COMMAND OF AERONAUTICS

AERONAUTICAL ACCIDENT INVESTIGATION AND PREVENTION CENTER

FINAL REPORT
A-103/CENIPA/2014

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PT-YJJ**
MODEL:	**AS 350 BA**
DATE:	**07 JUNE 2014**

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 item 3.1, 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 7 June 2014 accident involving the AS350BA aircraft, registration PT-YJJ. The accident was classified as loss of control in flight.

The aircraft crashed into the ground at a distance of 430 meters from the point where it started takeoff.

The aircraft sustained substantial damage.

As a result of the crash, the pilot and four passengers suffered fatal injuries.

An accredited representative from the French BEA (*Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile*) was designated for participation in the investigation..

CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ANAC	Brazil's National Civil Aviation Agency
ATS	Air Traffic Services
ATSB	Australian Transport Safety Bureau
ATZ	Aerodrome Traffic Zone
CA	Airworthiness Certificate
CENIPA	Aeronautical Accident Investigation and Prevention Center
CHT	Technical Qualification Certificate
CMA	Aeronautical Medical Certificate
CTR	Control Zone
DCTA	Department of Science and Airspace Technology
FAA	Federal Aviation Administration
FCU	Fuel Control Unit
GPS	Global Positioning System
GRAER	Air Radiopatrol Unit of the Goiás State Military Police
IAM	Annual Maintenance Inspection
IBAMA	Brazilian Institute of the Environment and Renewable Natural Resources.
ICA	Command of Aeronautics' Instruction
IFR	Instrument Flight Rules
IFRH	Helicopter Flight IFR rating
IMC	Instrument Meteorological Conditions
Lat	Latitude
Long	Longitude
NM	Nautical Miles
NTSB	National Transportation Safety Board (USA)
PCH	Commercial Pilot – Helicopter category
PM-GO	Goiás State Military Police
PPR	Private Pilot – Airplane category
PPH	Private Pilot – Helicopter category
RBAC	Brazilian Civil Aviation Regulation
RBHA	Brazilian Aeronautical Certification Regulation
SBGO	ICAO location designator - Santa Genoveva Airport
SBUL	ICAO location designator – Lt Col Aviator César Bombonato Airport
SERIPA	Regional Aeronautical Accident Investigation and Prevention Service
SIKL	ICAO location designator – Flamboyant Helipad
SIPAER	Aeronautical Accident Investigation and Prevention System
SJPI	ICAO location designator - *Planalto Indústria Mecânica* Helipad

SWFP	ICAO location designator - *Fazenda Planalto* Helipad
SWNV	ICAO location designator - Nacional de Aviação Aerodrome
TMA	Terminal Control Area
UTC	Universal Time Coordinated
VHF	Very High Frequency
VFR	Visual Flight Rules

1. FACTUAL INFORMATION

Aircraft	**Model:** AS 350 BA **Registration:** PT-YJJ **Manufacturer:** EUROCOPTER	**Operator:** *Planalto Indústria Mecânica Ltda.*
Occurrence	**Date/time:** 07JUN2014 / 04:27 (UTC) **Location:** Camp on island of the Araguaia River **Lat.** 14º47'55"S **Long.** 051º 02'42"W **Municipality – State:** Aruanã – Goiás	**Type:** Loss of control in flight

1.1 History of the occurrence

At 01:27 local time, the aircraft with the pilot and four passengers on board started the takeoff from a camp located in an island of the Araguaia River, destined for a residence in the city of Aruanã, at a distance of 14 km from the point of origin.

The first part of the takeoff was vertical, followed by a counterclockwise movement and normal departure.

The aircraft crashed into the ground at a distance of 430 meters from the point of departure.

The aircraft sustained substantial damage.

The pilot and the four passengers suffered fatal injuries as a result of the impact. One of the passengers was still alive when rescued from the site by the Firefighters' Rescue Team, but did not resist and died.

Figure 1 – Distribution of the PT-YJJ aircraft wreckage.

1.2 Injuries to persons

Injuries	Crew	Passengers	Third parties
Fatal	1	4	-
Serious	-	-	-
Minor	-	-	-
Uninjured	-	-	-

1.3 Damage to the aircraft

There was substantial damage to the whole structure of the aircraft.

1.4 Other damage

None.

1.5 Information on the personnel involved

1.5.1 Crew's flight experience

Hours Flown	
	Pilot
Total	Unknown
Total in the last 30 days	15:40
Total in the last 24 hours	01:30
In this type of aircraft	Unknown
In this type in the last 30 days	15:40
In this type in the last 24 hours	01:30

N.B.: The term "unknown" was used on account of discrepancies of the information available in a number of documents.

In his Pilot's Flight Logbook (opened and sealed by the GRAER PM-GO - Air Radiopatrol Unit of the Goiás State Military Police) on January 1st, 2010, the total hours flown were 3,608.

In his health checkup form, in May 2014, the pilot declared a total of 7,280 hours.

In the health check form of May 2014, the total number declared was 5,630 hours.

According to the GRAER statistics from January 2006 to January 2011, the pilot flew a total of 651 hours, 575 of which on AS350 aircraft.

According to the PT-YJJ aircraft logbook, the pilot flew 549.1 hours between 14 October 2011 and 6 June 2014.

1.5.2 Professional formation

The pilot did his Private Pilot Course (Helicopter category) at the *Aeroclube de São Paulo* (*São Paulo Flying School*) in 1999.

1.5.3 Validity and category of licenses and certificates

The pilot had a Commercial Pilot license (Helicopter category), and his H-350 Technical Qualification Certificate was valid.

The pilot was not IFR-rated for helicopters.

1.5.4 Qualification and flight experience

The pilot had qualification for night-time VFR in ATZ, CTR and TMA, or within a radius of 27NM from the aerodrome/helipad of origin.

1.5.5 Validity of medical certificate

The pilot had a valid Aeronautical Medical Certificate.

1.6 Aircraft information

The mono-turbine rotary-wing AS350BA aircraft was manufactured by EUROCOPTER in 1998, and had approval for day and night time VFR operations.

Its Airworthiness Certificate was valid.

Its last Annual Maintenance Inspection was done simultaneously with the 10-, 25-, 30-, 50-, 100-, 150-, 200-, and 600-hours inspections, as well as with the 3- and 6-months inspections, and was finished 26 February 2014, by the *Fênix Manutenção e Recuperação de Aeronaves Ltda.* Workshop. After the Annual Maintenance Inspection, the aircraft flew 49 hours and 20 minutes.

The aircraft had a total of 3,846.8 airframe-hours since new.

The AS350BA Maintenance Program is described in the Eurocopter's *Master Servicing Manual – MSM*, chapters 4 and 5. There are scheduled inspections programmed according to both calendar time and amount of hours flown.

According to the aircraft airframe logbook, between the date of the last inspections (26 February 2014) and the date of the accident (7 June 2014), there were no records relative to the 10-, 25-, 30-hours, 7-days, 1-month, and 3-months inspections, prescribed in the manufacturer's maintenance program.

Among the tasks of the inspections, there were maintenance actions or verification of the main rotor, main rotor mast, main rotor blades, tail rotor blades, treatment against fungi in the fuel system, and protection of the fuselage structure against corrosion.

In the aircraft logbook, between the date of the last inspection (26 Feb 2014) and the date of the accident (7 June 2014), there were no records of failure/malfunctioning of the aircraft equipment and systems.

1.7 Meteorological information

At the time of the occurrence, the prevailing meteorological conditions were VMC, visibility more than 10 km, SKC, temperature 25ºC, wind calm.

1.8 Navigational aids

Nil.

1.9 Communications

Nil.

1.10 Aerodrome information

The occurrence was outside of aerodrome area.

1.11 Flight recorders

Neither required nor installed.

The aircraft was equipped with a portable Garmin model Aera 500 GPS, which recorded part of the flight. The data stored in the memory of this equipment is presented in the item 1.18 - Operational Information.

1.12 Impact and wreckage information

The point of first impact was at a distance of 430 meters from the point where the takeoff began (figure 2).

The aircraft wreckage was spread for 61 meters between the point of first impact to the point where the aircraft came to a stop (figure 2), on a magnetic bearing of approximately 190°.

Between the point where the takeoff began and the point of first impact, there was a vegetation-covered area, in which the ground was located at a height of about four meters above the point of departure of the aircraft, with bushes of up to two meters (Figures 2 and 3).

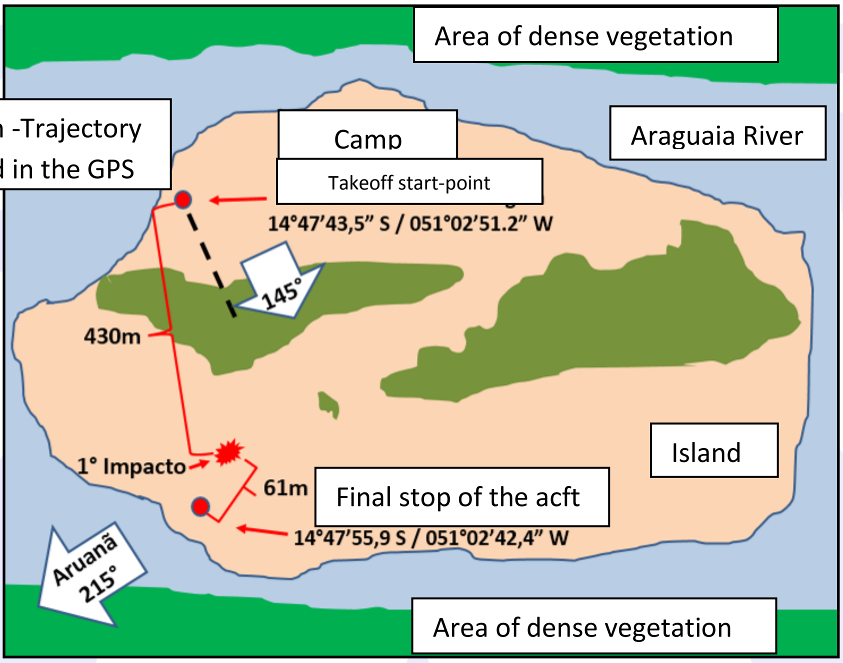


Figure 2 – Sketch of the departure site, with the point of first impact and the point of final stop. The dotted line represents the 200 meters of trajectory of the initial phase of departure, on the magnetic heading 145°, recorded in the GPS memory.

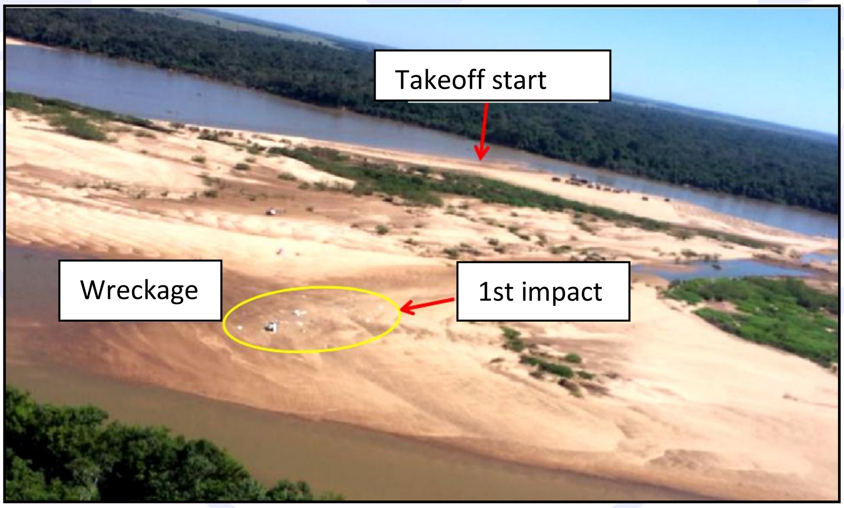


Figure 3 – Aerial photograph of the departure site, with the point of first impact and distribution of wreckage.

Figure 4 – Air view of the crash site. The red arrow indicates the initial points of impact.

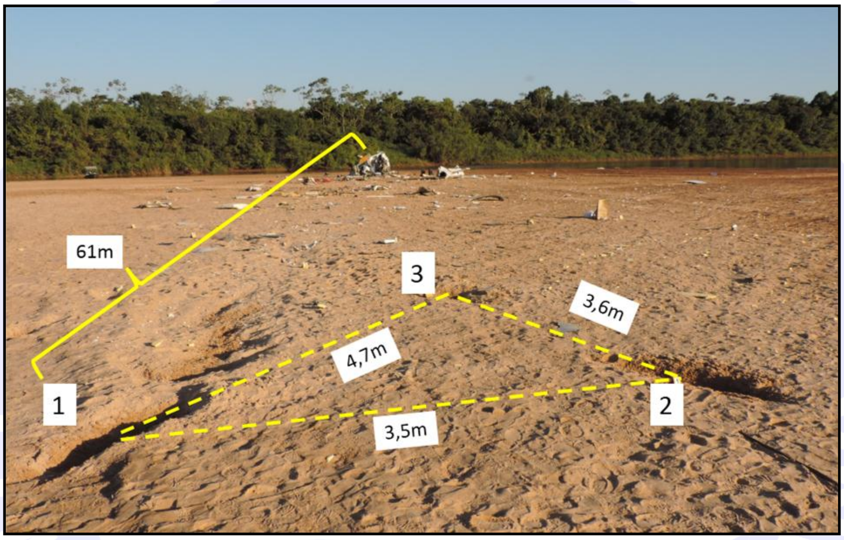


Figure 5 – Initial points of impact: 1 – front part of the right ski; 2 and 3 – cuts in the terrain made by the tips of the main rotor blades.

At point 1, traces of white paint from the end of the right ski were found.

Figure 7 – The end of the right ski, in highlight, was repositioned for evaluation.

At point 2, the metal component of the tip of one of the main rotor blades was found. At a distance of approximately 0.3 meters from point 3, another similar metal component was found.

In the direction of movement, to the right and sides of the points 2 and 3, there were fragments of the aircraft lateral windows.

Figure 8 – Point 2: in highlight, the metal component of the tip of one of the main rotor blades.

Figure 9 – To the side of point 3, highlighted by a yellow circle, fragments of the lateral windows.

At point 2, the blade made a cut in the terrain at an angle of 32º; at point 3, the cut was at an angle of 43º.

