figure 20 shows the oil pump as well as its gears, without operational damage. At the time of the accident, the engine of the aircraft had its crankcase and its primary oil filter ripped off. They were not located for analysis.

Figure 20 - Gears and housing of the engine oil pump without scratches.

Figure 21 shows a view of the engine synchronizing gears. It is observed that the drive gear bearing of the right magneto was misaligned. The impact that the magneto suffered at the moment of the collision against the ground caused this misalignment.

Figure 21 – Gears of the accessory box. The arrow indicates misalignment of the drive gear of the right magneto.

Figure 22 shows the detail of the misalignment with the bearing still assembled.

Figure 22 - Misalignment in the drive gear bearing of the right magneto.

The intermediate gear, which drives the left magneto and the valve control, had a fractured tooth. The misalignment caused by the impact promoted the decoupling of the "teeth" and allowed the incorrect contact between them.

This caused the "tooth" fracture of this intermediate gear by overload and the contact marks observed in the ridges of the neighboring teeth (Figure 23). Such evidence corroborates that, at the moment of impact, the magneto was spinning, because more than one "tooth" of the gear was affected.

Figure 23 - View of the tooth fracture of the left magneto drive synchronizing gear and the valve control.

Figures 24 and 25 show the interior of the engine cylinders. There were no scratches, no evidence of detonation or signs of overheating that could indicate engine malfunction.

Figure 24 - View of cylinders 1, 2 and 3, with no operational damage.

Figure 25 - View of cylinders 4, 5 and 6, without operational damage.

The same analysis procedure was adopted to inspect the pistons (Figures 26 and 27). No anomaly was found.

Figure 26 - View of the pistons 1, 2 and 3, with normal working color.

Figure 27 - View of the pistons 4, 5 and 6, with normal working color.

Figure 28 shows a view of the valve control shaft of the engine, which was also intact.

Figure 28 - Overview of the engine valve control shaft.

Figure 29 shows the dynamic counterweights of the crankshaft. They were normal and the pins were assembled correctly.

Figure 29 - Highlight for identification of the counterweight of the crankshaft.

The crankshaft of the engine is shown in Figure 30. All connecting rods (Figure 31) were moved before disassembly and no jamming or signs of lack of lubrication were observed, which could compromise the operation of the engine.

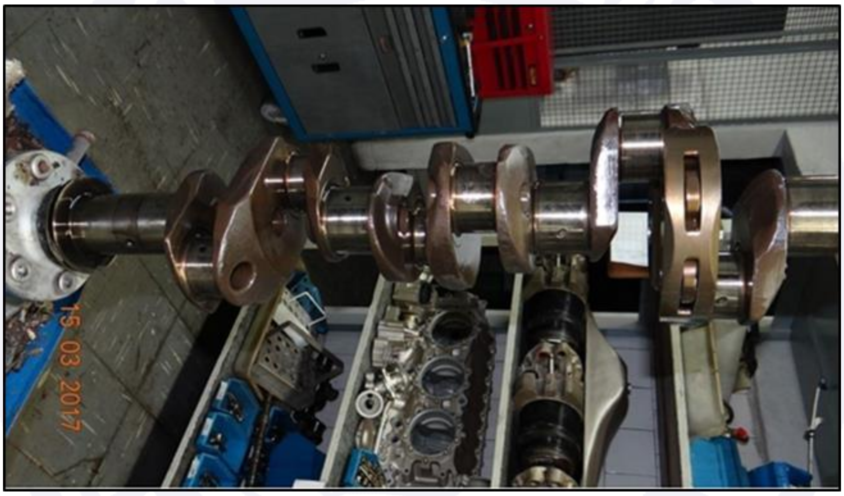


Figure 30 - Engine crankshaft in good condition.

Figure 31 - View of the connecting rods in good condition.

The semi-engine housings (Figures 32 and 33) were normal. No evidence of impact damage or bearing problems was found. The front connecting rod of the engine were normal and showed no evidence of abnormal wear or lack of lubrication.

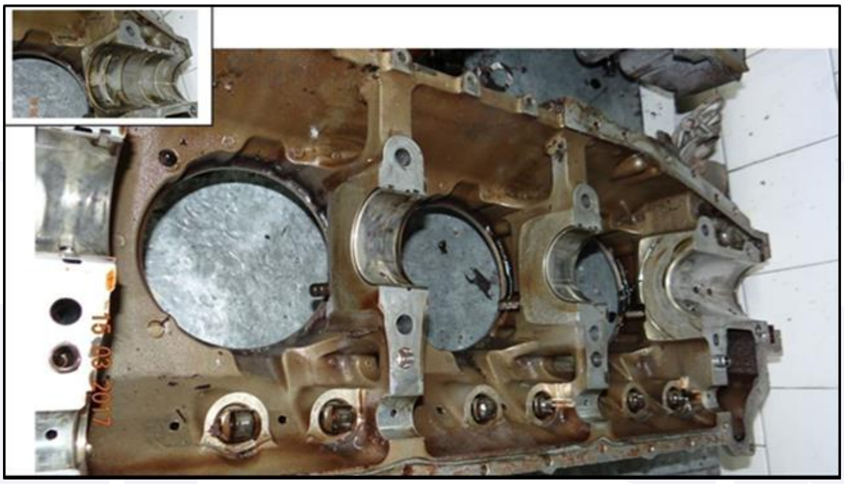


Figure 32 - View of the right semi-engine housing and of the connecting rod in good condition.

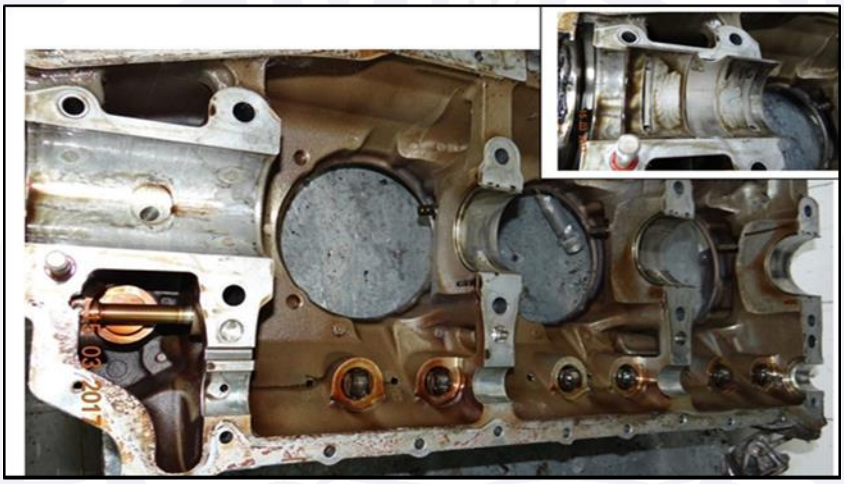


Figure 33 - View of the left semi-engine housing and the connecting rod in good condition.

In Figure 34 we observe the local temperature indicator (Telatemp heat indicator) that indicated high temperature in the hydraulic pump. This is why the gearbox was disassembled.

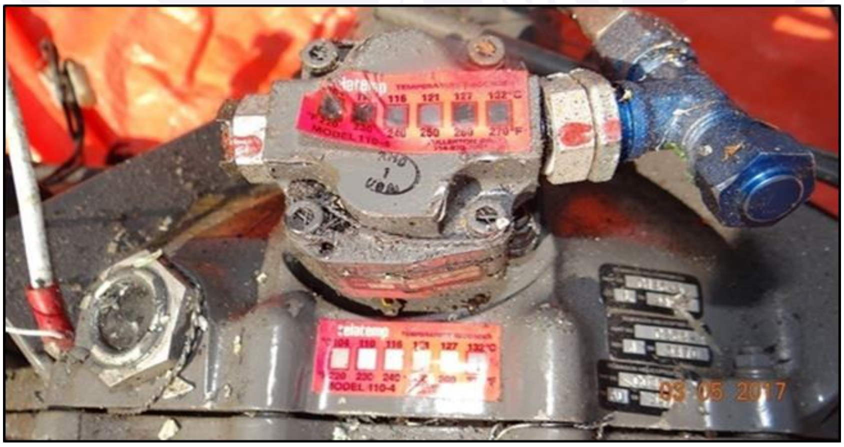


Figure 34 - Temperature indicator (Telatemp) showing temperature increase in the hydraulic pump.

Figures 35 and 36 show the main rotor drive assembly after opening the fairing. A gearbox casing fracture was observed, due to the collision against the ground.

Figure 35 - Overview of the transmission assembly after opening the fairing.

Figure 36 - View of the transmission case crankcase fracture.

Figure 37 shows a view of the hydraulic pump, component that showed temperature increase indication (Telatemp tape).

Figure 37 - Main gearbox hydraulic pump.

The interior of the transmission case and its components (rack, pinion, hydraulic pump gear, pump housing and bearings) did not present scratches and signs of overheating, due to lack of lubrication (Figures 38 to 46). No evidence of failure was found to compromise its operation.

Figure 38 - Housing of the hydraulic pump in the gearbox.

Figure 39 - Bottom view of the rack and bearing of the transmission box.

Figure 40 - Transmission case lower bearing outer race, undamaged.

Figure 41 - General view of the rack, the upper bearing and the gearbox pinion.

Figure 42 - Main gearbox rack.

Figure 43 - Top rack and top bearing of the main gearbox.

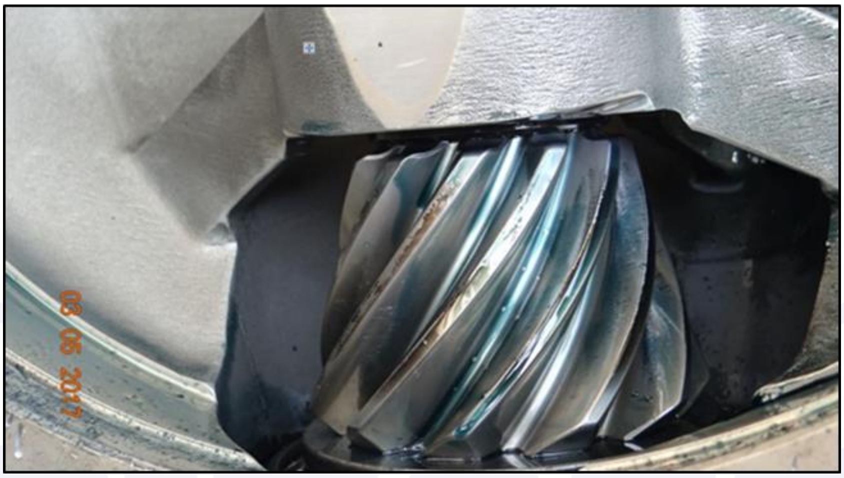


Figure 44 - View of the gearbox pinion.