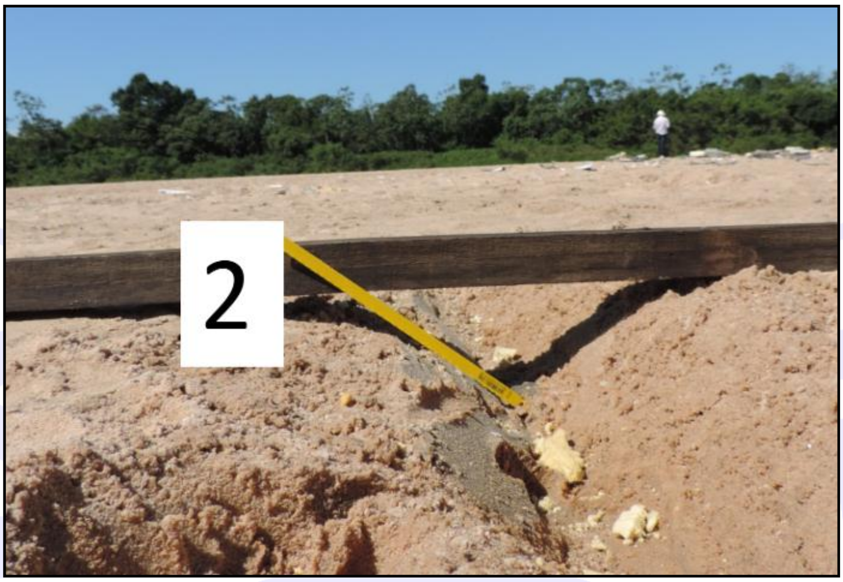


Figure 10 – Cut in the terrain at point 2, made by the main rotor blade (angle of 32°).

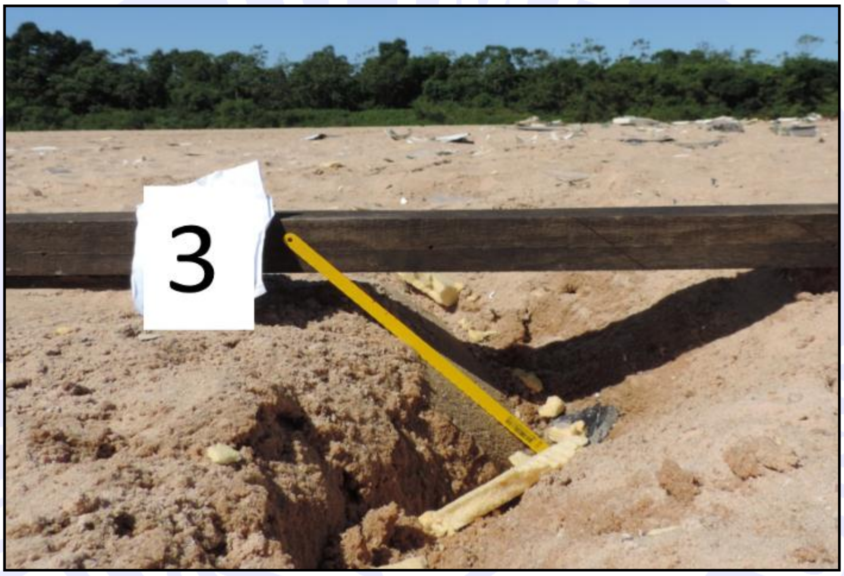


Figure 11 – Cut in the terrain at point 3, made by the main rotor blade (angle of 43°).

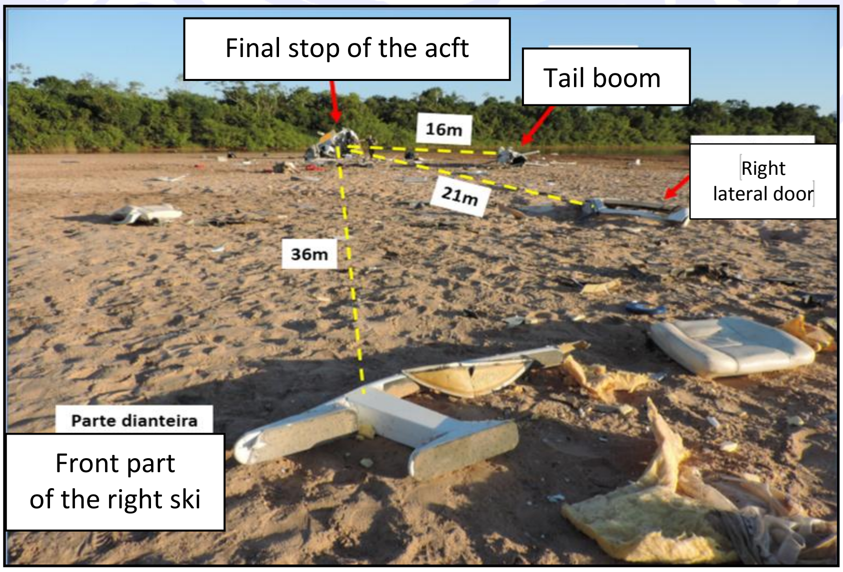


Figure 12 – Positions of the front part of the right ski, right hand side door and tail boom, at the final stop of the aircraft.

The right side of the front section, on the underside of the aircraft, sustained more damage and a more significant displacement of the floor in a down-up direction when compared with the left side.

Figure 13 – Damage to the underside of the aircraft front section.

In the figure below, it is possible to observe a more intense destruction fo the cabin floor on the right side of the aircraft.

The main rotor blades were substantially damaged, as would be expected in the situation of high rotational energy with which the aircraft impacted the ground. Fragments of the main rotor blades were scattered within a radius of 12 meters around the initial points of impact. (points 2 and 3 of figure 5).

Figure 14 – Main rotor blades after the full stop of the aircraft.

Along the line of wreckage, the first parts found belonged to the cabin structure (several fragments of the cowling, metal fragments of the lower part of the cabin, windshield, and part of the central column of the windshield).

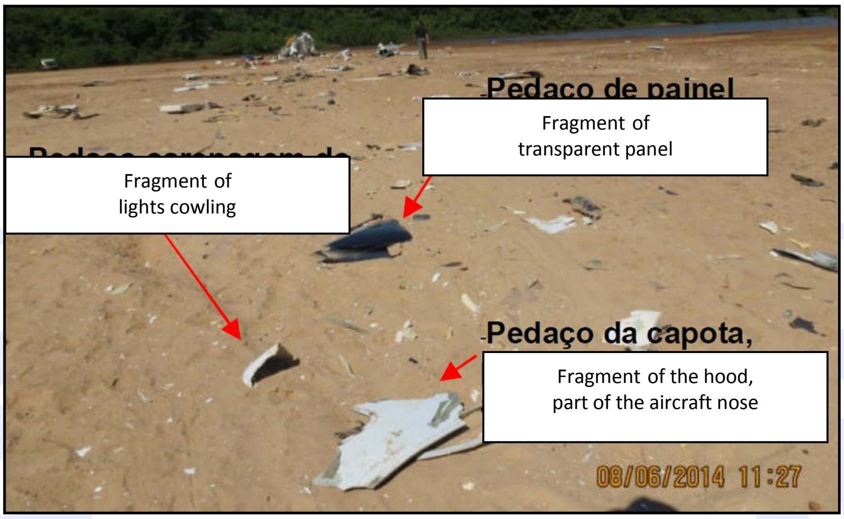


Figure 15 – First fragments of the aircraft found ahead of the point of first impact.

In the figure below, it is possible to observe part of the transmission shaft, connected to the engine of the aircraft. A the point of breakage, in highlight, it is possible to see signs indicative of significant rotational movement at the moment of fracture.

Figure 16 – Main rotor activation shaft connected to the engine. In highlight, the point of fracture.

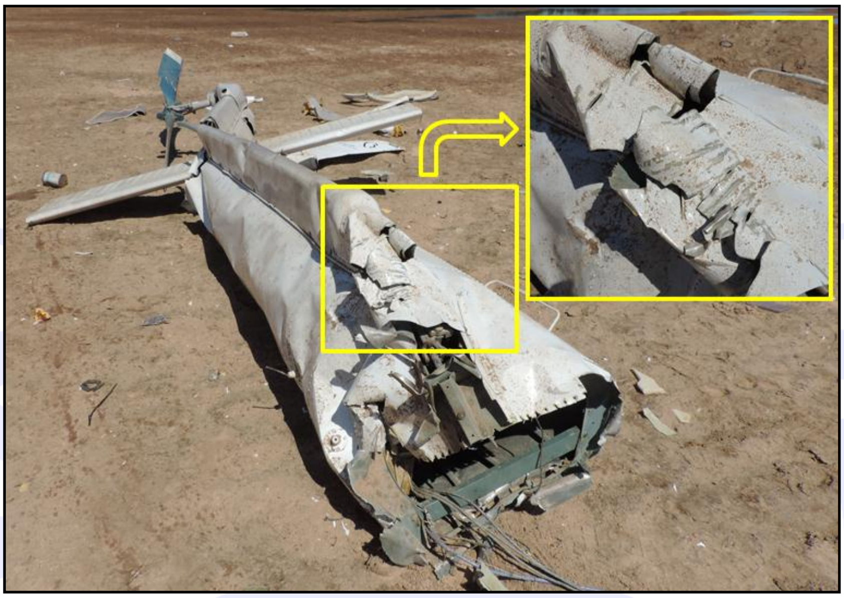


Figure 17 – Damage to the cowling of the tail rotor activation shaft, indicating high rotation movement at the moment of fracture and separation.

The aircraft landing light was found in the midst of the wreckage. The filament of the lamp was intact.

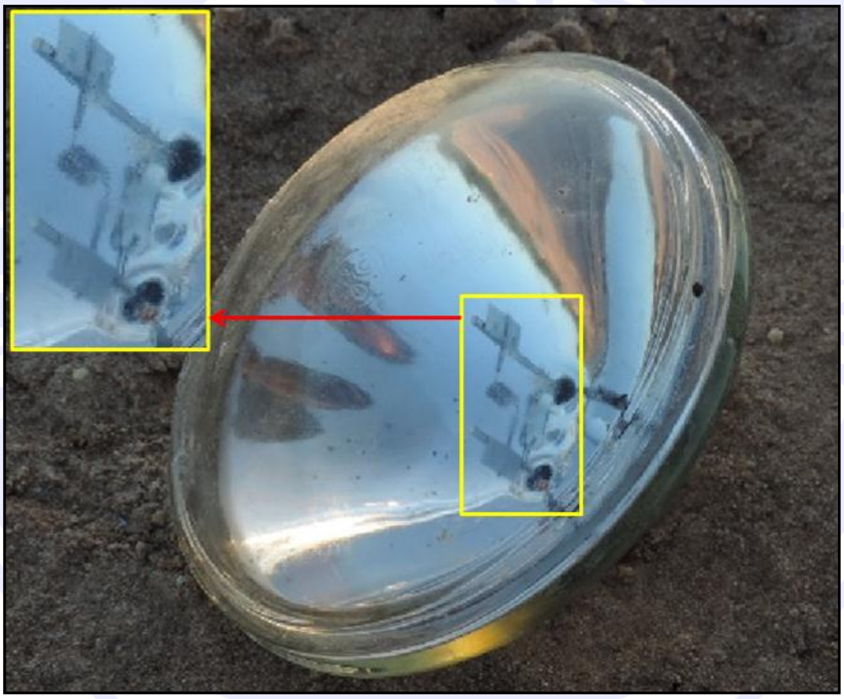


Figure 18 – Headlight with an intact filament.

The main rotor pitch control rods and the hydraulic servos' rods were duly connected and cotter-pinned.

The chains of command of the lateral cyclic, longitudinal cyclic, and collective were examined, and the anomalies found resulted of torsions, tractions and rupture of the structure on account of the impact of the aircraft with the ground.

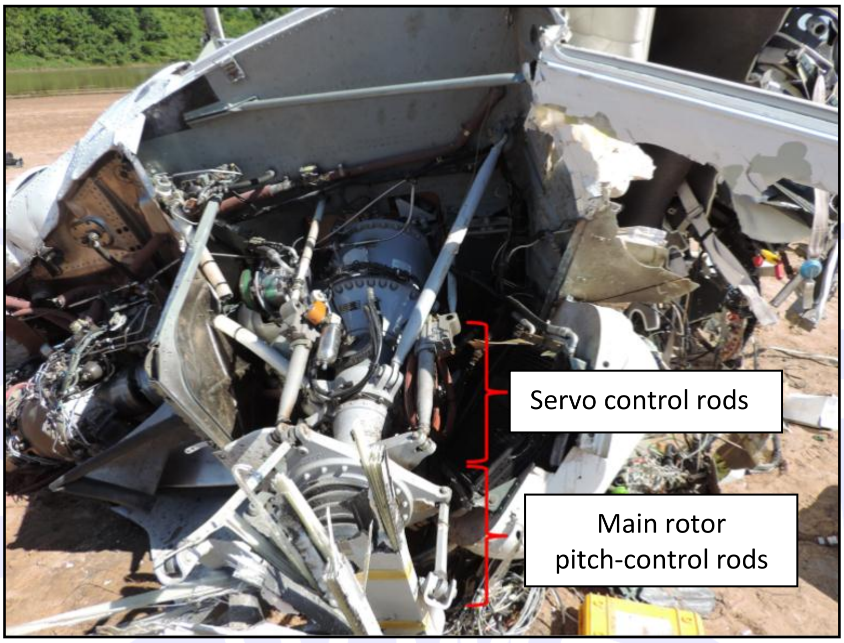


Figure 19 – Rods of the main rotor pitch control and of the servo controls.

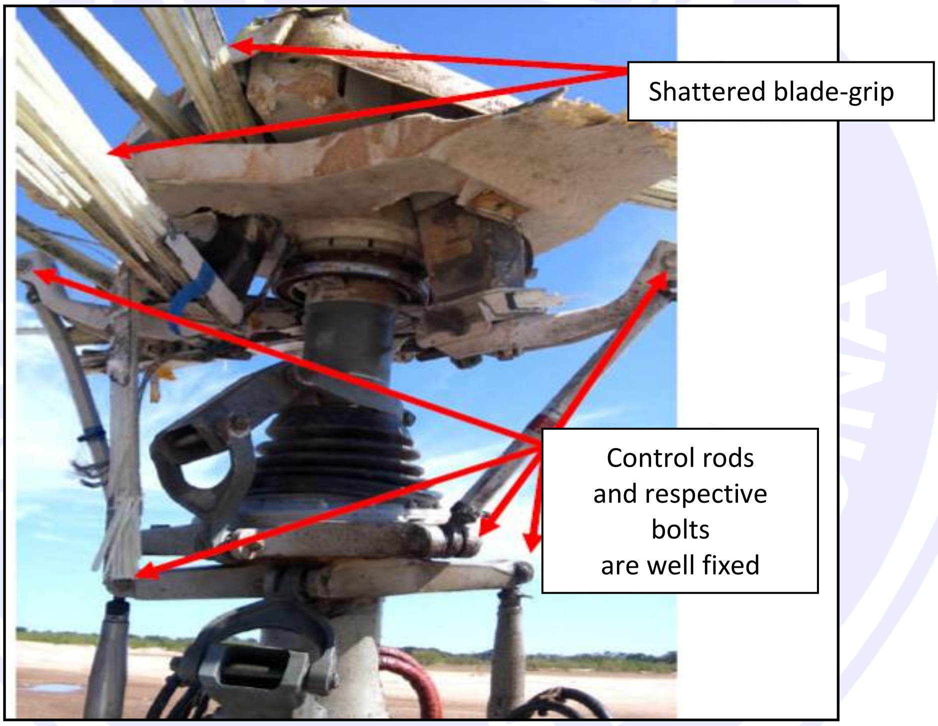


Figure 20 – Control rod and respective bolts with normal fastening.

The shattered blade grips shown in the previous figure resulted from the high energy rotation at the impact.

It was observed that there was no cyclic control in the left piloting position. Neither were there in the place designed for lodging the cyclic any signs of damage indicative of a contingent separation due to impact. In addition, the lid used to cover the empty space of the cyclic lodging was found.

The control of the cyclic of the right-hand side piloting position was found five meters short of the place where the control cabin had stopped.

Figure 21 – Left-hand side piloting position. The yellow circle shows that the cyclic was not installed. The red arrow shows the lid that was installed to cover to cyclic lodging.

Figure 22 – Cyclic of the right-hand side piloting position, found at a distance of five meters from the aircraft cabin.

All attachment points of both the pedal and cyclic control rods were with their bolts well fastened.

The position of the power levers (figure 25) was not reliable, due to damage and motions sustained by cabin when the impacts occurred.

The fuel tank did not sustain any breakage. The fuelling opening separated from the fuselage because of the impacts. Such disconnection allowed sand and humidity to enter and contaminate the fuel after the accident. More than 120 liters of fuel remained in the tank.

Figure 23 – Fuel tank of the aircraft.

1.13 Medical and pathological information

1.13.1 Medical aspects

The pilot was 50 years old, and his last health checkup was done on 21 May 2014, at the Brazilian Air Force Hospital in Brasilia. According to the result issued by the Special Board of Health, he was considered fit for the air activity.

Pilot's routine

From the interviews, as well as from the data contained in the aircraft GPS memory, the following information was gathered in relation to the pilot's routine in the 72 hours preceding the accident:

4 June 2014:

- The pilot did not fly. He participated in social events, with his family and friends, and returned home at about 22:30. His rest period is estimated to have begun at 23:30.

5 June 2014:

- Due to the fact that the GPS was turned on in the helipad of the operating company at 6:05 local time, it is estimated that the pilot had woken up at 4:30, considering the time spent for routine tasks, commute to work and preparation of the aircraft for departure at 6:20.
- At 6:20, the pilot took off from the *Planalto* company, bound for the *Aeródromo Nacional de Aviação*, in Goiânia, where he landed at 6:28. Between 7:18 and 7:20, the records show a probable repositioning flight on the apron of the aerodrome.
- He took off from Goiânia at 8:17, and arrived in Anápolis at 8:46.
- At 10:43, he took off from Anápolis, destined for Anhanguera, where he arrived at 12:03.

- In the last leg of 5 June 2014, the pilot took off from Anhanguera at 16:21 and arrived in Goiânia at 17:20.

6 June 2014:

- The pilot took off from the Planalto company at 10:50, destined for the *Aeródromo Nacional de Aviação*, where he landed at 11:05.
- At 11:48, the pilot departed from the *Aeródromo Nacional de Aviação*, bound for the helipad of the Planalto company, and landed at 11:54.
- At 12:27, the pilot departed from Goiânia, destined for the aircraft owner's residence, in the city of Aruanã, landing at 13:44.
- Between 14:00 and 19:00 approximately, the pilot remained in a room reserved for him. It was not possible to confirm whether he slept during this period.
- At 19:26, the pilot took off from the residence for a camping area in an island located at a distance of 14 km from Aruanã. The flight lasted 10 minutes.
- According to reports, he passed the time in the camp playing cards with his passengers up to the time of departure for his return to Aruanã.

07 June 2014:

- At about 1:22, the pilot left the hut where he was playing cards, with the intention of returning to Aruanã. The takeoff of the accident flight started at 1:27.

<u>Exams – Autopsy, Drugs, and Blood-Alcohol Level</u>

According to the autopsy, the excoriation on the left part of the pilot's chest could suggest a mark made by a belt. There were no comments about marks on the abdomen.

In the photos taken by the Goiás State forensic police, it was possible to observe excoriations on the left part of the pilot's chest and abdomen, one next to the left iliac crest, and another one in the same direction but in the epigastric region.

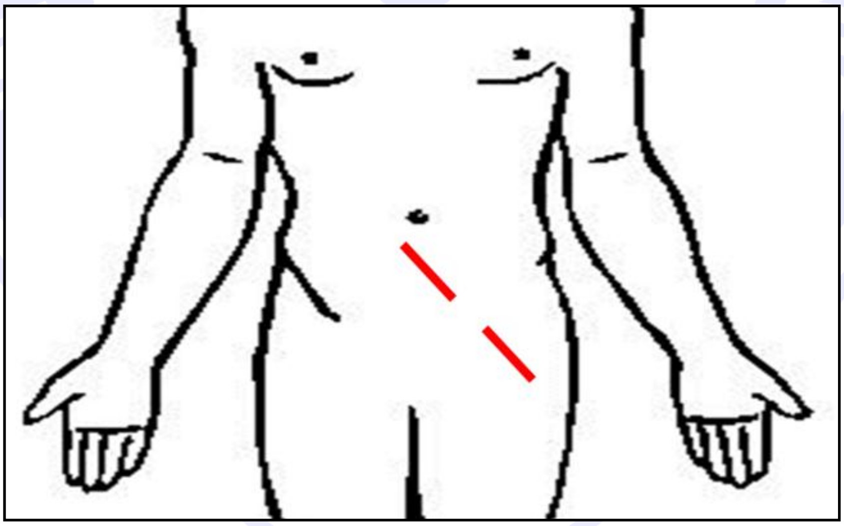


Figure 24 – Drawing representative of the excoriations in the abdominal region, as found in the pilot's body.

After the accident, drug and blood-alcohol level tests were carried out by the Internal Research Coordination in the premises of the Criminology Institute of the Goiás State Public Security Board.

The toxicology test was done by means of a competitive chemiluminescence immunoassay with a Randox Evidence Investigator semi-automatic analyzer, using the

Drugs of Abuse Array I Whole Blood Plus kit for detection of: amphetamines, barbiturates, benzodiazepines, buprenorphine, carboxy THC (THC metabolite), benzoylecgonine (metabolite of cocaine), methamphetamine, methadone, MDMA, opiates, phencyclidine, and tricyclic antidepressants. The analysis of the collected materials did not indicate the presence of these substances.

The blood-alcohol level exam of the pilot's blood sample resulted negative for the presence of alcohol.

Adaptation to darkness

A person who was with the pilot and his passengers in the camp reported that as soon as they decided to return to Aruanã, they left the brightly illuminated hut where they had been playing cards and went directly to the aircraft, apparently without taking the time to adapt to darkness.

Adaptation to darkness is recommended for night flights, and it takes from 30 to 45 minutes for a person to achieve maximum adaptation to minimal lighting conditions.

In the case of a pilot not adapted to darkness, the probability of occurrence of a visual illusion increases significantly because vision acuity and depth are reduced in the dark.

Visual illusion

Pilots are especially susceptible to poor perception of the horizon (false horizon illusion) when flying at night. Isolated lights on the ground may appear to them like stars, creating the illusion that the aircraft is in a nose-up attitude.

Conversely, with an overcast sky, without visibility of the stars and the moon, with the aircraft flying over a dark area, may induce the pilot to experiencing the illusion that the terrain in the dark is part of the sky.

The visual system is the most important of the systems which foster the maintenance of spatial orientation, and the majority of disorientation cases are associated with few visual references, such as during night-flights and IMC conditions.

Spatial Disorientation, according to the *Australian Transport Safety Bureau, Aviation Research and Analysis Report – B2007/0063 Final*:

The *Federal Aviation Administration (FAA)* in its *Advisory Circular* (AC 60-4A) of 1983 provided a simple definition for spatial disorientation, by stating that for the pilot, "it simply means the inability to tell which way is "up" (FAA, 1983).

Below, a more complex definition:

Spatial disorientation is a term used to describe a variety of incidents occurring in flight, where the pilot fails to correctly sense position, motion or attitude of his aircraft or of himself within the fixed coordinate system provided by the surface of the earth and from gravity on the vertical plane. In addition, pilot's errors of perception of his position, motion or attitude relative to his aircraft, or of his own aircraft relative to other aircraft, may also be embraced within a broader definition of spatial disorientation in flight (Benson, 1988).

The US Navy reported that in the period from 1980 to 1989 crew's spatial disorientation was present in some of the 112 major aircraft accidents (Bellenkes, Bason, Yacavone, 1992). The U.S. Air Force reported that in the same period spatial disorientation influenced 270 occurrences involving large aircraft (Holanda, 1992).

Another study conducted by the U.S. Air Force concluded that aircraft flown by just one pilot were more susceptible to the risk of spatial disorientation (Gillingham, 1992).

Under normal conditions, human beings are capable of determining accurately which way is “up”, with the help of information provided by three specialized sensorial systems:

- The visual system;
- The organs of balance of the inner ear (also known as vestibular system); and
- The proprioceptive system.

These three systems rely on several sensorial receivers for the collection of information, which is then sent to the brain, which, in turn, integrates the pieces of information received in a single model of orientation. Under normal conditions, this is a highly accurate mechanism.

The integrated information is used to determine our position within a fixed system of coordinates provided by the surface of the earth as a horizontal reference, and by the earth’s gravity force, which provides a vertical reference.

The three systems have different levels of importance as far as the provision of information for orientation is concerned

The visual system is the most important of the three, providing approximately 80% of the orientation information.

Under conditions in which visual references are either scarse or not available, such as under degraded meteorological conditions or during the night, up to 80% of the normal orientation information may be lost.

The remainder 20% is equally divided between the vestibular and proprioceptive systems. Both of them are susceptible to illusions and erroneous interpretations, being, therefore, less accurate.

In the scarcity or lack of visual signage, human beings have to rely on the remainder 20% of the orientation information.

In the aviation scenario, such situation may result in spatial disorientation on the part of the pilot. This becomes even more dangerous when the pilot is not aware of his disorientation, and believes that his sensorial information is correct, when, as a matter of fact, it is not.

The lack of good visual references deprives us from most orientation information. A great deal of disorientation events relate to the lack of visual clues, such as in VMC or during night-time flights.

The vestibular system is made up of two important components: the semicircular canals and the otholitic organs.

There are three semicircular canals in each ear. In functional terms, they operate as three corresponding pairs, around each of the three primary motion axes.

The canals in each ear are perpendicular to their counterparts, and function as angular accelerometers. Significantly, they have a threshold of stimulation of $2°/sec^2$; below this, they are not capable of detecting angular motion. This is crucially important in the aviation environment – if, either intentionally or otherwise, an angular acceleration rate below this limit is applied, the canals will not perceive the turn.

In the absence of visual indications that the turn is in progress, even if the force of gravity indicates the position of the head relative to the feet, without alteration of the proprioceptive information, the pilot will not sense that a turn is in progress and will interpret the movement as straight and level.

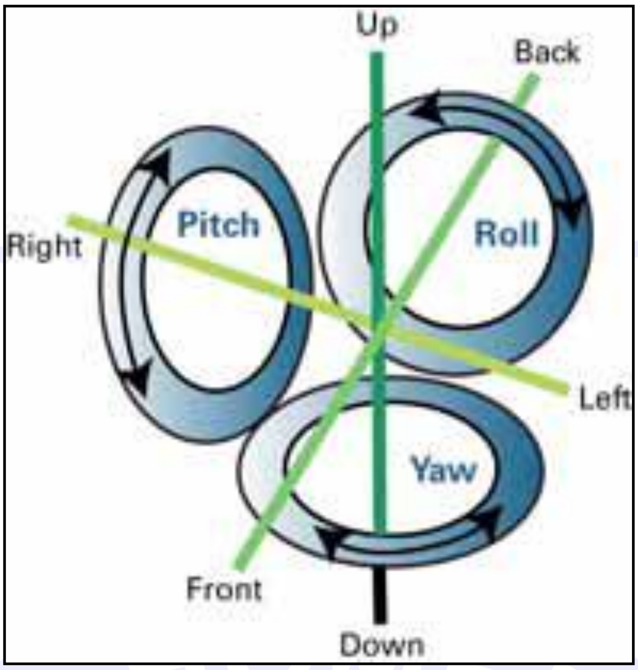


Figure 25 – The three semicircular canals operating around each one of the three primary axes.

There are two otholitic organs in each ear, one on the vertical plane and the other on the horizontal plane. These organs function as linear accelerometers and, under normal conditions, the vertical otholitic signals the effect of the earth gravitational field.

The vestibular system is extremely important for the human spatial orientation. It performs a series of complex functions relative to the integration of angular and linear accelerations, by means of numerous neural connections with the eyes and the centers of motor coordination in the brain, helping to regulate posture, keep balance, activate coordination, and maintain clear vision during movements.

The proprioceptive system consists of pressure sensors spread throughout the body, especially at the joints, tendons, ligaments, muscles and skin. Under normal conditions, the pressure exerted on a given set of pressure receivers contributes to a general sense of orientation. For instance, the pressure receivers on the sole of the feet, ankle and knee joints send a signal to the brain telling that the upright posture is being maintained.

All of these pieces of sensorial information are constantly being sent to the brain for processing, in order to maintain an accurate sense of direction relative to both the earth's surface and the vertical gravitational planes.

It is worth reminding that these systems, on which human beings are so dependent, are not designed for operations in the three-dimensional environment of the flight. In such environment, it is sometimes necessary to operate independently of normal visual indications, be it in bad weather conditions or during night-time flights, with the pilot exposed to the physiological limitations of the human orientation standards.

The somatographic illusion is among the most common types of vestibular illusions.

The somatographic illusion is also designated by other descriptive terms, such as dark-night takeoff illusion, “pitch-up” illusion, and inversion illusion (Benson, 1988a; Buley & Spelina, 1970; Campbell & Bagshaw, 2002; Gillingham & Previc, 1996; Lane, 1958).

In the somatographic illusion, a pilot at takeoff, without adequate external visual references (IMC conditions or night-time flights), on an aircraft being accelerated, experiences a strong sensation that the aircraft nose is moving upward excessively, something that is not happening.

In this case, the pilot's natural reaction is to work on the controls in order to counteract this sensation. This leads the pilot to unconsciously command a nose-down movement of the aircraft, putting it in a trajectory toward the terrain during takeoff.

A report by the then Bureau of Air Safety Investigation (BASI), now a component of the Australian Transport Safety Bureau (ATSB), examined dark-night takeoff-related accidents in Australia between January 1979 and May 1993, and verified that 15 out of the 35 accidents in this period (42%) had spatial disorientation as a primary factor (Brito, 1995). This report mentions a similar study conducted by the National Transportation Safety Board (NTSB) in the USA, in which 78% of the 291 night-time takeoff accidents in the period 1983 – 1993 involved spatial disorientation.

Among the factors that contribute to the spatial disorientation is the operation of the aircraft by a single pilot. In the operation by two pilots, one of them can alert the other pilot or takeover the controls upon realizing that the other crewmember has become disoriented.