Figure 45 - External track of the upper gearbox bearing.

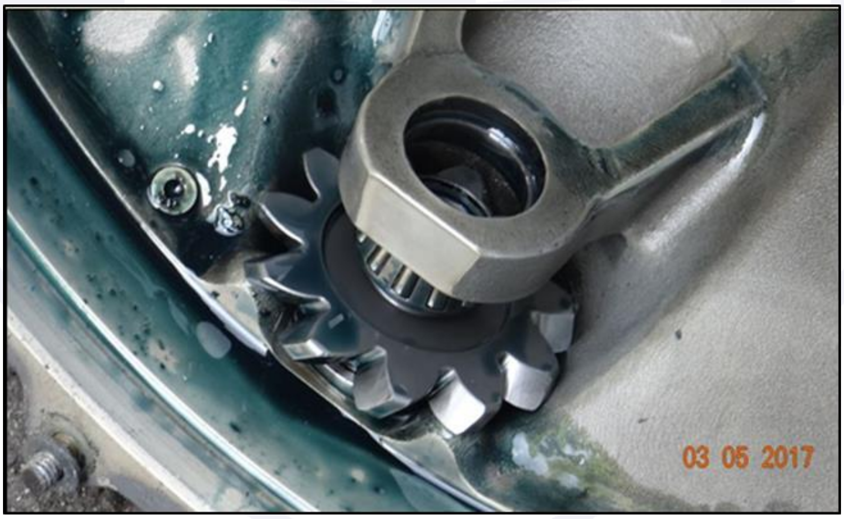


Figure 46 - Gearbox hydraulic pump drive gear.

The image of the camera on board the aircraft made it possible to observe the low-rotating light of the main rotor on (Figure 47) and, in the upper display, the indication that the engine was powered.

The lower highlight (Figure 47) shows an instrument similar to that of the aircraft panel. It was included, so that the reader could clearly observe the information provided by that instrument, that is, the engine and main rotor rotations in percentage.

Figure 47 - Low RPM Main Rotor Indicator Light. In the lower highlight, an indicator similar to that of the aircraft. In the top highlight, indication that the engine was powered.

The aircraft engine had severe damage from the collision with the ground. At the time of analysis, the engine was without the dry crankcase, oil crankcase and primary oil filter. Due to the impact, the magnetos were fractured, which impaired analysis and functional testing.

During engine disassembly, no evidence was found that could indicate malfunction or failure.

At the beginning of the engine inspection, the high temperature signature on the Telatemp tape of the hydraulic pump of the aircraft was verified. This observation was decisive for the dismantling of the transmission box.

During the disassembly process, the conditions of the rack, the pinion, the drive gears of the hydraulic pump, the bearings and the lubrication of the whole system of the transmission box were observed.

No abnormality was observed. Thus, it has been observed that the temperature excess observed in Telatemp was probably the result of heat irradiated by the engine after the accident.

1.17 Organizational and management information.

The PR-TUN aircraft operated by Helicop. Chart. Serv. Brazil Taxi Aer. Ltd was registered for TPP.

There were indications that the flight could be classified as TPX, and that the aircraft was not approved for this type of transport.

The pilot started his work as a freelancer. Prior to this work, he had acted as an instructor in the civil aviation school where he graduated, for approximately three years, without formal employment or fixed salary.

In 2016, according to family members, he began working as a freelancer for the PR-TUN aircraft operator and in October 2016 he received the invitation to formalize his bond in the work permit. The Investigation Team did not have access to such documents.

There was no fixed work routine. The callings occurred informally. There was no pre-established agenda and flights were made on demand.

According to reports from relatives, callings to attend events such as bridal transportation to the wedding were common. The pilot even participated in bridal fairs to promote this type of work.

Besides this professional bond, it was also reported that, occasionally, the pilot made flights to another company, with the purpose of performing cargo-tracking service.

This other company, in October 2016, even made a proposal for hiring with a formal contract. According to reports from people of his acquaintance, the pilot was evaluating the possibility of accumulating the two works.

In terms of professional training, it was verified that the pilot performed 107.8 total hours of training, divided into three phases of different learning complexities, being 16.5 hours on the first phase, 60.5 hours on the second phase and 20.4 hours on the third stage. Later, he completed another 10.4 hours for instructor.

In the period from July 2011 to August 2013, the pilot performed the practical operational stage and, according to the evaluation records of the training school, some relevant aspects that influenced his training were identified.

Regarding the organization of the practical flight assessment sheets, it was observed a lack of standard in their completion. In some records, the grades were not assigned and did not follow a clear and coherent continuity, in which it was possible to visualize a progression of student learning.

Some pieces presented medium grades s in some maneuvers, but in the observations, the instructor put the comment "great flight", without explaining what was considered great, nor the reason of the median grade.

In accordance with the School's Internal Rules, Art. 36:

> "... instructors shall perform, in all practical instruction classes, without exception, the procedures described: letter d Student's previous flight evaluation sheets (at least the last two sheets)".

However, it has been observed in many instruction files that some basic skills maneuvers, which should necessarily be assessed, were not taken into account, as there was no mention of the grade.

Regarding the phase changes in the instructions, it was observed that the student performed instruction from phase 2 and then returned to phase 1, as well as performed the check from phase 1 after having already performed some instructions in phase 2.

The student obtained low scores on Phase 1 check and continued to perform the instructions in Phase 2, performing more complex maneuvers than those for which he appeared to have not adequately absorbed the knowledge / skills.

By analyzing the flight records, difficulties were observed in basic maneuvers, phraseology, approximation and coordination in advanced phases of the course, which should already be remedied. The student performed the instruction, apparently, without emphasis in these aspects. It was also observed lack of emergency situations and flight safety.

On the flight sheets, there were few indications of instructions on adverse weather conditions (one in phase 2 and two in phase 3).

1.18 Operational information.

The takeoff weight was estimated at 1.084kg (2.390lb). The aircraft was within the weight and balance limits specified by the manufacturer.

According to the meteorological report, the on-site temperature was estimated at 20° C and the approximate pressure altitude of at most 3.600ft at 1830 (UTC) with a setting of 1.005hPa.

For the purposes of this report, the difference to the default setting - 1.013hPa - corresponding to approximately 200ft less, would not have a relevant influence on the final result.

Flight performance hovered out of the ground effect represents the most critical condition as to the power required within the approved envelope for the crashed aircraft model.

The above values were used in the takeoff power chart of the aircraft and the following result was demonstrated in Figure 48.

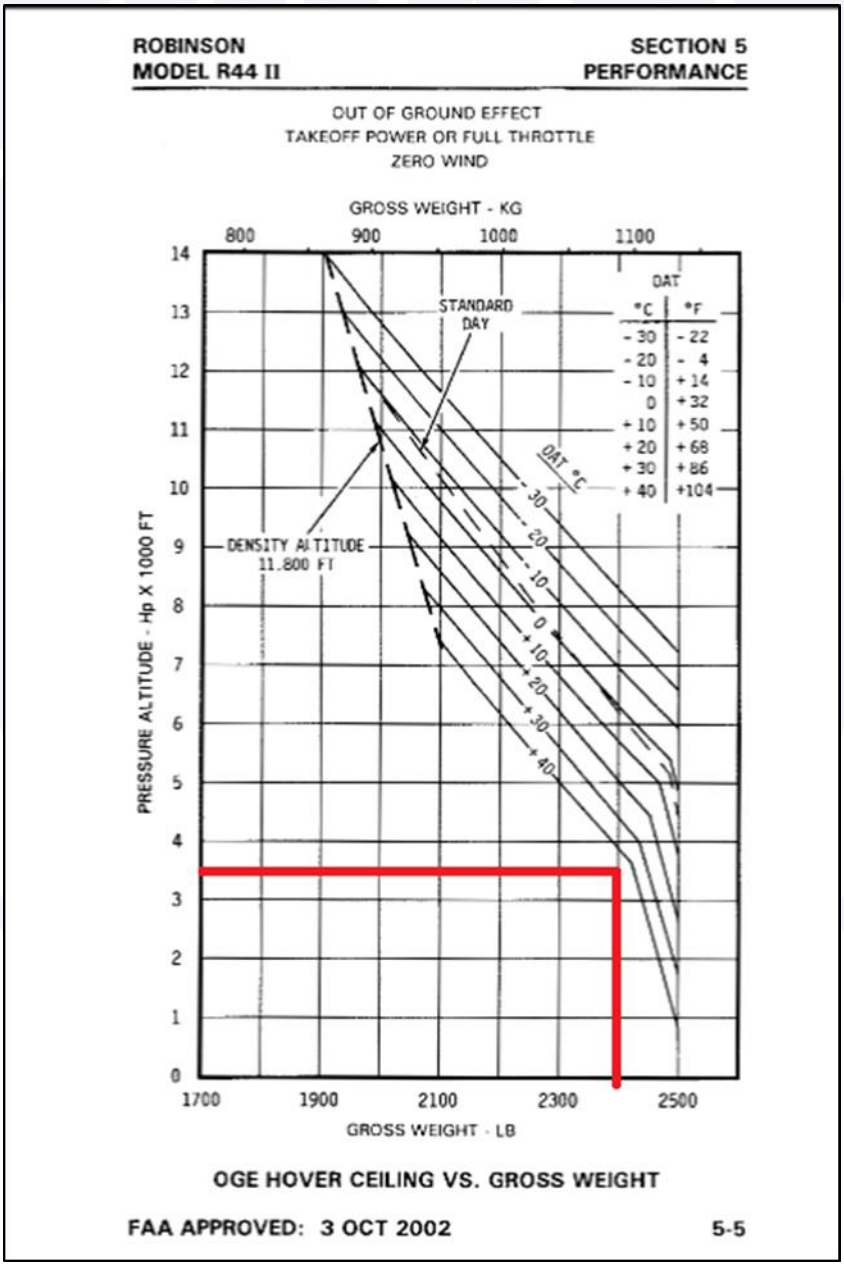


Figure 48 - Performance of Out of Ground Effect (OGE).