<u>Accidents involving spatial disorientation in helicopters of the American Army</u>

Summaries of 583 U.S. Army rotary-wing aircraft accidents in the period 1st May 1987 – 30 April 1992, received from the U.S. Army Safety Center - Fort Rucker, Alabama, indicated that spatial disorientation was the main factor in 32% of the occurrences (187 accidents).

<u>Workday</u>

According to the Law 7183, dated April 5, 1984:

"Article 20: Workday is the duration of an aeronaut's work, from the time he/she reported to his/her place of work until the time it is terminated.

§ 1º the workday at the home base will be counted from the time the aeronaut reports to his/her place of work.

Art. 21 The duration of an aeronaut's workday shall be:

a) 11 (eleven) hours, if working as a single crew, or a member of minimum crew;

§ 1º As for flights operated by air-taxi companies, specialized-service companies, regional air transport companies, or regional international regular air transport companies, if there is a programmed interruption of the flight for more than 4 (four) consecutive hours, and if the crew is provided with adequate rest accommodations, the workday will have its duration augmented by half the time of the interruption, without alteration of the limits prescribed in the paragraph "a", article 29 of this Law.

1.13.2 Ergonomic information

Nil.

1.13.3 Psychological aspects.

The pilot was a retired Colonel of the Goiás State Military Police (PM-GO).

Crews that had flown with the pilot saw him as a skilled professional, a reference in the operation of AS 350 helicopters, never deviating from the aircraft's prescribed operational envelope.

He had a rather technical operational profile, marked by an excess of caution every time he detected some abnormality during the operation.

The pilot was considered by many of his mates as an easygoing person; they also described him as detail-oriented and picky, besides being more introspective and discreet.

According to relatives' accounts, the pilot did not have time for the regular practice of physical activities due to his working conditions in the *Planalto* company since he had been hired, and had been complaining about his difficulty sharing moments of leisure with his family.

The pilot's motivation to continue working in aviation outweighed the discomfort generated by the working conditions in his routine, leading him to the point of submitting to flight situations with which he did not feel comfortable, such as operation of night-time flights and absence from the family.

According to information received, the pilot would feel upset when summoned for the operation of night-time flights. Now and then, he even made comments about safety criteria that should be considered on these occasions, but did not feel comfortable to refuse to do the flights.

In the afternoon prior to the accident, the pilot arrived in Aruanã at approximately 14:00. He rested in a room of his employer's residence until 19:00, when he was called for a flight destined for a camp owned by his bosses in the Araguaia River. On this flight, the pilot and four passengers were on board the aircraft.

That night in the camp, also according to information, the pilot socialized with the other persons in a game of cards, and was extremely smiley and extrovert, i.e., just the opposite of what used to be told of his behavior, always more introspective and discreet.

Around 00:30, the pilot received a call from his bosses, who questioned him about the time of return, since it was getting late. According to witnesses, shortly after the call, the game was finished amid lots of laughter. Then, the pilot, still overjoyed due to his winning the game, went to prepare the aircraft for flight and board the passengers.

According to accounts, night-flights of helicopters were common and frequent over the Araguaia River, mainly during the holiday period (June/July).

For this reason, the pilots operating in the area went to the point of informally establishing a corridor over the river, as a means of guaranteeing some degree of safety for the operations.

The pilot earned his Private and Commercial Pilot licenses when he was already an officer of the Goiás State Military Police.

As a means of gaining experience and flight-hours before flying for the GRAER, he flew for the Ceará State Military Police and for the Brazilian Environment Institute (IBAMA).

The formal employment contract between the pilot and the Planalto company was signed in mid-July 2011, after his retirement from the Goiás State Military Police.

His work conditions included a 24-hour-on-call alert during the whole week, as well as being available to fly on weekends.

His longer workdays coincided with school holiday periods. There was information that during the months of June and July the pilot was hardly at home, by coincidence, the same period in which the accident happened.

In addition to his activities as a pilot, he was also responsible for the control and record-keeping of all the information relative to the helicopter and its maintenance, being the one who negotiated the provision of services with the maintenance company.

1.14 Fire

There was no fire.

1.15 Survival aspects

There were no survivors.

The passengers were found between the point of first impact and the point of the aircraft final stop. The pilot's body was 10 meters ahead of the point where the aircraft stopped.

One of the passengers was rescued from the crash-site still showing vital signs, but died shortly after, before arriving at the hospital in Aruanã.

The suspenders of the front seats were intact, without indication of effort in the straps or points of attachment. No evidence was found that the passengers had been wearing them.

Figure 26 – Suspenders of the left front seat, not fastened.

Figure 27 – Suspenders of the right front seat (pilot's) not fastened.

The abdominal belts of the front seats sustained rupture of the stitch sewing (figure 26). These belts remained connected to the points of attachment in the aircraft (figure 27).

Figure 28 – Abdominal belt of the right front seat with its stitch sewing ruptured.

Figure 29 – Abdominal seat belts of the front seats.

The belts and suspenders of the rear seats were intact, without marks or damage that would be typical if the aircraft occupants had been wearing them.

Figure 30 – Safety belts of the rear seats.

Figure 31 – In highlight, suspenders of the rear seats.

1.16 Tests and research

Engine:

The area of the cabin where the block of power-levers is installed sustained substantial deformation resulting from the impacts. Consequently, the position of the levers was not presumed to be the same as the one in flight.

The air inlet cone of the engine axial compressor showed signs of circumferential friction, an indication that the engine was running at the moment of impact.

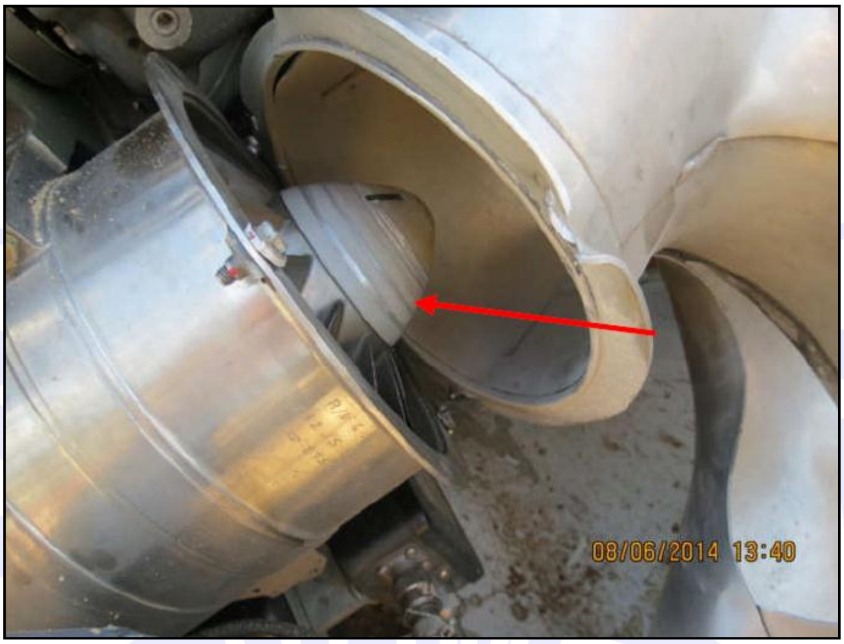


Figure 32 – Circumferential marks in the air inlet cone of the engine axial compressor.

All the lines between the FCU, accessories and engine were well connected and tight. The pre-blockage indicator of the engine oil filter was not popped-out - showed no clogging of the engine oil system.

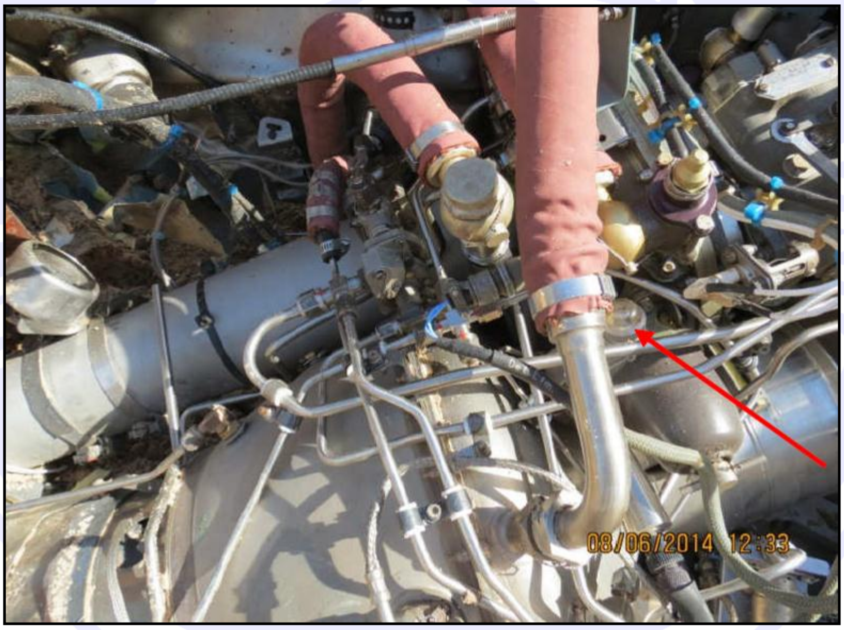


Figure 33 – Pre-blockage Indicator of the engine oil filter (not popped-out).

The bleed valve was in the open position, a normal condition for that phase of flight.

Figure 34 – Bleed valve in the open position.

The flow rate control (engine start-up and acceleration) and anticipator control (device connected to the collective control) remained firmly attached to the FCU.

These controls may have moved on account of the structural deformation, and the indication may not correspond exactly to their position prior to the impact of the aircraft with the ground, although they were in a position close to the one during the flight (figure 35).

The anticipator control, a device connected to the collective control, and that regulates the regime of the engine according to the pitch that is applied, was in a position of maximum degree, corresponding to a collective pulled all the way up. This control was subject to tension with the deformation of the structure, but it was possible to identify that there was application of the collective control at the moment of impact.

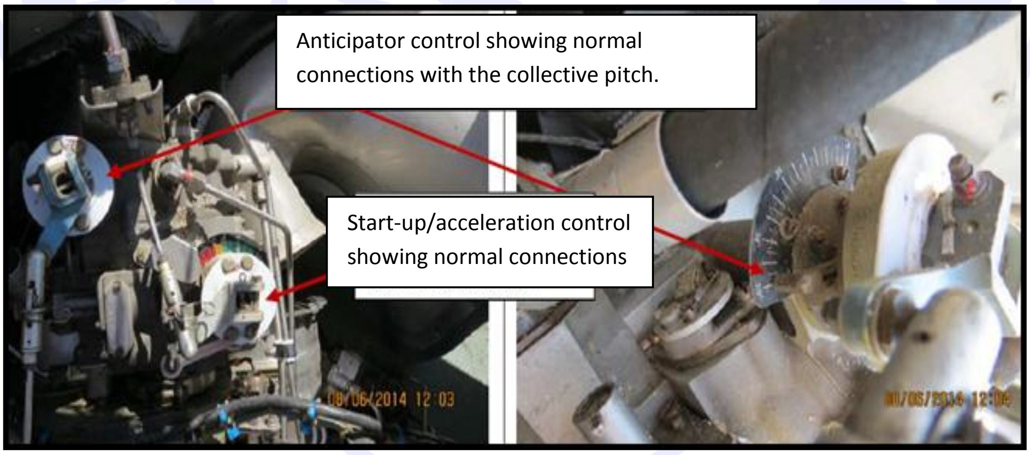


Figure 35 – Flow rate control (engine start-up and acceleration) and anticipator control.

Lubrication System:

The magnetic plugs of the engine lubrication system and of the rear box (tail rotor) did not have signs of metal residue.

Fuel System:

The Fuel System filter and piping assembly of the engine were not affected by the impacts, and showed a normal condition.

The fuel filter was removed for verification, and was found clean.

Hydraulic Systems and Flight Controls:

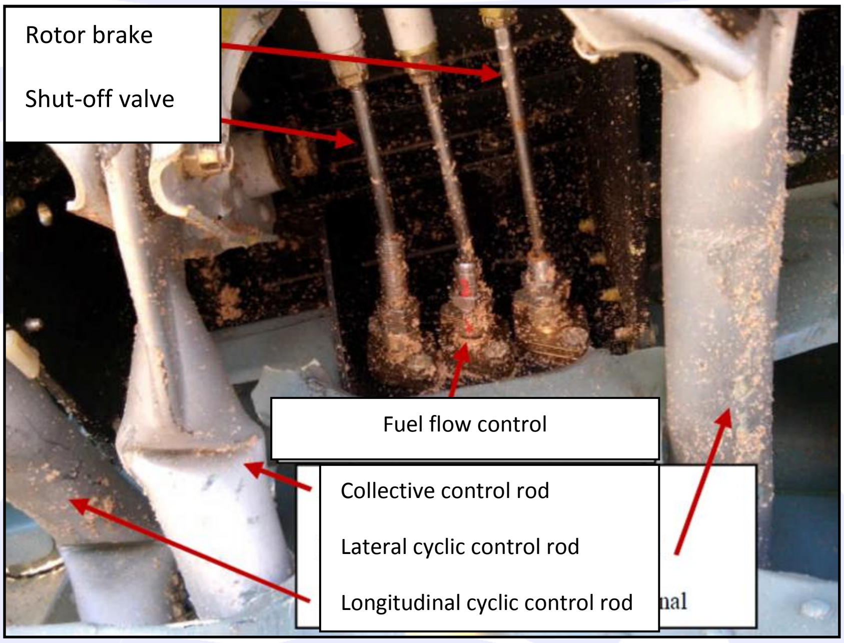


Figure 36 – Control rods, fuel flow rate control, rotor brake adn shut-off valve.

The cyclic control rods in the lower part of the cabin, below the box of power-levers, were well fixed and keeping their cotter pins. The control rods of the power-levers were also well connected. The only anomalies found resulted from torsions sustained by the structure due to the impacts with the ground.

The control rods of the lateral cyclic and collective in the lower part of the left side of the cabin were verified. The connecting rods were fractured on account of the deformation of the aircraft structure.

Figure 37 – Lateral cyclic and collective control levers on the left side of the lower part of the cabin.

The hydraulic reservoir was empty. The fluid was pumped out of the system through the hydraulic lines at the point of junction of the tail boom with the rear structure. The piping got broken with the impact, which caused the separation of the tail cone from the rear structure. The hydraulic pump continued functioning, activated by the transmission during the sequence of impacts sustained by the aircraft. The hydraulic pump activation belt remained connected in the normal way.

Figure 38 – Dirt adhered to the places where the hydraulic fluid spread on the main rotor mast during the impacts.

The servo controls were verified visually, presenting no leakage of hydraulic fluid. The hydraulic pipes remained firmly connected, and the control levers were also well connected and secured.

The left *servo control* showed deformation resulting from the impacts of the aircraft with the ground.

Despite the fact that no anomalies were detected, the three main servo controls, the rear servo and the hydraulic pump were removed for detailed laboratory analyses.

<u>Tail boom and activation of the tail rotor</u>:

The connection between the tail rotor control and the rotor itself was verified, and all the points were duly interconnected. The damage observed was in the points where deformation had occurred as a result of the impacts with the ground.

The cone presented deformation by compression on the right and on the lower parts. There were signs of traction (attachment points of the rivets were torn) on the upper left side, next to the point of attachment of the cone to the structure. These characteristics were an indication of a frontal impact, more significant on the right hand side of the aircraft, as it was with the tail pointing upward (figure 39).

Figure 39 – Section where the breakage of the tail rotor occurred. It is possible to observe that the points of attachment of the rivets were "torn".

The rear blade (tail ski), an item installed in the lower part of the drift did not present any recent signs of abrasion.

Figure 40 – Tail rotor blades and tail boom.

Tests of the engine:

After the accident, the Arriel 1B engine, serial number 4564, was removed from the aircraft by the SERIPA VI team, with monitoring by a Helibras engineer and another engineer from Turbomeca, in order to be examined.

The opening and exam of the engine were carried out in the premises of Turbomeca (Xerém, State of Rio de Janeiro), in the presence of members of the Investigation Commission, including the investigator in charge of the Material Factor, from the Department of Science and Airspace Technology (DCTA), a specialist in investigation of engines.

In the module 5 of the engine, a 2mm-misalignment was found in the splined nut of the driving gear (figure 41).

Figure 41 – Misalignment of 2mm in the splined nut of the driving gear.

In the module 4, the compressor turbine disk rotated freely, a normal functioning condition. Sand was present in the internal parts.

The boroscopic inspection of the module 3 indicated presence of sand in the combustion chamber.

In general, the exams confirmed that the abnormalities found were a result of the abrupt stop of the main rotor.

In the module 5, the misalignment of 2mm of the marks of the splined nut of the driving gear indicates that engine was submitted to an overtorque condition (a sudden increase of an important resistance torque while engine was delivering the required power).

Tests of the Hydraulic System and Flight Controls:

The hydraulic pump, the manometric contactor and the hydraulic accumulators of the servo controls (left, right and front ones) were bench-tested in the premises of Airbus Helicopter in Marignane, France, in the presence of members of the Investigation Commission. The aircraft components showed normal performance, with the exception of the manometric contactor.

The manometric contactor showed a defective functioning. This device is responsible for sending the hydraulic pressure information to the panel of warning and alerts of the aircraft.

If the manometric contactor becomes inoperative, the pilot will not receive any hydraulic pressure information during the startup procedures. The pilot should not perform the take off in such condition.

The servo controls (left, right, front and rear) and the hydraulic filter (Valve Filter Block) were bench-tested in the installations of UTC Aerospace Systems in Vernon, France, with the presence of members of the Investigation Commission.

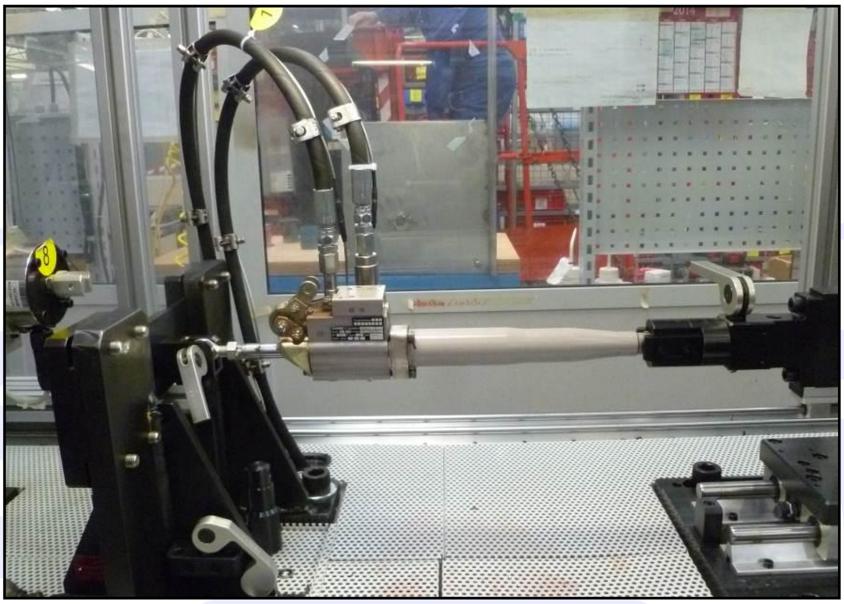


Figure 42 – Bench-test of the front servo control.

The right, front and rear servo controls, together with the hydraulic filter, presented normal performance upon being tested on the bench.

The left servo control presented deformations caused by the impacts of the aircraft with the ground, and it was not possible to test it on the bench. Thus, it was necessary to disassemble the left servo control, in order to confirm the origin of the damage.

In figure 44, it is possible to observe that the central part of the cylinder does not make contact with the surface under it. This occurred on account of an expansion of the cylinder diameter at the right hand side end.

The exams indicated that the deformation in the cylinder was compatible with the information contained in the technical report *UTAS Report Ref. CE3523*. In the case in question, the servo control had the prescribed pressurization. At the high speed impact, there was no way to transmit the pressure, resulting in an overpressure condition (from the inside to the outside) which caused the deformation of the cylinder.

Figure 43 – Disassembly of the left servo control.

Figure 44 – The central part of the cylinder would not touch the floor surface.

No evidence was found that could indicate malfunctioning of the left servo control before the impacts of the aircraft with the ground.

<u>External lighting system</u>:

The aircraft was equipped with a landing light of 450W, installed under the cabin on the right side. There was also a taxi light of 150W, installed under the cabin on the left side.

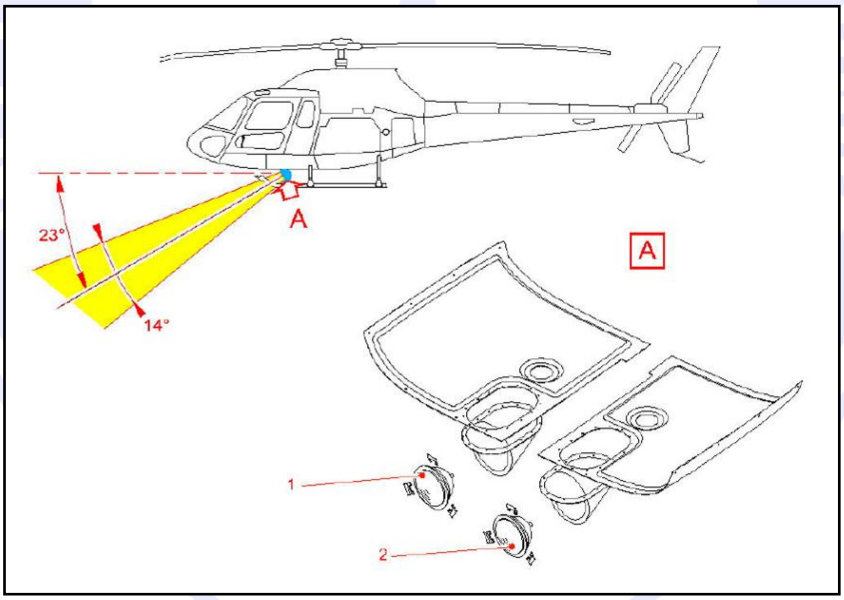


Figure 45 – External illumination system of the AS-350BA aircraft.

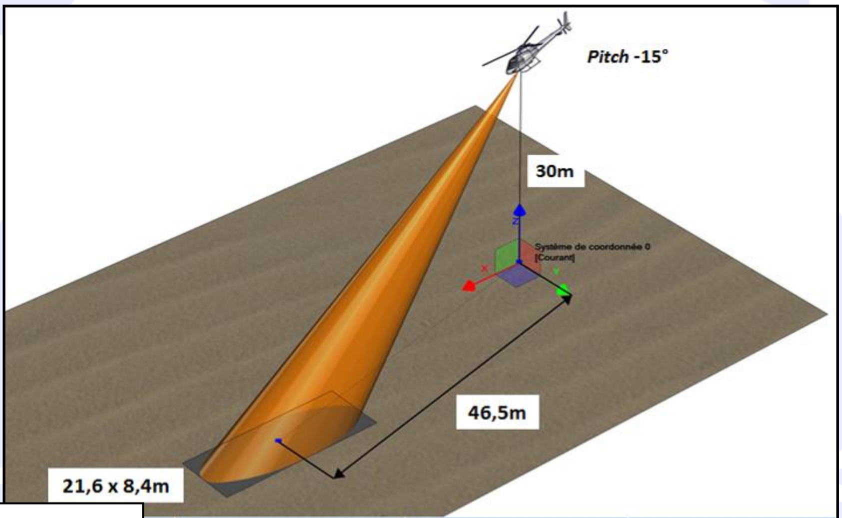
The aircraft lights were fixed, so it was not possible to control their angle and direction. According to information provided by the aircraft manufacturer, the ranges of the landing light beam were 13º and 14º on the horizontal and vertical planes, respectively. This beam is oriented at an angle of -23º from the aircraft longitudinal axis.

According to a witness that saw the initial phase of the takeoff, the external lights of the aircraft were operating normally.

The Investigation Commission requested more detailed information from the aircraft manufacturer relative to the area ahead of the aircraft illuminated by the lights in a situation consistent with the takeoff phase, at a height of 30 meters AGL (last height recorded in the GPS).

HELIBRAS (manufacturer) and Airbus Helicopter (responsible for the design) considered -15º as the longitudinal attitude for this phase of the flight. The Investigation Commission asked them to associate the lateral attitudes of 0°, 10°, 20° and 30° with that longitudinal (pitch-down) attitude of -15º.

The area on the ground illuminated by the aircraft at a height of 30 meters corresponds to an ovoid surface with dimensions compatible with a rectangle of 21.6m x 8.4m. With a lateral attitude (banking) of 0°, the center of the illuminated area would be 46.5 meters ahead of the aircraft. The variations for 10°, 20° e 30° are shown in the table below:



Banking	10°	20°	30°
Distances	X_0X_{beam} = 41,9 m Y_0Y_{beam} = 3 m	X_0X_{beam} = 43,1 m Y_0Y_{beam} = 6,4 m	X_0X_{beam} = 45,4 m Y_0Y_{beam} = 10 m

Figure 46 – Illumination pattern of the AS-350BA aircraft head-lights.

In figure 46, X_0Xbeam corresponds to the distance along the X axis (in red) from the zero position to the center of the illuminated area; Y_0Ybeam corresponds to the lateral distance along the Y axis (in green), from the zero position to a position abeam the central point of the illuminated area.

For a better assessment of the condition of illumination of the external environment with the aircraft at a height of 30 meters at takeoff, a member of the Investigation Commission (from the Institute of Airspace Medicine, and responsible for the investigation of the Human Factor - Medical Aspect, with specialization in Ophthalmology) performed a series of night-time takeoffs on a similar aircraft (an AS 350 of the Brazilian Air Force).

Due to safety issues, there was a tactical lighting system available in the scenario utilized for the tests. This is the reason why a point of light is seen ahead of the aircraft in some photographs. It is worth stressing that there was no illumination on the ground.

Figure 47 – Landing run with landing/taxi light. Image of the 30th second of the video recording of the takeoff from the tactical lighting point. There is a light on the ground that did not appear in the scenario of the accident.

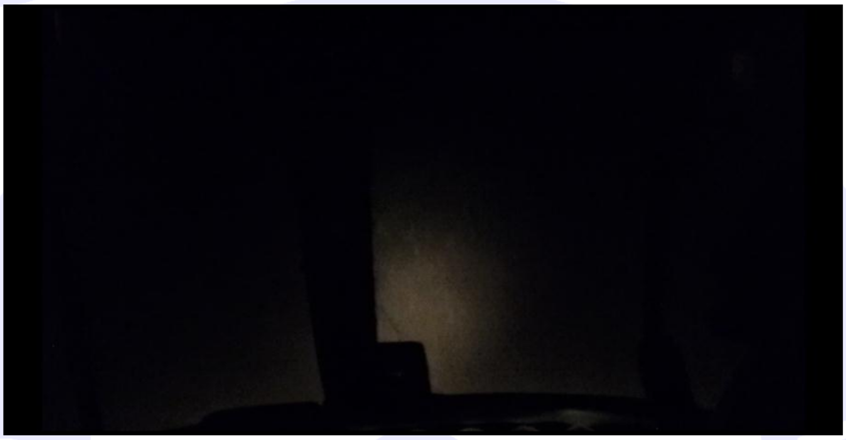


Figure 48 – Takeoff run with landing/taxi light. Image of the 55th second of the video recording of the takeoff from the tactical lighting point.

Figure 49 – takeoff run with landing/taxi light. Image of the 60th second of the video recording of the takeoff from the tactical lighting point.

In the takeoffs performed, at the height of 30 meters AGL there was no natural horizon to orient the flight with visual references (figure 49).

The figure below shows a takeoff assisted by external lights for the provision of spatial orientation.

Figure 50 – Takeoff with assistance of external lights.

The figure below shows an aircraft on a flight test, making a left turn. It is possible to see the skyline, taking the city lights as a reference.

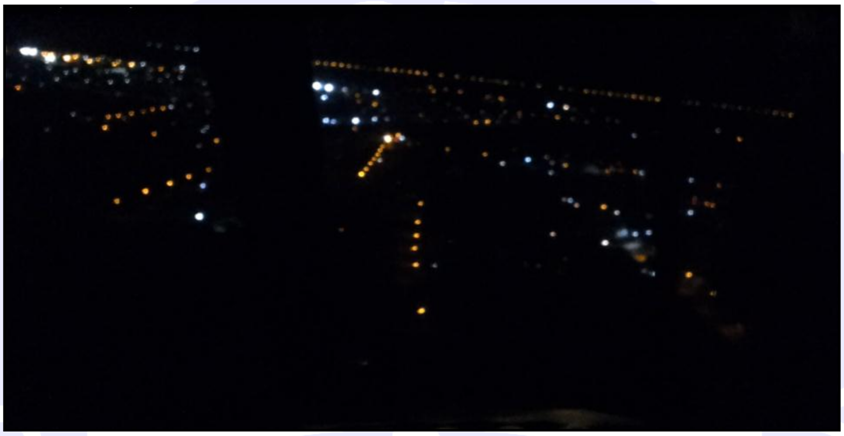


Figure 51 – Making a left turn.

1.17 Organizational and management information

The owner of the aircraft did not possess aeronautical knowledge at a management level. He made use of the helicopter as a means of transportation. The pilot was the one in charge of managing the air movements and maintenance activities.

1.18 Operational information

The pilot had flown for more than 10 years as a GRAER crew member for the Goiás State Military Police. During this period, he flew AS 350 aircraft.

In the Military Police, the night-time flights were conducted in an urban environment, and were much less frequent than day-time flights.

In the final phase of his career in the Military Police, he had the opportunity to do a theoretical course on the AW-119, but chose not to do any practical trainings on this aircraft in order to continue operating the AS-350.