Based on the recorded videos, the following events were observed:

At 18:01:40 (UTC) - Engine on and start of rotor acceleration.

All occupants had their seatbelts buckled. There was a runway attendant watching the outside area. The sky was sparse and the pilot wore sunglasses (Figure 49).

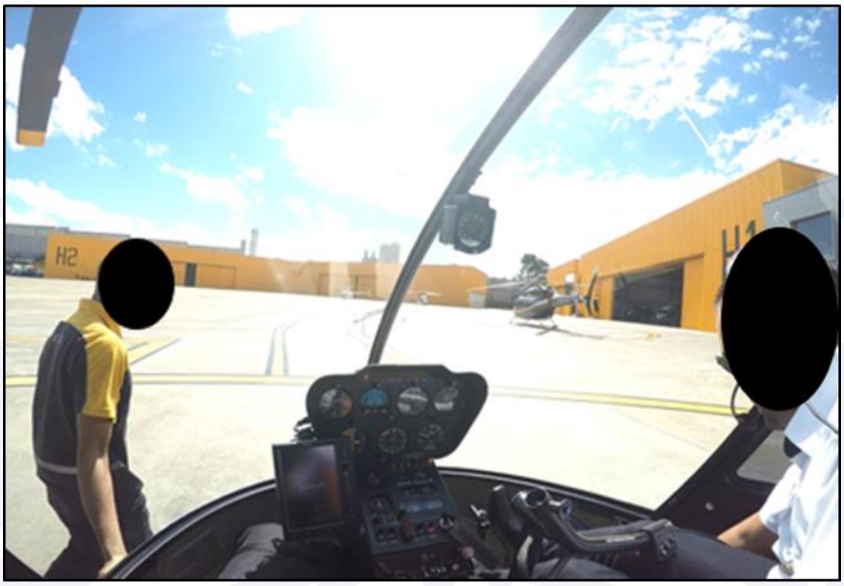


Figure 49 - Moment of the engine start, where the sky was with scattered clouds.

At 18:02:56 UTC (UTC), the aircraft was ready for takeoff.

At 18:06:57 (UTC), the aircraft overflew Castelo Branco-Osasco toll, 2.5 NM from the SSUB Helipad. The helicopter had head 260°, altitude 3.030ft, speed 97kt, Manifold Pressure 21.5inHg, Rotor Tachometer 100%, Engine Tachometer 101%, proving to be within the approved limits of operation (Figure 50).

Picture 50 - 18:06:57 (UTC), overpass of the Castelo Branco-Osasco tollbooth.

At 18:12:17 (UTC), the aircraft overflew the interconnection of the Rodoanel Governador Mário Covas with Régis Bittencourt highway (in the city of Embu), 10.5 NM away from the SSUB Helipad. The pilot follows the route of the Régis Bittencourt highway (BR-116). The sky remained sparse and the operation of the aircraft was normal.

At 18h16min00s (UTC) the aircraft flew over a leg between Itapecerica da Serra and São Lourenço da Serra, on the BR-116. At this point, changes in weather began to occur and the sky was overcast. There is no way to specify the height of the cloud layer. Flight conditions were visual (Visual Meteorological Conditions - VMC) (Figure 51).

Picture 51 - 18h16min00s (UTC), overcast sky.

At 18:17:51 UTC, the aircraft flew over the Jardim Los Angeles neighborhood in Itapecerica da Serra, where a first evidence of mist and low clouds was observed. The sky was overcast.

All instruments were within operational limits. The altitude was 2.980 feet, the speed was 100kt, the manifold pressure was 20inHg, the rotor tachometer was at 100%, the engine Tachometer at 101% and the conditions remained visual for helicopter flight.

At 18:18:37 (UTC) the aircraft was flying over a power grid network that passed on a BR-116, close to the bridge over the São Lourenço river, 21.5 NM of SSUB in São Lourenço da Serra. It was observed light rain. The aircraft was within normal operating limits, the pilot remained wearing sunglasses and the conditions were still VMC (Figure 52).

Figure 52 - 18:18:37 (UTC), overflight of a power grid network that passed on the BR-116, close to the bridge over the São Lourenço River.

At 18:20:14 UTC, the aircraft flew over the BR-116, at km 80, Despezio neighborhood, in São Lourenço da Serra. Light rainfall was observed, but still under VMC conditions.

At 18:21:30 (UTC) the aircraft flew across the city of São Lourenço da Serra (shed in the center of the city), still on the BR-116 vertical. The pilot took off his sunglasses (evidence that visibility conditions began to degrade). Conditions remained VMC (Figure 53).

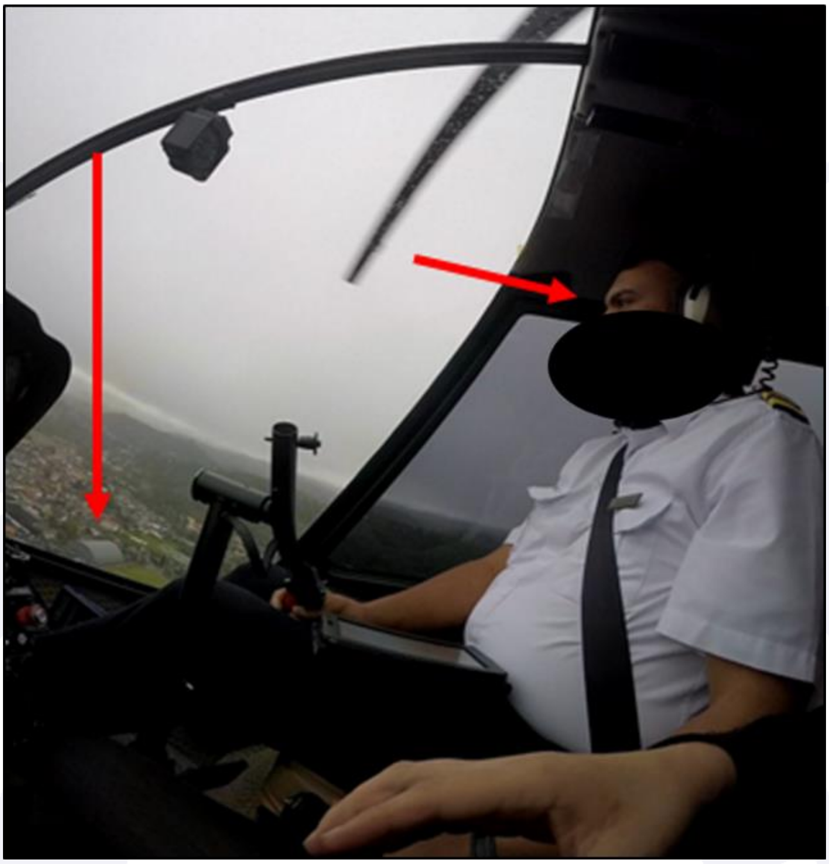


Figure 53 - 18h21min30s (UTC), arrow indicates the shed in the center of the city and the pilot is without sunglasses.

At 18:21:57 (UTC), it was not possible to identify the exact position of the aircraft, which had 95kt of speed and had traveled from the last position 1.350m. The passenger (PAX) occupying the left front seat (CAE) established the following dialogue with the pilot:

PAX CAE: "Are you using the GPS?"

Pilot: "What?"

PAX CAE: "Are you using the GPS or do you know where the site is?"

Pilot: "..." [inaudible]

PAX CAE: "Have you been there?"

Pilot: "What?"

PAX CAE: "Have you ever been there?"

Pilot: "Yes!"

Pilot: "..." [inaudible]

The transcripts were performed by the IPEV, through the audios captured by the camera of one of the passengers.

At 18:22:23 (UTC), the aircraft had 97kt of speed and had traveled a maximum of 2,700m after crossing the São Lourenço da Serra shed, but it was not possible to identify its exact position. Conditions were VMC. The pilot began to search the landing site and mentioned the power grid.

In the region, a large power grid network should be surpassed for landing at the destination. From the shed in the city of São Lourenço da Serra, the power grid to be transposed was away approximately 5.3 km (Figure 54).

Figure 54 - Distance between the shed and the landing place, marked by the arrow.

At 18:23:02 (UTC), the helicopter was at 95kt speed and had traveled at most 4.500m after crossing the São Lourenço da Serra shed, but it was not possible to define its exact position. The pilot started a 180° turn, looking for a landing place. You could hear the following dialogue:

Pilot: "There I think it's the bridge ... [inaudible]"

PAX CATE (Cabin / Left Rear Seat): "There's a house there."

...[Inaudible]...

Pilot: "Bridge? It was left behind. "

...[Inaudible]...

PAX CAE: "We were going here."

...[Inaudible]...

Pilot: "I'm coming back here ... it's very close, it's going to be right here ... [Inaudible]"

Pilot: "Do you remember a reference point?"

...[Inaudible]...

PAX CATE: "Two Shell gas stations, one Ipiranga gas station at one side, two Shell gas stations at the other ... [Inaudible]."

The aircraft returned to São Lourenço da Serra under VMC conditions.

At 18:25:00 (UTC), the aircraft made a curve over the city of São Lourenço da Serra at 2.700ft, under VMC conditions. You could hear the following dialogue:

Pilot: "Isn't it back here, is it?"

PAX CATE (Cabin / Left Rear Seat): "No."

Pilot: "Didn't we pass by the power grid?"

PAX CATE: "No."

...[Inaudible]…

PAX CAE: "Passed a power grid network, I do not know how many wires."

...[Inaudible]...

PAX CATD (Cabin / Right Rear Seat): "Toll, there is the Toll."

At 18:25:59 (UTC), the aircraft flew over the southern region of São Lourenço da Serra. The pilot turned to the left and began to fly through the clouds, with low visibility and in instrument meteorological conditions (IMC), but it was possible to observe that he still had visual contact with the ground (Figure 55).

Figure 55 - 18:25:59 (UTC), low visibility flight and under IMC conditions.

At 18:26:13 (UTC), the weather deteriorated. There was no visual contact with the ground and the visibility ahead was zero. The flight conditions were IMC and it was not possible to define the exact position of the aircraft.

The aircraft turned to the left with 25° inclination, 5° pitched up, 52kt of indicated speed, was passing through 2,940ft, with a rate of ascent of 800ft / min. The Manifold Pressure was 21.5inHg, the Rotor Tachometer was 100% and the Engine Tachometer was 101% (Figure 56).

Figure 56 -18:26:13 (UTC), there was no visual contact with the ground and the visibility ahead was zero.

At 18:26:33 (UTC), the helicopter remained in IMC conditions. The pilot started looking for references on the panel because there were no external references. It was not possible to identify where the aircraft was.

At 18:26:55 (UTC), visual contact with the ground was reestablished (the arrow indicates the visualization of a building and vegetation), but the conditions remained IMC. The pilot continued searching for the place of destination (Recanto Beija-Flor). The indicated speed was 60Kt, the altitude was 2.860ft, the Manifold Pressure was 16inHg, the Rotor

Tachometer was at 100% and the Engine Tachometer at 101%. In addition, it was not possible to identify the position of the aircraft. (Figure 57).

Figure 57 – 18:26:55 (UTC), visual contact with the ground reestablished (the arrow indicates the visualization of a building and vegetation).

The image recorded at 18:27:32 (UTC) shows that the pilot appeared to be staring only at the aircraft's GPS equipment (Figure 58), but the attitude information from the GPS and the aircraft's original instrument were conflicting, as shown in Figure 59.

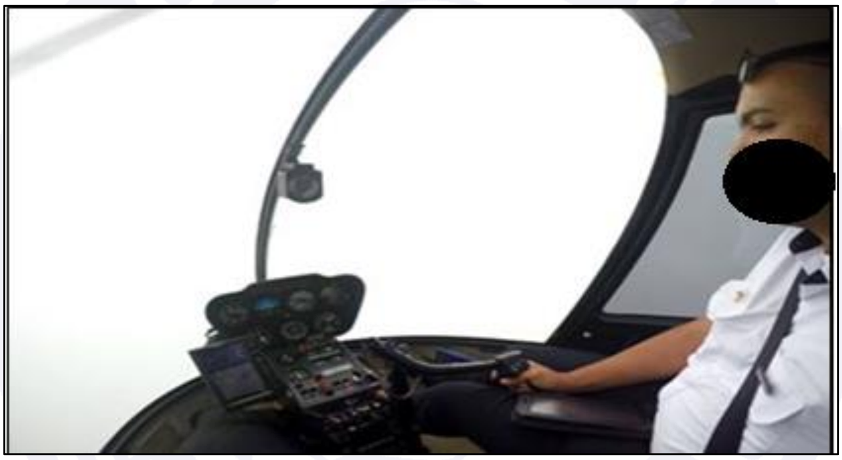


Figure 58 - Fixed look, apparently, in the GPS at 18:27:32 (UTC).

Figure 59 - 18:29:40 (UTC), aircraft attitude indicator and GPS with different indications.

At 18:27:47 (UTC), the pilot saw a power grid network ahead and identified a metallic sound, probably an alert message from the GPS equipment installed on the aircraft. It is still not possible to identify the exact position of the aircraft.

The pilot started a 30° turn to the left. The power was increased to 21inHg, the speed was decreased to 35Kt and the rate of climb reached 400ft / min. The conditions remained IMC, but there was visual contact with the terrain (Figure 60). The following dialogue was established between the passenger and the pilot:

PAX CATE: "There's a power grid down there."

Pilot: "Yes."

Figure 60 - 18:27:47 (UTC), flight conditions IMC (arrow indicates the power grid).

At 18:28:37 (UTC), conditions were IMC and without ground references. The exact position of the aircraft could not be identified.

At 18:28:58 UTC, conditions remained IMC and visibility was zero, the pilot constantly looked at the instrument panel (there were no external references). The aircraft had 90kt of indicated speed, passing through 3.500ft of altitude with rate of climb of 800ft / min. The Manifold Pressure was at 25.5inHg, the Rotor Tachometer at 100% and the Engine Tachometer at 101% (Figure 61).

Figure 61 – 18:28:58 (UTC), the visibility was zero.

At 18:30:05 (UTC), conditions remained IMC, with no reference to the ground, indicated speed was 0kt, altitude of 3,500ft, Manifold Pressure was at 24inHg, Rotor Tachometer at 100% and Engine Tachometer at 101%. The exact position of the aircraft could not be identified.

The pilot increased the movements of the cyclic. The aircraft tilted to the right, then to the left and reversed again to the right. There were variations in the pitch angle from +30° to -10° and around 45° of banking for each side (Figure 62).

Figure 62 – 18:30:05 (UTC), high pitch and bank angles.

At 18:30:13 (UTC), the aircraft was in the immediate vicinity of the site where the wreckage was found. The helicopter fell practically vertically, without lateral displacements or ahead. Conditions were IMC. There was the illumination of the LOW RPM light (low rotation of the main rotor). There was no external reference.

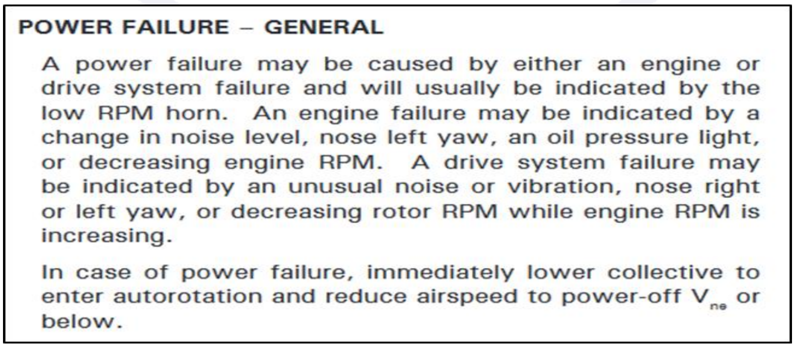
The low rotation rotor light (LOW RPM) illumination occurs when the main rotor rotates at 97% or less, according to the Robinson Helicopter Company, Pilot's Operating Handbook (page 7-25).

At the same time as the light was on, the buzzer sounded.

There are several factors that lead to a decrease in rotation below the safety limits set by the manufacturer.

Generally speaking, whenever the power required to maintain the flight is greater than the available power, there will initially be the sinking of the aircraft. If the pilot opposes the descent using the collective (increase of the collective pitch), there will be a reduction of the main rotor rotation (NR). In order for the NR to be kept constant, the collective must be reduced or the power supplied by the engine must be increased.

In the aircraft flight manual, power failure is described as a fault caused by engine or transmission failure (Figure 63).



POWER FAILURE – GENERAL

A power failure may be caused by either an engine or drive system failure and will usually be indicated by the low RPM horn. An engine failure may be indicated by a change in noise level, nose left yaw, an oil pressure light, or decreasing engine RPM. A drive system failure may be indicated by an unusual noise or vibration, nose right or left yaw, or decreasing rotor RPM while engine RPM is increasing.

In case of power failure, immediately lower collective to enter autorotation and reduce airspeed to power-off V_{ne} or below.

Figure 63 - Power failure.

In case of engine failure the signals are: noise change, yaw to the left, OIL PRESSURE light on and engine RPM drop.

The transmission failure would be indicated by unusual noise and vibration, nose to the right or left, decrease of the main rotor rotation (NR) with increase of the engine RPM. In Figure 64, it was found that engine (Engine RPM) and rotor (NR) rotations were synchronized.

Figure 64 – 18:30:13 (UTC), engine RPM and rotor synchronized (NR).

The Manifold Pressure indicated 24inHg, that is, the Maximum Takeoff Power (PMD) limit. According to pages 2-9 in the aircraft manual, the Maximum Continuous Power (PMC) is 21.8inHg.

The attitude indicator (artificial horizon) was banked to the right between 45° and 50°, and the aircraft rose with 400ft / min.

The aircraft entered an abnormal attitude, with an indicated speed of 0kt, a 50° bank to the right, Manifold Pressure was at 24inHg, Rotor Tachometer at 94% and Engine Tachometer at 96% (Figure 65).

Figure 65 - 18:30:13 (UTC), aircraft in a 50° bank to the right.

At 18:30:15 (UTC), the aircraft was out of control. The LOW RPM light was still on. The aircraft had an indicated speed of 54kt, in a 75° bank to the right and a 25° pitched down attitude. The altitude was of 3.560ft, the Manifold Pressure was 25inHg, the Rotor Tachometer was 92% and the Engine Tachometer was 94% (Figure 66).

Figure 66 - 18:30:15 (UTC), aircraft with a 75° bank to the right and a 25° pitched down attitude.

At 18:30:18 (UTC), the aircraft remained uncontrolled. The pilot's body was projected to the left, toward the passenger. The camera fell and the images became blurred by the speed of the events. The low RPM horn of the main rotor kept ringing.

Until that moment, the engine has been in normal operation (Figure 67).

Figure 67 – 18:30:18 (UTC), indication that the engine was still running.

There are indications that the helicopter has reached 140° of bank and 30° of pitch down, already with a high rate of descent (Figure 68).

Figure 68 - Uncontrolled aircraft at 18:30:19 (UTC).

At this time, the OIL PRESSURE and AUX FUEL PUMP alarm lights came on (Figure 69).