In January 2011, the pilot retired from the Goiás State Military Police. Months later, he was hired by the *Planalto Indústria Mecânica* company to fly and be the manager of the AS 350 operation.

In the PT-YJJ aircraft logbook, the first records of the pilot as a crew member hired by the *Planalto Indústria Mecânica* company were written on 14 October 2011, when the aircraft had 3,297.7 airframe hours. From that date until the day of the accident, the name of the pilot is present in all the records related to this aircraft.

Aircraft logbook records

In the period from 14 October 2011 to 6 June 2014, the investigation found the following records concerning night-time flights of the PT-YJJ:

DATE	CREW	ROUTE	SUSNSET (UTC)	FLIGHT TIME (UTC)	NIGHT TIME
16/Apr/12	Pilot+Copilot A	Jaraguá (GO)-SWBP	21:08	21:20 to 21:55	35 min
17/Apr/12	Pilot+Copilot A	SBUL–Caldas Novas	21:04	21:00 to 22:00	56 min
18/Apr/12	Pilot+Copilot A	Caldas Novas-SIKL	21:07	21:00 to 21:49	42 min
18/June/12	Pilot+Copilot A	SIKL - SIKL	20:53	22:30 to 22:49	19 min
18/June/12	Pilot+Copilot B	SIKL- SIKL	20:53	22:50 to 23:04	14 min
18/June/12	Pilot+Copilot B	SIKL- SIKL	20:53	23:05 to 20:19	14 min
15/July/12	Pilot	**Aruanã Residence-Aruanã Residence**	21:11	21:01 to 21:19	08 min
28/Aug/12	Pilot+Copilot C	Goiânia-Goiânia	21:11	21:16 to 21:27	11 min
07/Sept/12	Pilot	Aruanã Residence - Caldas Novas	21:09	20:00 to 22:00	51 min
16/Mar/13	Pilot	SBGO-SIKL	21:31	23:00 to 23:20	20 min
16/Mar/13	Pilot	SIKL-SIKL	21:31	00:00 to 00:26	26 min
16/Mar/13	Pilot	SIKL-SIKL	21:31	02:00 to 02:26	26 min
20/Mar/13	Pilot	Brasília–Planalto Helipad	21:28	21:00 to 21:56	28 min
20/Mar/13	Pilot	Planalto Helipad -SWNV	21:28	22:10 to 22:23	13 min
29/Mar/13	Pilot	**Aruanã Residence - Aruanã Residence**	21:29	21:01 to 21:38	09 min
03/Apr/13	Pilot	Zezé Farm - SNNV	21:18	21:00 to 21:54	36 min
10/Apr/13	Pilot	SWNV-Brasília	21:07	21:01 to 21:56	50 min
10/May/13	Pilot	SWFP-SWFP	20:57	02:00 to 02:14	14 min
10/May/13	Pilot	SWFP-SJPI	20:57	02:30 to 02:43	13 min

29/May/13	Pilot	**SWFP- Aruanã Residence**	21:02	20:00 to 21:38	36 min
29/May/13	Pilot	**Aruanã Residence - Aruanã Residence**	21:02	22:00 to 22:20	20 min
05/June/13	Pilot	SJPI-SWFP	20:53	22:40 to 23:00	20 min
13/June/13	Pilot+Copilot A	SJPI-SIKL	20:53	22:10 to 22:30	20 min
13/June/13	Pilot+Copilot A	SIKL-SWFP	20:53	23:00 to 23:20	20 min
13/June/13	Pilot+Copilot A	SWFP-SJPI	20:53	23:40 to 23:59	19 min
13/June/13	Pilot+Copilot A	SJPI-SJPI	20:53	00:10 to 00:24	14 min
13/June/13	Pilot+Copilot A	SJPI-SWFP	20:53	00:30 to 00:50	20 min
14/June/13	Pilot+Copilot A	SJPI-SWFP	20:53	22:50 to 23:04	14 min
14/June/13	Pilot+Copilot A	SWFP-SJPI	20:53	23:20 to 23:40	20 min
15/June/13	Pilot+Copilot A	SWFP-SIKL	20:52	21:40 to 21:54	14 min
15/June/13	Pilot+Copilot A	SIKL-SWFP	20:52	22:50 to 23:04	14 min
15/June/13	Pilot+Copilot A	SWFP-SIKL	20:52	23:30 to 23:44	14 min
29/June/13	Pilot	**Aruanã camp – Aruanã Residence**	21:06	21:00 to 21:16	10 min
02/July/13	Pilot	**Aruanã Residence - Aruanã Residence**	21:07	21:00 to 21:19	12 min
21/Aug/13	Pilot	SWNV-SWNV	21:10	21:30 to 22:00	30 min
30/Aug/13	Pilot	SWFP-SWFP	21:12	23:00 to 23:25	25 min
01/Sept/13	Pilot	SWFP-SWFP	21:13	21:40 to 21:50	19 min
04/Sept/13	Pilot	SWNV- **Aruanã Residence**	21:20	20:10 to 21:35	15 min
12/Sept/13	Pilot	SJPI-SWFP	21:14	23:10 to 23:29	19 min
13/Sept/13	Pilot	SWNV-SJPI	21:13	21:30 to 22:01	31 min
13/Sept/13	Pilot	SJPI-SWFP	21:13	02:57 to 03:16	19 min
15/Sept/13	Pilot	SJPI-SWFP	21:14	21:30 to 21:49	19 min
18/Sept/13	Pilot	SWNV-SWFP	21:14	21:10 to 21:29	15 min
22/Nov/13	Pilot	SBGO-SWFP	21:35	22:11 to 22:42	31 min
24/Nov/13	Pilot	SIKL-SIKL	21:34	02:05 to 03:18	01h13min

16/Dec/13	Pilot	**Aruanã Residence - Aruanã Residence**	21:51	21:40 to 21:59	08 min
16/Dec/13	Pilot	**Aruanã Residence - Aruanã Residence**	21:51	22:10 to 22:35	25 min
09/Jan/14	Pilot	Trindade Farm- Trindade Farm	21:56	01:40 to 02:06	26 min
17/Jan/14	Pilot	Trindade Farm -SWBP	21:57	00:20 to 00:39	19 min
19/Jan/14	Pilot	Trindade Farm -SIKL	21:57	00:40 to 00:59	19 min
19/Jan/14	Pilot	SIKL-SWBP	21:57	01:00 to 01:07	07 min
08/Feb/14	Pilot	Trindade Farm -SWBP	21:53	21:41 to 22:22	29 min
24/Mar/14	Pilot	SWNV- Trindade Farm	21:25	21:50 to 22:15	25 min
20/Apr/14	Pilot	Água Limpa- **Aruanã Residence**	21:14	21:00 to 21:31	17 min

In the aircraft logbook, with reference to the years 2012, 2013 and 2014, there were a number of records of day-time flights between the Aruanã residence and the Araguaia River camp (at a distance of 14 km). There weren't any records of landing at, or takeoff from, the camp during the night.

On 29 May 2013, according to the aircraft logbook, the pilot had a workday of 13 hours, operating as single crew.

Flight information based on GPS stored data and witnesses' accounts

On 6 June 2014, the aircraft took off from a residence in Aruanã (19:26) and landed at 19:36 on an island of the Araguaia River, located at the coordinates 14°47'43,5"S / 051°02'51.2"W, with its front facing the camp (distance from the residence to the camp: 14 km).

Figure 52 – Marks made by the helicopter skis in the place where it parked.

On this flight, the pilot and four passengers (the same ones who got involved in the accident) were on board the aircraft.

The takeoff of the accident flight was on 7 June 2014, at 01:27.

The pilot left a hut in the camp, performed procedures outside the aircraft, monitored the boarding of all passengers, then boarded the aircraft and started the startup and takeoff procedures.

The aircraft started takeoff with a counterclockwise turn, i.e., a nose counterclockwise turn of more than 180º, climbing vertically until reaching a height of 10 meters. Then the aircraft began moving horizontally at heading 145º, leaving the height of 10 meters to reach 30 meters at 57 kt, at a distance of 200 meters from the takeoff start point (figure below). From this position onward, the data were not stored in the GPS memory.

The initial takeoff phase (vertical climb) was observed by a person in the hut, who confirmed that the aircraft headlights were functioning normally. When the aircraft started its horizontal movement, the person was no longer observing it, but heard the noise of the impact, and called for help via cell phone.

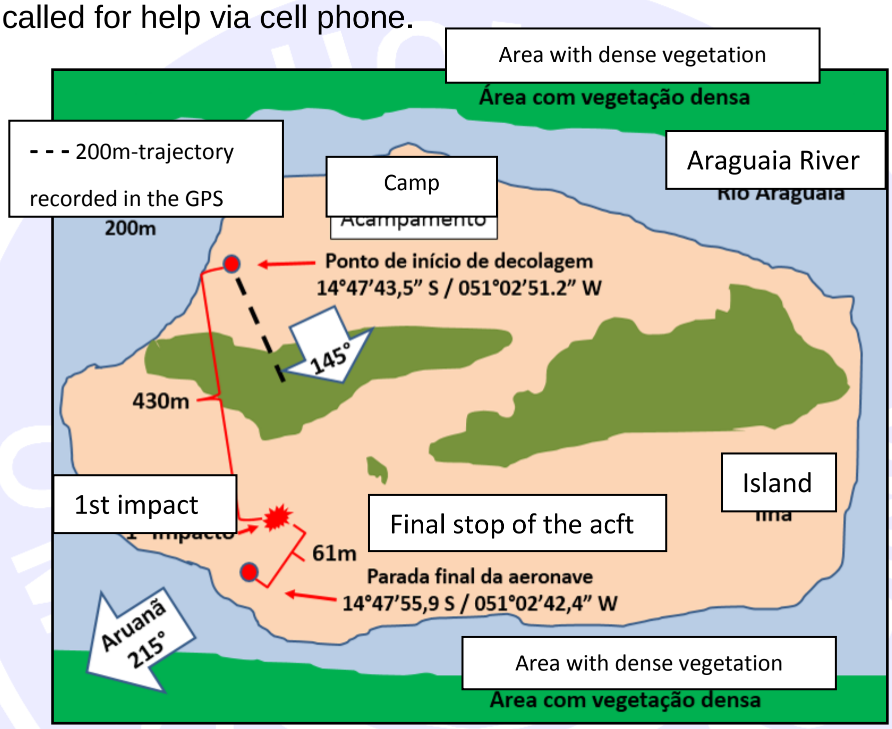


Figure 53 – Sketch of the takeoff site, showing the points of first impact and final stop. The dotted line represents the 200 meters of trajectory of the initial phase of takeoff, at heading 145°, which was recorded by the GPS.

<u>Characteristics of the takeoff site:</u>

The area utilized for landings and takeoffs was neither homologated nor registered; it was located outside of an ATZ, CTR or TMA; it did not have a lighting system, helipad beacon or illuminated wind direction indicator.

In a radius of more than 10 km from the takeoff site, there were no illuminated references on the ground, mainly along the projection of the takeoff axis (HDG 145º).

On 6 June 2014, the sunset in Aruanã was at 18:51. The moon was at its crescent phase (crescent period: 5 – 13 June 2014), and its position relative to the aircraft at the time of the accident was in the rear sector, if one considers the heading 145º taken for departure.

The takeoff site was at a distance of a 14 km from Aruanã, at bearing 215º.

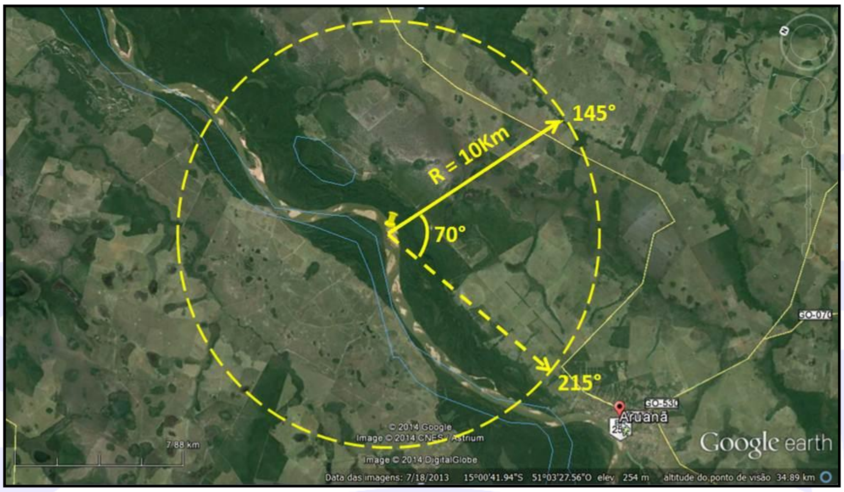


Figure 54 – Air view of the crash-site. Heading 145° was used for takeoff, and heading 215° was the one to be used for a flight to Aruanã.

The figure below shows an aircraft flying from the city of Aruanã, bound for the Araguaia River camp, i.e., along a route opposite to the one the pilot of the accident aircraft intended to fly. It is possible to observe the dense vegetation of the region, totally deprived of illuminated references.

Figure 55 – Route from Aruanã to the crash-site (indicated by the arrow).

The figure below shows the lighting condition of the departure site, approximately one hour after the accident. In the background, at a distance of less than 200 meters, there is dense vegetation (trees) which cannot be seen in the photograph.

Figure 56 – Underside of the aircraft illuminated by the camera *flash*. Behind the position of the aircraft, due to the ineffectiveness of the flash, one cannot see the trees at a distance of less than 200 meters.

Takeoff performance:

The elevation of the departure site was approximately 775ft, and the temperature was 25°C.

The basic weight of the (empty) aircraft was 1,393.40kg.

The weight of the five aircraft occupants was approximately 415kg.

In relation to the fuel weight, at the moment of the accident, the fuel tank filler separated from the fuselage, resulting in leakage after the impacts. Thus, the investigators considered the situation that would result in the heaviest weight, estimating that the pilot had filled up the tank (540 liters) when he refueled the aircraft in Goiânia.

The overall flight time of the legs flown between the last refueling and the accident was 1 hour and 40 minutes. The flight time, with an average fuel consumption of 180 liters/hour being compatible with the type of operation conducted, would result in a consumption of 300 liters of fuel.

Based on this estimate, the remaining fuel at the takeoff in which the accident occurred was 240 liters. Such quantity, at a density of 0.78, would correspond to 187 kg.

The aircraft takeoff weight was approximately 1,995.4 kg.

According to the AS-350BA Flight Manual, section 5, the aircraft had enough performance capability for a takeoff with a maximum structural weight of 2,100kg, considering the conditions prevailing at the takeoff site.

Before-Takeoff procedure

The list of normal procedures before takeoff included an item related to the aircraft artificial horizon – “*Gyroscopic instruments – ON*.”

Figure 57 – The aircraft panel detached after the impacts. The artificial horizon is the instrument indicated by the yellow arrow.

The list of after-startup and before-takeoff normal procedures determined the verification of the hydraulic system, of the hydraulic system light on the alert panel, of the hydraulic accumulators, and of the flight controls with isolation of the hydraulic system.