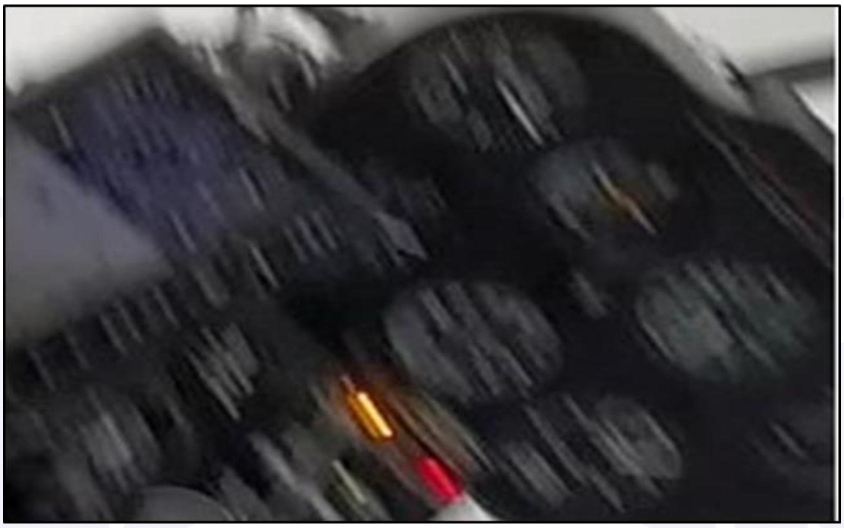


Figure 69 - Alarm lights on at 18:30:19 (UTC).

After the loss of control, the main rotor hit the front of the fuselage. There was loss of several components and great damage to the structure with the helicopter still in the air (Figure 70).

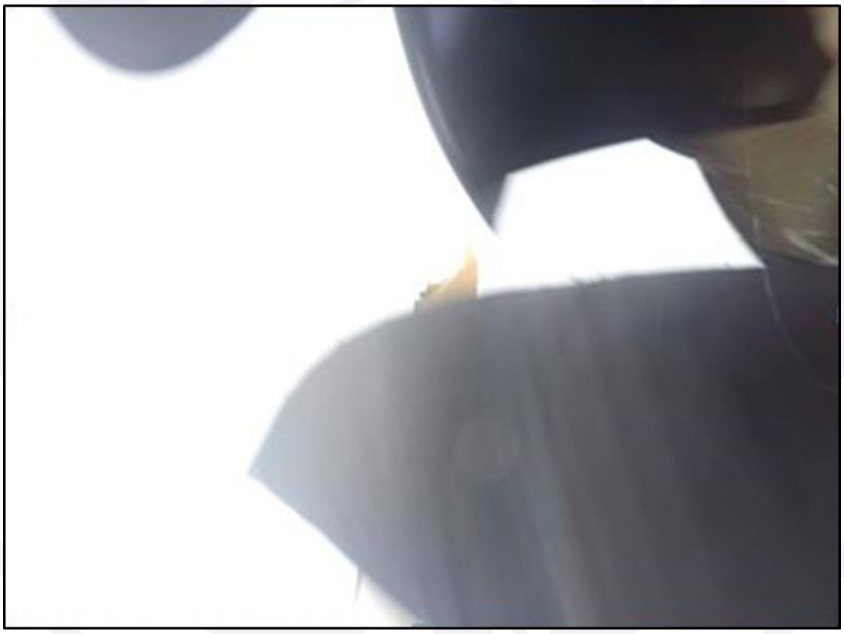


Figure 70 - Part of the left door broken at 18:30:22 (UTC).

The camera was launched into the air and recorded the image (even if blurred) of the damaged aircraft in the air (Figure 71). In the highlight, one could see the detail of the external painting (three golden bands).

Figure 71 - View of external parts of the aircraft still in the air at 18:30:22 (UTC).

At 18:30:23 (UTC), the camera touches the ground. You can hear sounds of falling pieces. The camera remains switched on for another 12 minutes, when it was possible to hear people who arrived at the crash site.

As a research methodology, the images were analyzed frame-by-frame, and it was possible to extract information from the reading of the on-board instruments, which were compiled in a spreadsheet.

According to the recording, it was found that the aircraft entered IMC conditions at 18:28:37 (UTC), seconds after spotting the power grid network. From that moment until 18:28:58 (UTC), the camera was turned towards the passengers, not being possible to identify the parameters of the aircraft.

Thereafter, the flight parameters were recorded for 14 seconds until the camera was directed again to the passengers.

At 18:29:58 (UTC) the camera re-filmed the front, until the moment of irreversibility of the accident.

Figures 72 to 78 show the flight parameters up to 18:29:12 (UTC).

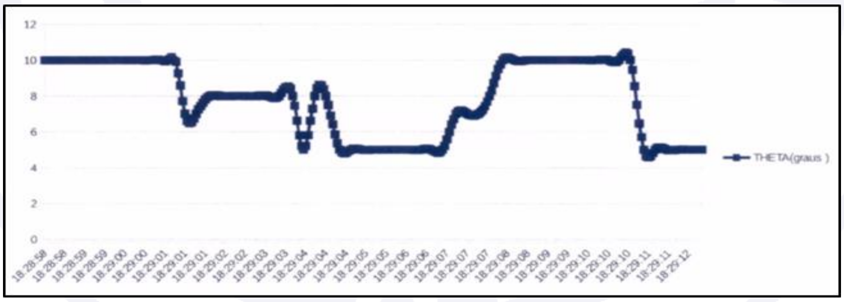


Figure 72-Theta (Attitude in º) up to 18:29:12 (UTC).

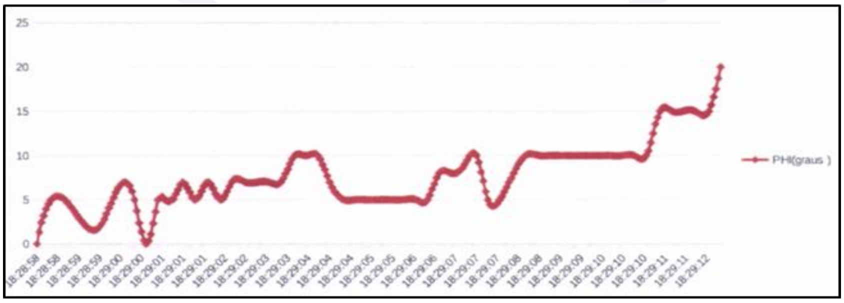


Figure 73 -Phi (bank in °) up to 18:29:12 (UTC).

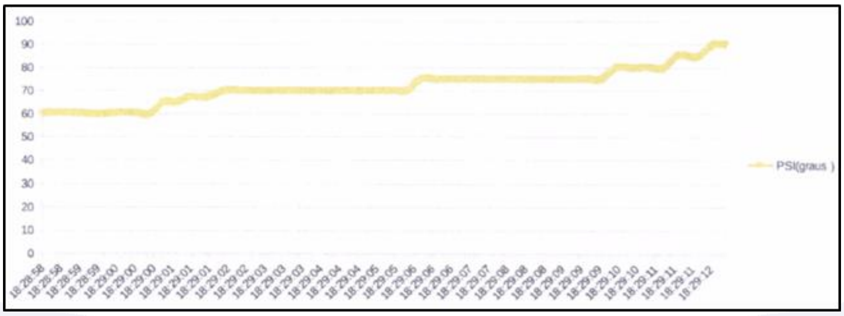


Figure 74 -Psi (Heading in º) up to 18:29:12 (UTC).

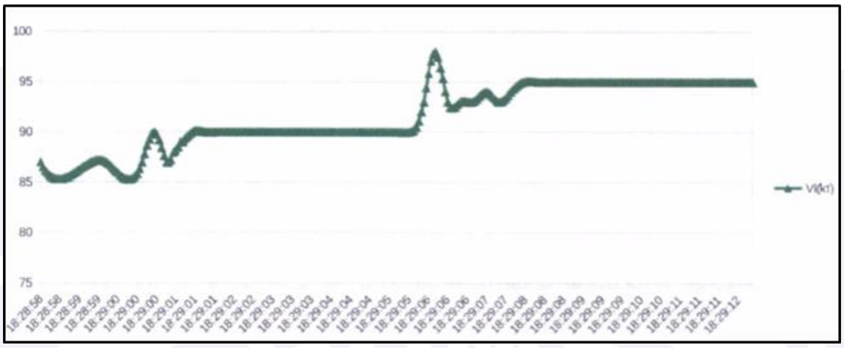


Figure 75 - Vi (Speed in kt) until 18:29:12 (UTC).

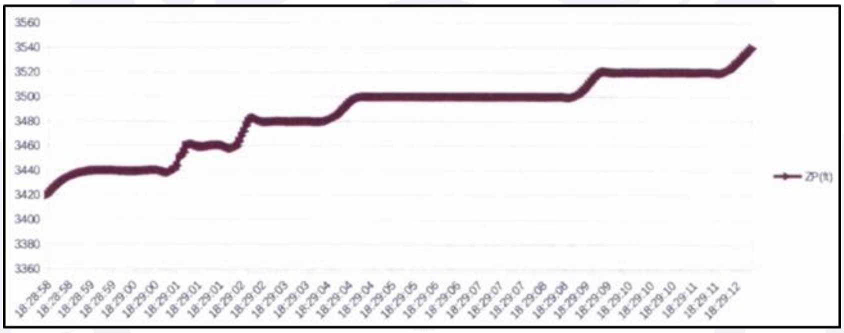


Figure 76 - ZP (Altitude in ft.) to 18:29:12 (UTC).

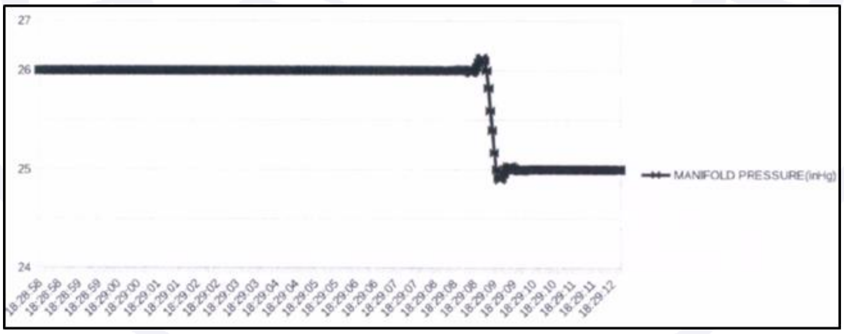


Figure 77 -Manifold Pressure (inHg) up to 18:29:12 (UTC).