1.19 Additional information

Conditions for operation of Helicopter VFR flights

In accordance with the ICA 100-4 (Air Traffic Rules and Special Procedures for Helicopters) in force at the time of the occurrence:

3.4 CONDITIONS FOR VFR FLIGHT OPERATIONS

3.4.1 DAY-TIME PERIOD

3.4.1.1 The aerodromes/helipads of origin, destination and diversion must be registered or homologated for VFR operations.

3.4.1.2 The prevailing meteorological conditions at the aerodromes/helipads of origin, destination and diversion must be equivalent or better than the minimums established for helicopter VFR operations.

3.4.2 NIGHT-TIME PERIOD

3.4.2.1 In addition to the conditions prescribed in 3.4.1:

a) The pilot shall possess an IFR rating;

b) The helicopter shall be certified for IFR flights;

c) The aerodromes/helipads of origin, destination and diversion shall possess:

- Lighting systems for the operating runways/landing strips;

- Aerodrome/helipad beacon in operation;

- Illuminated wind direction indicator or ATS unit in operation; and

d) The helicopter shall be equipped with a VHF transponder in operation to establish two-way communications with the pertinent ATS units.

3.4.2.2 The prescriptions for night-time VFR flights contained in the letters a) and b) of the item 3.4.2.1 shall not be applied when the flight evolves entirely within an ATZ, CTR or TMA, including the projections of their lateral limits, or still, in the case of inexistence of these portions of the airspace, when the flight *is conducted within a radius of 50 km (27 NM) from the aerodrome/helipad of origin."*

The operation of the PT-YJJ aircraft was under the regulation of the RBHA 91. However, it is worth mentioning the requirement established for helicopters which fly in accordance with the Brazilian Civil Aviation Regulation (RBAC) 135:

"135.207 VFR: requirement of surface references for helicopters

No-one shall be allowed to operate a helicopter under VFR, unless they have visual references on the surface or, at night, illuminated visual references on the surface below the helicopter sufficient for safe control of the flight."

Conditions for the operation of helicopters in non-homologated/non-registered locations

In accordance with the ICA 100-4 (Air Traffic Rules and Special Procedures for Helicopters) in force at the time of the occurrence:

"2.4.5 NON-HOMOLOGATED/NON-REGISTERED LOCATION

2.4.5.1 Landings and/or takeoffs in non-homologated/non-registered locations may be performed, as an occasional operation, under full responsibility of the operator and/or pilot-in-command of the aircraft, as applicable, provided that the conditions established by the ANAC are met."

In accordance with the Brazilian Aeronautical Homologation Regulation 91.327:

"91.327 OPERATION OF HELICOPTERS IN NON-HOMOLOGATED/NON-REGISTERED LOCATIONS.

(a) Notwithstanding the prescriptions of the paragraph 91.102(d) of this regulation, landings and takeoffs of helicopters in non-homologated/non-registered locations are allowed to be made, as an occasional operation, under full responsibility of the operator (in the case of operations under the RBHA 135) and/or pilot-in-command, as applicable, provided that:

(1) There is no prohibition of operations in the location of choice ;

(2) The owner of, or person responsible for, the location has granted authorization for the operation;

(3) The operator of the helicopter has made the pertinent provisions for guaranteeing the safety of the operation, the aircraft, aircraft occupants and third parties;

(4) The operation neither becomes part of the routine nor frequent;

(5) If within controlled area, the operation is conducted with two-way ATC radio communications;

(6) The SERAC of the area in informed, as soon as practicable, of any abnormalities affecting the operation, and

(7) The location selected necessarily meets the following physical features:

(i) Landing area: the landing area shall be sufficient for containing, at least, a circle with a diameter equal to the largest dimension of the helicopter to be utilized;

(ii) Safety area: the landing area shall be surrounded by a safety area free of obstacles, with its surface elevation not higher than that of the landing area, extending beyond the limits of this area by half the total length of the helicopter to be utilized;

(iii) Approach and departure surfaces: the surfaces of approach and departure have form an angle of at least 90º, with ramps of a maximum 1:8; and

(iv) Transition surfaces: in addition to the surfaces defined in the paragraph (a)(7)(iii) of this section, and not coincidental with them, there must be transition surfaces extending above and outside these limits with a maximum ramp of 1:2."

1.20 Utilization of other investigation techniques

NIL.

2. ANALYSIS

Power plant

The initial evaluation of the distribution of the aircraft parts in the crash site, as well as the level of destruction and separation of the structure indicated a high energy impact with the ground.

In the same way, the pattern of damage to the main rotor blades was indicative that there was a high rotational energy in that component.

The separation pattern of the main rotor transmission shaft (torsion) also indicated operation of the engine compatible with the required flight power rating.

In addition to the characteristics mentioned, the aircraft engine was disassembled after the accident for purposes of detailed analyses. The results confirmed that the abnormalities found resulted from an abrupt stop of the main rotor.

In the module 5 of the engine, the 2mm misalignment of the marks existing in the splined nut of the driving gear indicates that engine was submitted to an overtorque condition - the engine encountered an important sudden increase of resistant torque while delivering power.

The overtorque condition was compatible with an abrupt stop at the moment the main rotor blade struck the ground, with the engine running at a rotation consonant with the engine running at a rotation consonant with the required flight power rating.

All of these characteristics led the Investigation Commission to rule out a possible engine failure at takeoff as a contributor to the accident.

Flight Controls and Hydraulic System

The flight controls and the hydraulic system were analyzed in the crash site, and their components were removed in order to be analyzed in test-benches.

The field analyses indicated that all of the cyclic and collective control rods were duly connected and with their prescribed cotter pins. The damage found in the flight controls and in the hydraulic system was typical of overload due to the impacts of the aircraft with the ground.

The servo controls on the right, front, and rear, as well as the hydraulic filter, showed normal operation upon being tested on the bench.

The left servo control presented deformation caused by the impacts of the aircraft with the ground. Such deformation hindered the bench tests, and demanded a disassembly of the internal mechanisms of the cylinder.

After the disassembly, the exams showed that with the high speed impact, since there was not a way to transfer the pressure, a condition of inside-out overpressure appeared which caused deformation of the cylinder. Thus, no evidence was found, indicative of a left servo control malfunctioning before the sequence of impacts of the aircraft with the ground.

The only abnormality found had occurred in the manometric contactor of the hydraulic system. However, the characteristics were indicative that the problem had occurred during the sequence of impacts of the aircraft with the ground. This is reinforced by the fact that the normal procedures determine verification, after start-up and before takeoff, of the hydraulic system and the hydraulic system light in the alarm panel. It is understood that the pilot must have performed the prescribed procedures before takeoff, since a failure of the manometric contactor of the hydraulic system would have meant a rejection of the aircraft for flight.

In addition to the functionality of the flight control system, the possibility of undue interference on the controls by one of the passengers was considered. However, the control of the cyclic only existed on the right side of the aircraft, and the empty place for lodging this control on the left side was duly covered.

The analysis of the victims' injuries also indicated that the only person showing an injury possibly caused by the cyclic control was the pilot, reinforcing the idea that he was the one occupying the front right seat.

In summary, no abnormalities with the flight controls and hydraulic system were found that might have contributed to the accident.

<u>Compliance with the Manufacturer's Maintenance Program</u>

The investigation verified that between the date of teh last inspections (26 February 2014) and teh date of the accident (07 June 2014) according to the airframe logbook, there were no records of the 10h-, 25-, 30-hours, 7-days, 1-month and 3-months, prescribed by the manufacturer's maintenance program.

In these inspections, there were prescribed tasks for the main rotor, main rotor mast, main rotor blades, fuel system (treatment against fungi), and protection of the fuselae against corrosion.

The analysis of these tasks did not establish any correlation between the omission of the inspections and the characteristics found in the accident.

<u>The operating environment</u>

The takeoff site utilized by the aircraft was neither homologated nor registered. In accordance with the regulation in force at the time of the accident (ICA 100-4 Rules and Special Procedures for Helicopter Air Traffic, item 2.4.5.1), the takeoff from such location has can be only an occasional operation, under full responsibility of the operator and/or pilot in command of the aircraft, meeting the requirements established by the ANAC.

Upon analyzing the conditions established by the ANAC for operation of helicopter in locations neither homologated nor registered (RBHA 91.327) one verifies that such operation is possible under full responsibility of the pilot in command, provided it does not become a routine and/or frequent operation, and that the operator has made all the pertinent provisions to guarantee the safety of the operation, the aircraft and its occupants, and third parties, among other requirements

Considering that the regulation (RBHA 91.327) does neither define a routine or frequent operation, nor the minimum requirements for this type of operation, one understands that it is subject to the discretion of the operator and/or pilot in command to establish the parameters to be applied. Thus, a regulation favors the establishment of operating standards may not meet the minimum safety requirements.

In fact, based on the RBHA 91.327, despite the risk conditions involved, there is not a prohibition to operate in non-homologated/non-registered locations during night-time. However, in the case in question, the pilot decided to conduct this type of operation in visual conditions. Then, one understands that the pilot should meet the prescriptions of the item 3.4.2 of the ICA 100-4, which defines conditions under which a VFR flight is to be conducted in the night-time period.

Since the takeoff site was neither an aerodrome nor a helipad, nor was the flight within an ATZ, CTR or TMA, the pilot was required to have IFR rating and the aircraft had to have IFR certification. In the case in question, neither the pilot, nor the aircraft met the requirements. Therefore, compliance with the regulation would have served as an important barrier to prevent the accident from happening.

There was, therefore, an inaccurate and inadequate evaluation of the risks involved, when the pilot adhered to a type of operation for which he was not qualified.

The inadequate evaluation of a context and elements which pose a risk to the intended operation leads, consequently, to the adoption of unsafe attitudes; in this case, the non-observance of the regulation.

For a helicopter pilot intending to take off from an aerodrome homologated or registered for VFR operations during night-time, the ICA 100-4, item 3.4.2.1, establishes that the location must have: runways or landing areas with an operative lighting system; an operative aerodrome/helipad beacon; and a wind direction or ATS unit in operation.

In the same way, the RBAC 135.207, which, in spite of not being applicable to the PT-YJJ case (operation under the RBHA 91), establishes a requirement of surface references, stating that no-one is allowed to operate a helicopter under VFR, unless they have visual references of the surface or, if at night, visual illuminated references on the surface, sufficient for the safe control of the flight.

The lighting requirements mentioned in the two paragraphs above have, among other factors, the purpose of preventing spatial disorientation on the part of the pilot during night-time takeoff and landing operations.

Upon taking off at 01:17 from the Araguaia River camp, located at a distance of 14 km from the city of Aruanã, heading 145º, with the moon behind him, without visual references of the surface, and without definition of external references of the skyline, the pilot entered an IFR flight scenario. Ahead of the aircraft, there was a large area of dense vegetation without any form of lighting (more than 10 km). Such scenario is similar to the one shown in the pictures 58 and 59.

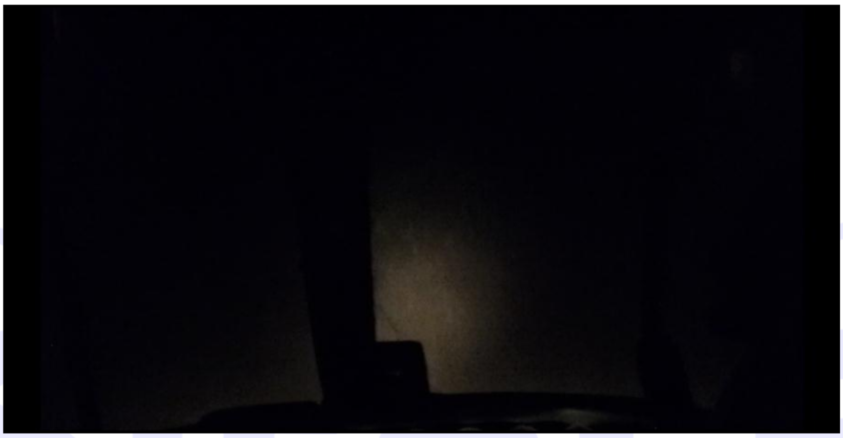


Figure 58 - Takeoff run with landing/taxi light. Image of the 55th second of the video recording of the takeoff from the tactical lighting point.

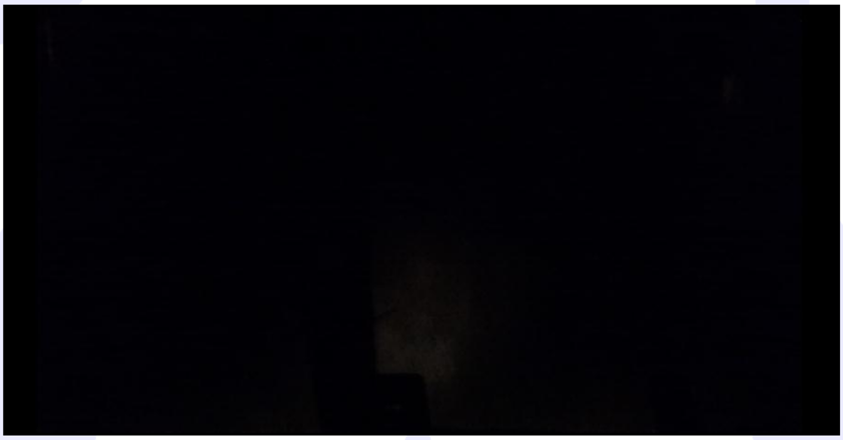


Figure 59 – Takeoff run with landing/taxi light. Image of the 60th second of the video recording of the takeoff from the tactical lighting point.

The Investigation Commission inquired the aircraft manufacturer about what would be the projection of the area illuminated by the aircraft landing and taxi lights with the aircraft at a height of 30 meters AGL. The answer was that, at a longitudinal takeoff attitude (-15°), the lights would illuminate an ovoid area, whose dimensions are compatible with a rectangle of 21.6 meters x 8.4 meters, in a position on the ground located between 41.9 meters to 46.5 meters ahead of the aircraft, varying in accordance with the lateral aircraft attitudes (banking) from 0° to 30°.

By means of tests of night-time takeoffs with another AS 350 aircraft, from a location without ground illumination, the Investigation Commission examined the extent to which the illumination provided by the landing and taxi lights would mitigate the lack of illumination on the ground.

The results indicated that, with the aircraft at a height of 30 meters (last altitude measured by the GPS onboard the PT-YJJ), the area illuminated by the aircraft lights is little effective to determine a horizontal plane capable of orienting the pilot. When a pilot seeks a definition of the skyline, such situation may generate disorientation in terms of the longitudinal and lateral attitudes.

This scenario is completely different from the ones experienced by the pilot in his night-time operations at the GRAER, in the aerodromes and helipads of the vicinity of Goiânia, and at the very residence of Aruanã, locations for which there were records of night-time takeoffs and landings.

In these locations, the lighting on the ground served as reference marks which provided the pilot with a notion of the horizontal plane. It is worth stressing that no records were found of concerning any night-time departures made by the pilot in this camp of the Araguaia River.