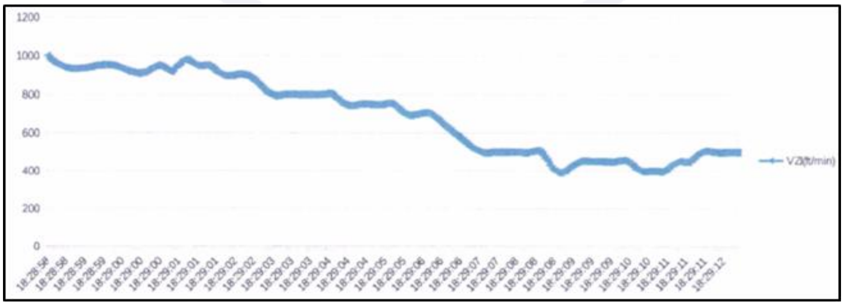


Figure 78 -Vzi (Rate of climb/descent in ft./min) to 18:29:12 (UTC).

Below (Figures 79 to 85), the data obtained by the frame-by-frame observation of the on-board instruments are presented.

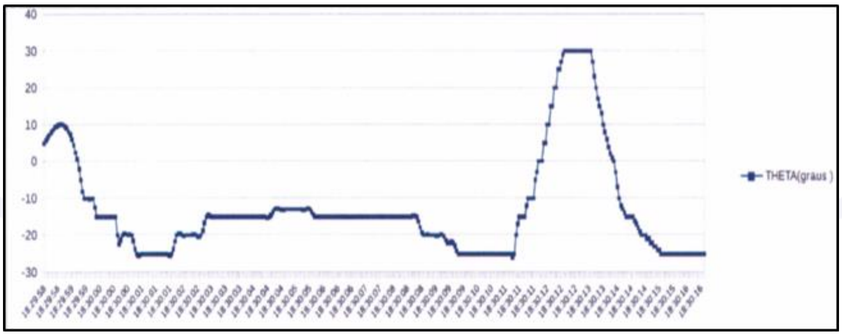


Figure 79 -Theta (Attitude in º) final moments.

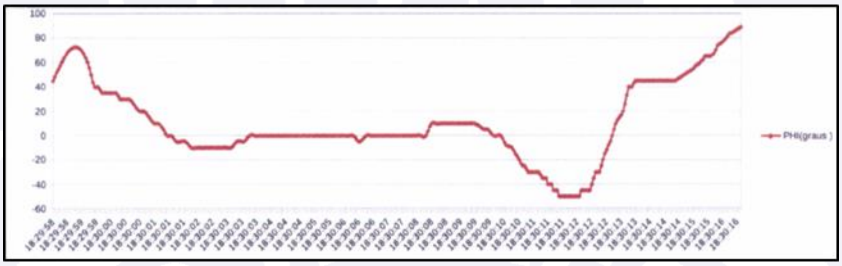


Figure 80 -Phi (bank in º) final moments.

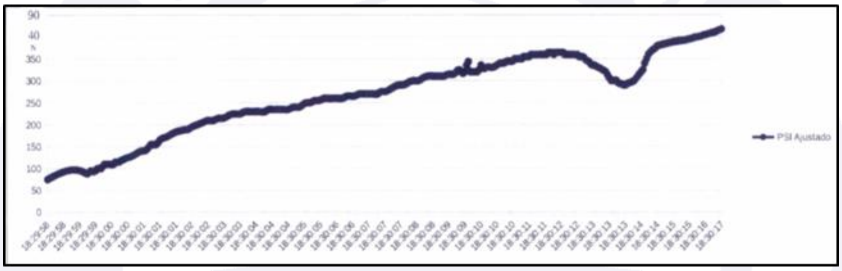


Figure 81 -Psi (Heading in º) final moments.

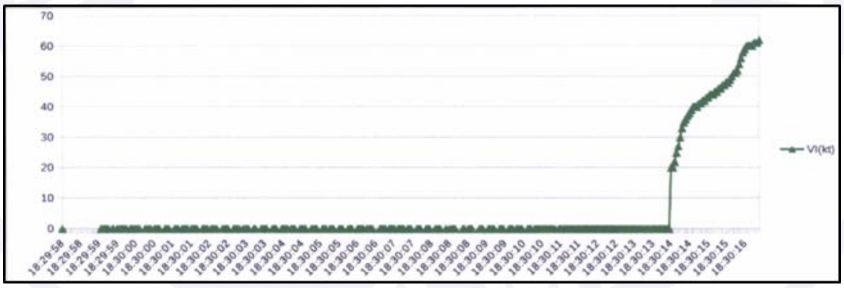


Figure 82 - Vi (speed in kt) final moments.

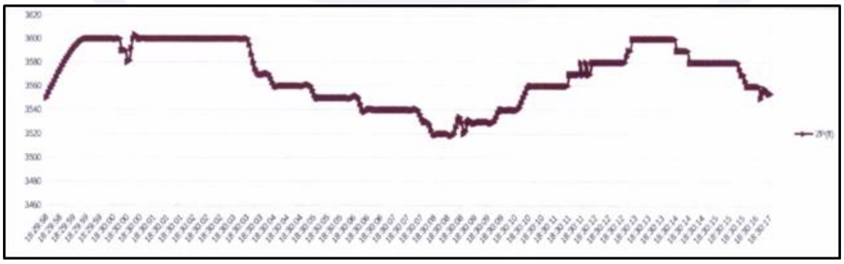


Figure 83 - Zp (Altitude in ft.) final moments.

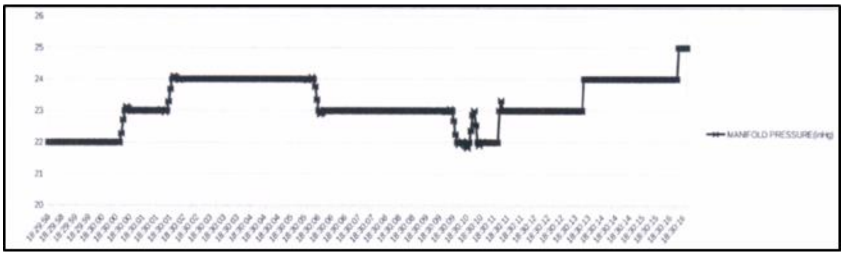


Figure 84 - Manifold Pressure (inHg) final moments.

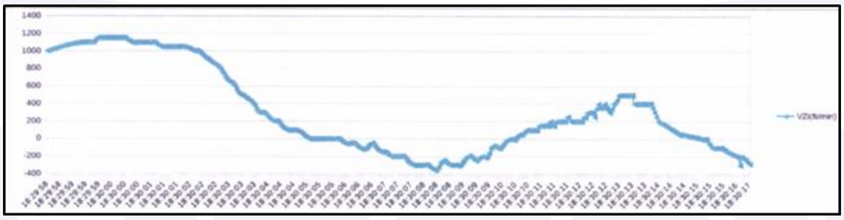


Figure 85 - Vzi (Rate of climb/descent in ft./min) final moments.

Regarding the routine of the pilot in the previous days, it was verified that he carried out flights during the early morning and in the morning of the day of the occurrence. It should be noted that he had been called on the night of 03DEC2016, the accident's eve, to perform the flights in the early hours of 04DEC2016. Throughout the day, he had few opportunities to rest.

By analyzing the last flight missions recorded in the aircraft logbook and the report about the coverage of the show at Anhembi, it was verified that the pilot, between 02DEC2016 and 04DEC2016, had an extensive working day.

Between the first and the second flights in the morning of 04DEC2016, he would have taken an interval of less than two hours.

There followed another interval of approximately two hours, when he performed another flight, and then an interval of four hours before the flight in which he was a passenger. Three and a half hours later, the flight that followed resulted in the fatal accident.

Section "a" of Article 21 of Law 7183/1984, in force at the time of the accident, recommended that:

> "The duration of the aeronaut's workday shall be:
>
> 11 (eleven) hours, if member of a minimum or simple crew"

Also, according to the recommendation on repose in item "c" of Article 34 of the same Law:

> "The rest will have the duration directly related to the journey of the previous day, observing the following limits:
>
> c) twenty-four (24) hours of rest after a journey of more than fifteen (15) hours "

On the flight that originated the accident, a bride was transported to the place of her wedding. According to the information reported, the pilot was familiar with that region, since he had already made other flights to that destination and for the same purpose.

In the recorded video of the flight, it was observed that the passengers showed signs of high anxiety.

1.19 Additional information.

According to the Federal Aviation Administration (FAA) Instrument Flying Handbook:

> "... orientation is the awareness of the position of the aircraft and of oneself in relation to a specific reference point".

The disorientation, therefore, would be the loss of this consciousness. When entering in meteorological conditions of flight by instrument, the pilot loses the visual references with the ground, which affects his perception of where the aircraft is in relation to the terrain.

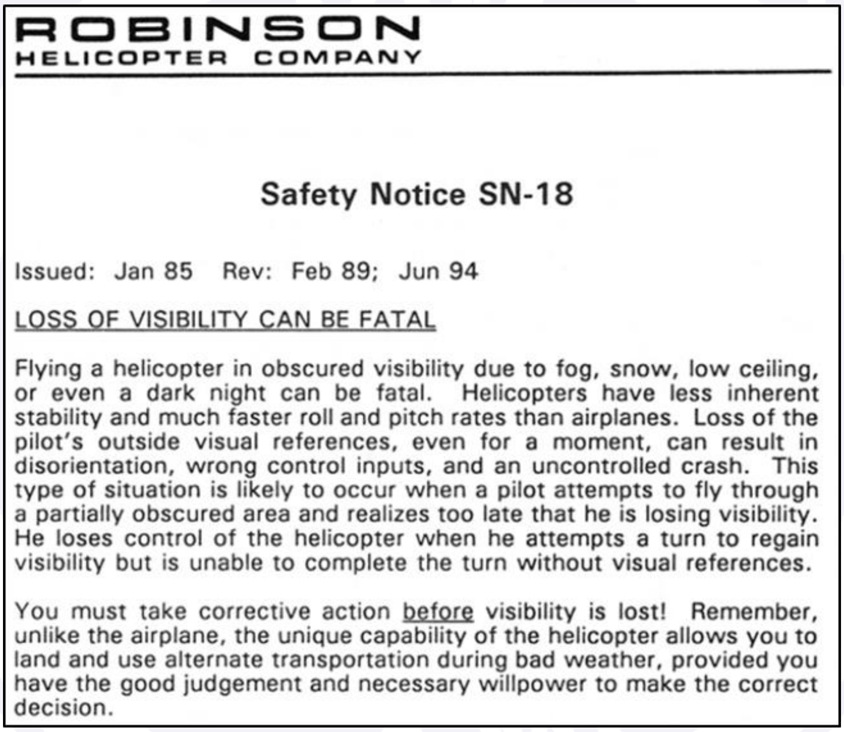
The human orientation capacity in space is dependent on a coordinated system of sensory stimuli, represented mainly by the vision and the labyrinth system, located in the inner ear. The latter provides the sense of static equilibrium of the human body with respect to the surrounding environment.

Without external references, the pilot’s labyrinth balance system can convey different sensations of movement from what is actually happening.

The aircraft model involved in the accident was not certified for flight under IMC conditions.

In the aircraft's flight manual, there was an express limitation for flights to be conducted only under VFR/VMC conditions (meteorology and visual flight rules).

In addition to the constant limitation in chapter II of the aircraft flight manual, there was a Safety Notice alerting users to the risks in case of loss of visibility. The recommendation was to take action not to enter into a condition of loss of visibility (Figure 86).



ROBINSON
HELICOPTER COMPANY

Safety Notice SN-18

Issued: Jan 85 Rev: Feb 89; Jun 94

LOSS OF VISIBILITY CAN BE FATAL

Flying a helicopter in obscured visibility due to fog, snow, low ceiling, or even a dark night can be fatal. Helicopters have less inherent stability and much faster roll and pitch rates than airplanes. Loss of the pilot’s outside visual references, even for a moment, can result in disorientation, wrong control inputs, and an uncontrolled crash. This type of situation is likely to occur when a pilot attempts to fly through a partially obscured area and realizes too late that he is losing visibility. He loses control of the helicopter when he attempts a turn to regain visibility but is unable to complete the turn without visual references.

You must take corrective action before visibility is lost! Remember, unlike the airplane, the unique capability of the helicopter allows you to land and use alternate transportation during bad weather, provided you have the good judgement and necessary willpower to make the correct decision.

Figure 86 - Safety Notice.

In the R-44 model, a tail rotor loss, whether due to mechanical failure or loss of tail-rotor efficiency (LTE), would cause tail turns to the left (nose rotating clockwise) and the speed of this rotation is determined as a function of the power employed, the travel speed (longitudinal and lateral), among other parameters.

The vortex stall occur in vertical descents with applied power, where the helicopter enters its own turbulent air and loses lift.

1.20 Useful or effective investigation techniques.

Data were extracted from the video recorded by one of the passengers for collecting the flight parameters, by the IPEV. The data were analyzed for signs of mechanical failures, aircraft performance and piloting.

2. ANALYSIS.

It was a passenger transport flight between the Osasco Helipad (SSUB) - SP, to the Recanto Beija-Flor party house, located in the municipality of São Lourenço da Serra - SP.

The pilot had PCH and valid HMNC Rating and he was not rated to fly an aircraft under IFR.

There were indications that the flight could be classified as TPX, and that the aircraft was not approved for this type of transport, since it was registered in the TPP category.

The context of informality that characterized the professional relationship between the pilot and the operator favored a flexible working routine and sometimes with little time for proper planning.

It should be noted that the data obtained on the pilot's routine before the occurrence indicated that, on the day of the accident, he had performed flights during the early morning after being called at night.

It is possible that the lack of prior scheduling for these flights has interfered with the pilot's availability of rest, leading to an extended wakefulness condition.

Although the pilot was able to rest in the crew's rest lounge between one flight and another, it was not possible to assess whether he had rested at these intervals or whether the conditions would be favorable to adequate rest given the short time available.

Thus, the work organization to which the pilot was exposed placed him in a condition of greater susceptibility to fatigue, due to sleep deprivation. These circumstances may have hampered the pilot's performance in a critical air operation context, such as that which occurred on the day of the accident.

As for training, there were mistakes in the completion of pilot-student assessment sheets, which, in addition to going against the regulation of the aviation school, did not provide continuity between the flight records filled out by the different instructors. That is, the progress and difficulties faced by the student were not explicit to the subsequent instructor.

The lack of knowledge of the evolution in learning of the student in formation probably led to a subjective evaluation, on the part of the instructor, which could be corroborated by the oscillation of grades in the same maneuvers during the same phase of the stage, or even the absence of a grade.

Another point observed was the lack of standardization in the completion of the evaluation sheets. The field "observations" was often used improperly, sometimes mentioning the maneuvers to be improved, others filled out in disagreement with the grades evaluated, and in many others, it was not even filled.

It is considered pertinent that a maneuver classified as deficient or unsatisfactory to be described and scored so that the next instructor is aware of this deficiency and can help the student to overcome it, repair it, in addition to giving feedback that is more realistic to the student.

As a result of the deficiencies present in the evaluation process, the instructor might not be able to know how to evaluate the evolution of the student's performance, since there was no adequate register in the record.

Such circumstances prevented a process of instruction based on the needs of the student, thus affecting the quality of his training.

Therefore, difficulties were observed in basic maneuvers, phraseology, approach and coordination in advanced stages of the course, which should already be remedied. The student performed the instruction, apparently, without emphasis in these aspects. It was observed, also, the lack of emergency situations and flight safety.

On the assessment sheets, there were few indications of adverse weather conditions (one in phase 2 and two in phase 3). Thus, it is assumed that the pilot in question, despite having hours of flight to act as commander and flight instructor, did not have enough experience in his training to avoid bad weather conditions.

It is possible that the lack of experience in situations with adverse meteorology, together with the possible difficulties in maneuvers of the aircraft, due to the failures in its formation process, could have affected the capacity of the pilot to evaluate and respond adequately to the critical situations related to the meteorological degradation.

As shown in the graphs (Figures 72 to 78), the pilot kept high engine power (Maximum Takeoff Power - PMD) and the aircraft kept climbing (Figure 76).

On this first moment, the attitude variation in relation to the horizon (Figure 72) and the bank (Figure 73) suggest that the pilot was already showing signs of spatial disorientation, since the parameters were not kept stabilized.

There is no evidence of components failure related to aircraft flight commands. The information is compatible with the responses to normal aircraft piloting.

After this initial period in IMC, the camera was directed to the passengers and thus remained for 46 seconds. During this period, even if the instruments were not filmed, it is possible to perceive, due to the sounds collected, that there was an increase in the speed ahead and then a subsequent rapid deceleration until the speed is reduced to zero.

The sequence of images and data observed in the following moments, with the camera focused on the aircraft's panel, corroborated this statement.

From then on, instrument panel images were recorded until the final moments of the flight.

The graphs in the sequence of Figures 79 to 85 were used for the analysis of the hypothesis of failure or loss of the yaw command (tail rotor failure) and vortex stall.

It was not possible to determine exactly what would be the rate of turn of the aircraft on the day of the accident. However, if there were a tail rotor fault, that flight would expect rotations of the order of 60 to 100 degrees/sec, at least.

Figure 81 shows the helicopter's headings at the final moments. If there was a loss of the yaw command there would be no tendency to reverse the heading, which occured at least twice: at 18:30:09 (UTC) very quickly and at 18:30:12 in a more smooth and clear manner.

Thus, it could be ruled out that there has been a failure or loss of the yaw command (tail rotor).

Vortex stalls occur in vertical descents with applied power. In Figure 85, it is seen that there has not been a steady descent, but rather an upward sequence interspersed with a rapid descent.

In addition, the indication of the yaw string on the aircraft windshield demonstrates that there was lateral displacement, and the occurrence of vortex stalls is unlikely.

This leaves only the hypothesis of loss of control of the aircraft motivated by spatial disorientation.

Upon entering instrument meteorological conditions, the pilot lost visual references to the ground, which affected his perception of where the aircraft was in relation to the terrain.

Based on the analysis of the video that recorded the final moments of the flight, the pilot lost all visual references of the external environment for the continuation of the flight. In this way, he tried to guide himself through the instruments available on the aircraft, for which he stared.

Without external references, and associated with the fact that the aircraft is not certified for instrument flight, the pilot labyrinth balance system may have interpreted a static equilibrium situation, inducing the pilot's sensation of flying in a horizontal rectilinear trajectory.

As observed in Figures 72 to 76, when the forward speed was kept close to 90Kt, the stability of the helicopter favored the flight without catastrophic control loss.

By allowing (or commanding) speed reduction to zero, the stability characteristics of the aircraft were altered in the sense of hindering piloting without external visual references.

This means that, for the same command, the reasons for pitching, rolling and yawing increased considerably when compared to the traveling flight.

As shown in Figure 80 the pilot commanded the cyclic on the right, reaching 75° of bank at 18:29:59 (UTC). Realizing it, he reversed the command to the left, but in an overly pitched down attitude (-15 ° to -25 °) and finally precipitated an aggressive 90° banking right.

By analyzing the information from the aircraft panel instruments, confirmed by the examinations and tests carried out on its components, it was concluded that, from the mechanical point of view, there was no evidence that any anomaly had occurred in the aircraft.

The yawing, banking and pitching attitudes were controlled by the pilot, who experienced the phenomenon of spatial disorientation.

Another fact that must be taken into account is that, apparently, the pilot fixed the eye only on the GPS equipment of the aircraft. This fact is relevant because the attitude information shown in the GPS did not match the information of the original equipment of the helicopter.

Although the pilot has entered an unapproved operating condition, using conflicting information tools may have aggravated the situation.

GPS equipment should not be used as a source of attitude information on instrument flights, as they generally use information derived from the shifts to infer the attitude of the aircraft.

Thus, possibly by focusing his attention on GPS information rather than aircraft instruments, the pilot may have failed to observe more accurate information on flight parameters, which could have aided in identifying and reversing spatial disorientation.

When considering the pilot's record of his link with aviation, it is possible that the untimely trips to the flights have, over time, favored a sense of urgency on the flights he was executing.

In this context, it is possible that the pilot felt compelled to proceed with the flight, despite the weather conditions in degradation, since he was close to his destination.

In the video record of the flight, it was observed that the passengers showed signs of high anxiety. Such a reaction may have contributed to raising the pilot's self-imposed pressure to complete the flight as scheduled.

However, in considering that the aircraft was not approved for instrument flight (IFR), the decision to proceed, even with the visual conditions degrading and not capable of operating by instruments, proved to be inadequate.

Failure to comply with the flight rules and guidelines prevised for the operation of that aircraft model compromised flight safety as it increased the risks involved in that air operation.

It is possible that familiarity with that operational context has raised the level of confidence of the pilot to the point of motivating him to continue, in spite of the unfavorable conditions. However, as identified in the filming and in the transcripts of the communications, in the final moments of the flight, the pilot expressed difficulties to locate himself in that region, even though he had already made the journey to the destination other times.

This attitude may have been fostered by the informality that existed in the management of air operations performed with the PR-TUN aircraft, leading to a low adhesion to the norms and values of a safety culture.

It could be concluded that in the last 14 hours before the accident, the pilot underwent an extensive workload, with few intervals between the flights carried out in the period. Thus, the involvement with air activity during this period, together with a possible sleep deprivation, may have made the pilot more susceptible to fatigue.

However, probably pressured by the need to fulfill the flight assignments attributed to him, he underestimated the symptoms of fatigue and continued with the activities.

It should be emphasized that the fatigue condition can impact the skills required for the flight and, in emergency situations, can favor failures in decision-making and problem solving. Thus, the pilot's ability to properly assess flight conditions and their alternatives to that critical condition may have been impaired.

From the point of view of performance analysis and flight qualities, the accident had the point of irreversibility at 18:30:13 (UTC). From that point, there was loss of control of the aircraft, and all other events were consequences of this loss of control.

There are indications that the helicopter has reached 140° of bank and 30°pitched down, already with a high rate of descent.

In this condition, it is possible that the lubrication of the engine has been impaired by the action of gravity, which would have caused the OIL PRESSURE and AUX FUEL PUMP illumination.

After loss of control, the main rotor hit the front of the fuselage. There was loss of various components and large damage in the structure with the helicopter still in the air.

The camera was launched into the air and recorded the image of the damaged aircraft, proving that there was damage to the front of the helicopter before contact with the ground.

As for the meteorological conditions, it was observed that between 1800 (UTC) and 1820 (UTC), they degraded on the location of the accident.

The weather radar images reported the cloud cover, as well as light to moderate rainfall over the region during the approximate time of fall.

The METAR information served as an aid in verifying the height of the cloud base, but it is important to emphasize that it was not possible to accurately state that the clouds which passed over the accident region were at the same level as those reported at aerodromes, once the relief and weather characteristics of the accident area were not the same as the airports.

The distance from the METAR data collection point is another limiting factor. Even so, it could be observed that, as the hours passed, at both airports, the cloudiness increased and the height of the cloud base fell to between 800ft and 2.000ft, in relation to the altitude of each Aerodrome.

Regarding communications, they were not established with the control bodies. In the conversations between the passengers and the crew, extracted from the filming, no situations were raised that could have affected the performance of this one.

During the investigation, it was observed that all items inspected were operational. No evidence of malfunction of components that could have contributed to the occurrence was found.

The observed aspects indicated that the fractures observed occurred due to overloading, due to the application of stress above the support of the structure and not of failure due to fatigue or impact at the fracture site.

Based on factual information and in accordance with the flight manual, the aircraft operated within the limits established by the manufacturer until the entry into IMC.

It could be concluded that the helicopter had sufficient power to perform the intended flight in normal engine operation.

From the images obtained, it was possible to verify that the engine remained in normal operation until the moment the helicopter was out of control at 18:30:18 (UTC).

The loss of control was evidenced by the illumination of the low rotation rotor light (LOW RPM). The ignition of this light occurs when the main rotor rotation reaches 97% or less, according to the Robinson Helicopter Company Pilot's Operating Handbook (page 7-25).

At the same time as the light was switched on, the buzzer sounded. There are a number of factors that may have led to a decrease in rotation below the safety limits set by the manufacturer.

In the aircraft flight manual, power failure is described as a fault caused by engine or transmission failure, but the characteristic indications of such failures have not occurred.

The illumination of the LOW RPM light in the present case was motivated by an excess load factor caused by the maneuver performed. In Figure 64, it was found that the engine (Engine RPM) and rotor (NR) rotations were synchronized.

The applied power was higher than the expected maximum power. The Manifold Pressure indicated 24inHg, which was the Maximum Takeoff Power (PMD) limit and according to page 2-9 of the aircraft manual, the Maximum Continuous Power (PMC) was 21.8inHg.

It was observed that the attitude indicator (artificial horizon) showed a right inclination between 45° and 50°, and the aircraft climbed with 400ft/min. Such information led to the conclusion that it was applied cyclic to the right and back, increasing the load factor in the main rotor, which would require more power than the maximum supplied by the engine, with the initial consequence of the NR falling.

As provided in the aircraft flight manual, in case of the LOW RPM light on, the pilot should reduce the collective and adjust the speed. None of these procedures were performed, which corroborates the hypothesis that there was loss of control of the aircraft and not an engine failure.

From the information obtained, it was concluded that there was no engine failure or transmission failure. The illumination of the LOW RPM light was a consequence of the increase of the load factor in the main rotor, due to the loss of control of the aircraft.

No evidence was found of problems related to the performance of the aircraft that may have contributed to the accident.

3. CONCLUSIONS.

3.1 Facts.

a) the pilot had valid Aeronautical Medical Certificate (CMA);

b) the pilot had valid HMNC Rating;

c) the pilot was qualified and had experience in that kind of flight;

d) the aircraft had valid Airworthiness Certificate (CA);

e) the aircraft was within the limits of weight and balance;

f) the airframe and engine logbooks records were updated;

g) the meteorological conditions were not favorable for the flight;

h) the aircraft was not certified for IFR flight;

i) the aircraft was registered in the TPP category;

j) the pilot has worked more than the legislation prevised;

k) there was loss of control of the aircraft in flight;

l) the aircraft was destroyed; and

m) the pilot and the 3 passengers suffered fatal injuries.

3.2 Contributing factors.

- **Anxiety – undetermined.**

Reactions caught by the camera suggested signs of high anxiety from the passengers, which may have promoted self-imposed pressure on the part of the pilot, contributing to the decision to complete the flight as scheduled.

- **Attention – undetermined.**

It is possible that relevant information provided by aircraft instruments has not been observed by the pilot, whose focus could be on the GPS information. Such attention shifting may have favored disorientation as it reduced the proper perception of flight parameters.

- **Attitude – a contributor.**

The flight rules, as well as the guidelines contained in the Flight Manual, were not properly observed by the pilot. In that sense, the continuation of the flight denoted an excessive confidence of the crewmember in his capacity, to the detriment of the adverse conditions present.

- **Training – undetermined.**

It is possible that the low exposure to adverse weather conditions affected the ability to identify, evaluate and respond promptly to the situation experienced on the flight that caused the accident.

These difficulties may have been exacerbated, due to the failures related to the pilot training process, which did not have standardized evaluation actions and corrective actions according to the level of performance of each student.

- **Adverse meteorological conditions – a contributor.**

Adverse weather conditions seriously impaired the pilot's spatial orientation in the visual aspect, since he had no visual references that could guide his trajectory.

- **Disorientation – a contributor.**

Upon entering IMC flight conditions, there was loss of visual references and awareness of the position of the aircraft, causing loss of control.

- **Fatigue – undetermined.**

Flights performed on the day before and on the day of the accident, coupled with the short time available for rest and possible sleep deprivation to meet such demands, may have induced the pilot to fatigue and degraded his performance during the flight.

- **Piloting judgment – a contributor.**

The pilot opted to join in adverse weather conditions and to continue the flight, without having technical qualification, specific training and aircraft certified for IFR conditions.

- **Work organization – undetermined.**

The routine performed by the pilot increased the conditions of susceptibility to fatigue, due to the few opportunities for adequate rest and sleep.

This context may have hampered the pilot's performance during critical flight management.

- **Perception – a contributor.**

Visibility restrictions and consequent loss of visual references promoted favorable conditions for pilot disorientation and loss of control of the aircraft, due to an inaccurate perception of the helicopter's behavior and its position in relation to the terrain.

- **Flight planning – a contributor.**

The lack of knowledge of the route operational conditions, mainly regarding the meteorological conditions, denoted a poor planning.

- **Decision-making process – a contributor.**

The decision to proceed with the flight in degraded meteorological conditions denoted an imprecise assessment of the conditions in that operational context, setting up a failed decision-making process.

- **Flight Indiscipline – a contributor.**

The pilot did not comply with the visual flight rules when entering adverse weather conditions, allowing the occurrence of spatial disorientation.

4. SAFETY RECOMMENDATION.

A proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident. In addition to safety recommendations arising from accident and incident investigations, safety recommendations may result from diverse sources, including safety studies.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of the air activity operational safety, and shall be treated as established in the NSCA 3-13 "Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State".

Recommendations issued at the publication of this report:

To the Brazil's National Civil Aviation Agency (ANAC):

A-157/CENIPA/2016 - 01 **Issued on 08/06/2019**

Act with AGD Aviation Escola de Aviação Civil LTD., in order to verify if that organization continuously meets the requirements established in the current regulation, especially what is foreseen in MMA 58-4 (Private Pilot Course Manual – Helicopter), and operates with the appropriate levels of competence and safety required for the performance of the activities for which it is certified.

A-157/CENIPA/2016 - 02 **Issued on 08/06/2019**

Perform an audit on the Helicop Chart. Serv. Brazil Taxi Aer., in order to verify the compliance of its Safety Management System, the control of its crew's fatigue and the suitability of its aircraft for non-scheduled public air transportation.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

None.

On August 6th, 2019