From the trajectory recorded in the GPS, it was observed that the first 200 meters of the horizontal movement were at heading 145°. The approximate direction of the line of wreckage distribution was 190°. It was understood, therefore, that between the moment of GPS recording termination and the first point of impact with the ground, the aircraft made a turn to the right. Such right turn is compatible with the course toward the city of Aruanã, which would require the maintenance of the turn for an arc of 70°, until reaching heading 215º.

The first impacts with the ground (upper part of the right ski - figures 6 e 7 - and tip of the main rotor blade - figure 10 -, indicated that the aircraft was on a pitch-down attitude of more than 15º with an angle of bank to the right of 32º. Both the longitudinal and lateral attitudes were not compatible with a situation of controlled flight of a night-time environment.

The analysis of the fracture at the point of separation of the tail boom showed deformation by compression in the right and lower sections. There were signs of traction (tearing at the fixation of the rivets) on the upper left side, next to the point of attachment of the cone to the structure. Such characteristics were indicative of a frontal impact, more prominent on the right side of the aircraft, with the tail resting on top of the cabin wreckage.

The absence of flight data recorders did not allow the confirmation of maximum angle of bank reached by the aircraft during the turn to the right, and one cannot rule out the possibility that it exceeded an angle of bank of 32°. As a matter of fact this was the angle of bank at the moment of the impact.

Considering the scenario in question, the execution of a turn with such angle of bank at about 30 meters AGL indicates the probability that the pilot was not monitoring (by means of cross-checks) the condition of the flight with the artificial horizon on the aircraft dashboard. Although the helicopter possessed this instrument, and the normal procedures required it to be turned on during the preparation of the aircraft for flight, the pilot in question was not qualified for IFR operations in the helicopter. Besides, the very altitude of the flight would induce the pilot to seek for external references for orientation

The lack of ground illumination, the lack of references of the skyline, the position of the moon in back of the pilot, and the poor effectiveness of the aircraft lights to determine a horizontal plane on the ground with the aircraft at a height of 30 meters may have interfered in the processes of sighting, assimilation, and interpretation of elements external to the aircraft, favoring a poor perception of lateral and frontal obstacles, as well as of the position of the aircraft in relation to the ground.

In addition to the lack of references external to the aircraft for the maintenance of a night-time VFR flight, at the initial takeoff heading and the direction of the impact trajectory, the aircraft impact attitude and the very energy of the impact indicated spatial disorientation and visual illusions as the most probable hypotheses for the accident.

Considering all the characteristics of the scenario, it is estimated that the pilot, upon attempting to reach the heading that would put him in the direction of Aruanã, searching for the city lighting on his right, may not have perceived that the variations of his aircraft longitudinal and lateral attitudes put it in a trajectory towards the terrain.

Spatial disorientation is not directly correlated with a pilot’s psychomotor skills. It results from a physiological restriction that is inherent to every human being. In the situation in question, it seems that the pilot lost orientation due to lack of visual references, which correspond to 80% of the orientation information. The other 20% comes from the vestibular and proprioceptive systems, when in IMC conditions or during night-time flights, and are susceptible to illusions and erroneous interpretations, being, therefore, less accurate.

Spatial disorientation presents a high level of participation in accidents during night-time takeoffs. The National Transportation Safety Board (NTSB) conducted a study of the period 1983-1993, in which 78% of the 291 accidents in the USA during the takeoff phase involved spatial disorientation.

The inexistence of a second pilot to alert the pilot acting on the flight controls (and, therefore, with a high workload), as was the case in the accident flight, further favored the onset of spatial disorientation and visual illusions.

Another aspect observed in this accident relates to the fact that the pilot spent a long time (several hours) in an illuminated environment (thatched hut). Between the time he left the hut and the time of departure approximately five minutes elapsed. Adaptation to darkness is recommended for night flights, and 30 to 45 minutes are necessary for maximum adaptation of one's vision to conditions of minimum lighting.

Thus, considering that the pilot was not adapted to darkness, the probability of the occurrence of visual illusion increases significantly, because in the dark visual acuity and depth are reduced.

At the takeoff of the accident flight, the pilot performed the initial climb of the aircraft almost vertically up to a height of 10 meters in the direction of the camp (illuminated area). Then, he turned counterclockwise to reach the heading to be utilized as the initial climb track (145°). At this heading, the aircraft left the height of 10 meters at a zero horizontal speed and reached a height of 30 meters at a speed of 57 kt. (approximately 105 km/h, after traveling a distance of 200 meters. These characteristics indicated that, during the takeoff, the pilot entered a scenario that may have favored the occurrence of a somatographic illusion.

In a somatographic illusion during the takeoff procedure, the pilot (deprived of adequate external visual references under IMC or on a night-time flight), with the aircraft being accelerated, has a sensation as if the aircraft is in an excessive nose-up attitude, something that is not happening.

In such case, the pilot's natural reaction is to act on the controls in order to counteract his sensation. This leads the pilot to unintentionaly command the aircraft to a nose-down attitude, putting it in a trajectory which points toward the terrain, during the takeoff.

The decision-making process

Notwithstanding the characteristics of the operational environment, and the fact that the pilot was not rated IFR in helicopters, in addition to the fact that the aircraft was not certified for IFR flights, the investigation commission analyzed the factors that may have influenced his decision to conduct the flight in which the accident occurred.

The trip to the camp had not been previously planned. His summoning for the flight at approximately 19:00 had been unexpected, with the aircraft departing from the Aruanã residence at 19:26 already at night time.

The owner was not onboard the aircraft, and the other passengers were not knowledgeable of aeronautical regulations. Therefore, it was the pilot's responsibility to advise them about the unviability of the flight, after considering the criteria for night-time VFR flights, in accordance to the ICA 100-4 prescriptions.

The investigation verified that in the previous year there were several night-time VFR flights which departed from the Aruanã residence, overflew the Araguaia River, returned, and landed at the point of origin.

For this type of flight, with a pilot not rated IFR flying an aircraft not certified for IFR operations, the operation has to be performed within the limits of an ATZ, CTR or TMA, or within a 27NM radius of the aerodrome/helipad of origin (item 3.4.2.2 of the ICA 100-4). However, the pilot was not being compliant this requirement of the regulation with by, since the point of origin was neither a helipad nor an aerodrome, in addition to not being within an ATZ, CTR or TMA.

According to information gathered, the pilot had already made comments about his discomfort related to night-time flights. However, he did not discuss the subject with the aircraft owner. The investigation was not conclusive as for the reason he had not discussed the issue with his boss.

According to the first record of a night-time flight in Aruanã found in the PT-YJJ logbook and dated 15 July 2012, the pilot took off from the Aruanã residence 10 minutes before the sunset, and landed 8 minutes after sunset. On the occasion, considering the sunset time proximity, there was a well-defined natural horizon for flight orientation, in addition to the lighting features of the city and of the landing site.

In the second record of a night-time flight in Aruanã (dated 29 March 2013), in a way similar to the one afore mentioned, the pilot departed from the Aruanã residence 28 minutes before sunset, and landed 9 minutes after the sun had set.

According to the records of the third night-time flight in Aruanã (29 May 2013), the pilot took off from an aerodrome in Goiânia at day-time, and later landed at the Aruanã residence, 36 minutes after sunset.

In the fourth record of a night-time flight in Aruanã (29 June 2013), the pilot took off from the Araguaia River camp (the same of the accident) 6 minutes before sunset, and landed at the Aruanã residence 10 minutes after sunset.

The fifth record of this type of event (2 July 2103) shows that the pilot departed from the Aruanã residence 7 minutes before sunset, and landed 12 minutes after the sun had set.

On 4 Sept 2013, according to the records of the sixth night-time flight, the pilot departed from an aerodrome in Goiânia at day-time, and landed at the Aruanã residence 15 minutes after sunset.

The seventh and eighth night-time flights in Aruanã took place on 16 December 2013, with the aircraft departing from, and landing at, the Aruanã residence. As for the seventh, the aircraft took off 11 minutes before/ and landed 8 minutes after sunset. The eighth flight was entirely night-time, with the aircraft departing 19 minutes after sunset for a flight which lasted 25 minutes.

The ninth (and last) record of a night-time flight in Aruanã (20 April 2014, shows that the pilot took off from another location in the State of Goiás at day-time, and landed at the Aruanã residence 17 minutes after sunset.

The night-time operations at the Aruanã residence were not in accordance with the night-time VFR flight regulations (ICA 100-4), since that helipad was neither homologated nor even registered, nor were the flights conducted within an ATZ, CTR or TMA. However, the investigation observed that the pilot gradually became accustomed to this type of operation.

An increasing frequency of this type of operation would naturally tend to augment the pilot's self-confidence. Such fact reinforces the natural tendency of human beings in seeking support in the success of early experiences as a foundation for attitudes they deem similar to those ones.

In this case, a successful landing made 5 minutes after the sunset would pave the ground for landings 10 minutes after the sunset on a next flight on account of self-confidence increase, so on and so forth. Therefore, since the pilot had already flown during night-time over the city, it is possible that this may have reinforced his confidence to do the same again, although in another location – in the camp.

The tendency to accept night-time flights may be associated with both the praxis in the region (already a routine among the pilots operating in the area) and the very discomfort felt by the pilot with the idea of refusing to fly at night, due to the employment relationship existing between the pilot and the owner of the aircraft.

Despite the fact that there was not a helipad in the Aruanã residence, the conditions of illumination in the takeoff/landing site, together with the city lights, provided the pilot with visual references for flight orientation. These features, associated with his increasing familiarization with night-time operations at the residence of Aruanã, may have created in the pilot a feeling of self-confidence for the conduction of such flights.

Besides, there weren't any records in the aircraft logbook regarding either a takeoff or landing during the night in the Araguaia River camp, the site of the accident.

Upon his unexpected summoning for the flight around 19:00 (local time) of 6 June 2013, the pilot may have rated the factors involved in the operation in a fashion similar to the ones he would encounter in the operations at the residence in Aruanã. However, in addition to not comply with the ICA 100-4 prescriptions, he may have failed to consider that the characteristics of the operation in the Araguaia River Camp were completely different from the ones at the residence of Aruanã.

In the camp, there was a factor of high potential of risk, due to the lack of illuminated visual references on the ground, below the helicopter, to assist in the safe conduction of the flight.

Workday

In relation to the workday, in reference to the Law 7183 of 5 April 1984, it was verified that, in the period from 14 October 2011 to 6 June 2014, only once was there a workday extension of 2 hours for a single crew, on 29 May 2013. Therefore, workday extension was not characterized as part of the pilot's operational profile.

On 6 June 2014, the pilot reported to the workplace at approximately 10:20 local time, half an hour before the first takeoff.

After landing at the Aruanã residence at 13:44, the pilot enjoyed a rest period from 14:00 to 19:00 in appropriate accommodations.

The rest period of five hours would allow a workday extension from 11 hours to 13 hours and 30 minutes, if one considers the paragraph 1 of the Article 21 of the Law 7183, dated 5 April 1984. Thus, the pilot's workday on 6 June 2014 should have finished at 23:50.

Between 19:26 and 19:36, the pilot flew the helicopter from the residence in Aruanã to the camp in the Araguaia River. After the landing, he stayed for more than five hours in a thatched with the other occupants of the aircraft, and playing cards. The result of his alcohol-blood test was negative.

The accident occurred at 01:27, i.e., one hour and thirty seven minutes after the time at which the workday should have been terminated (23:50). This may have generated fatigue in the pilot, degrading his piloting performance. However, the lack of accurate data on the pilot's overall condition; the fact that the accident occurred at the first minute of flight; the fact that even a pilot in normal conditions of rest may suffer spatial disorientation and visual illusions; all of this did not allow the commission to determine fatigue as a contributor to the accident.

3. CONCLUSIONS

3.1 Facts

a) The pilot had a valid Aeronautical Medical Certificate and a valid Technical Qualification Certificate;

b) the pilot was not qualified for IFR flights in helicopters (IFRH);

c) the aircraft had a valid airworthiness certificate;

d) the aircraft was not certified for IFR flights;

e) the prevailing weather conditions were VMC, wind calm;

f) the site from which the aircraft took off was neither homologated nor registered. It had no illuminated ground references in the direction of departure for over 10 km.

g) The aircraft initiated a vertical takeoff up to 10 meters, made a tail-turn to the right of more than 180°, and then moved horizontally at heading 145°, reaching a speed of 57 kt at a height of 30 meters AGL.

h) the aircraft impacted the ground at a distance 430 meters from the point where the takeoff began;

i) the engine and dynamic assemblies examination indicated a high rotational energy impact with the ground;

j) The examination of the flight control and hydraulic system do not exhibit pre-ground impact failure;

k) all the aircraft occupants perished; and

l) the aircraft sustained substantial damage..

3.2 Contributing factors

- **Disorientation – undetermined**

The absence of lighting on the ground, the lack of visual references of the skyline, the position of the moon in the rear sector, the poor effectiveness of the headlights for the definition of a horizontal plane on the ground with the aircraft at a height of 30 meters AGL, and the very aircraft impact attitude were indication of spatial disorientation on account of visual and/or vestibular illusion as the most probable hypothesis for the accident.

- **Fatigue – undetermined**

The extension of the workday to a point beyond what was stipulated by the regulation may have favored a progressive degradation of the pilot's operational performance.

Nevertheless, the lack of accurate data concerning the pilot's overall condition would not allow affirming the occurrence of fatigue.

- **Visual illusions – undetermined**

In the case in question, a false horizon visual illusion may have occurred, related to a poor perception of the horizon, commonly experienced in night-time flights without visual references; and/or somatographic illusion, which affects the spatial orientation on account of poor perception related to the visual and/or vestibular systems.

- **Attitude – a contributor**

The pilot's non-observation of the ICA 100-4 prescriptions regarding night-time VFR flights gave origin to a type of operation for which he was not qualified, reflecting a complacent attitude in relation to the existing regulation.

- **Motivation – undetermined**

It is possible that the pilot did not turn down his boss' request for a night-time flight operation which was not in accordance to the rules, motivated by the desire of keeping his job and his bonds with the air activity.

- **Perception – undetermined**

The lack of external visual references may have interfered in the processes of sighting, assimilation, and interpretation of the elements external to the aircraft, favoring an inefficient perception of lateral and frontal obstacles, as well as of the very position of the aircraft relative to the ground.

- **Decision making process – a contributor**

The decision to take off from a non-homologated/non-registered location during a night-time period, without external illuminated references, with a helicopter not certified for IFR flights, and a pilot not rated IFR, reflected a sequence of inadequate judgments in relation to the context of the operation, fostering a takeoff under significantly adverse conditions.

- **Work group culture – undetermined**

The routine of flights over the Araguaia River not in accordance with the regulation may have interfered in the pilot's judgment of the minimum safety requirements for night operations in the camp.

- **Work physical conditions – undetermined**

The absence of appropriate conditions for night-time operations in the camp, without illuminated references for takeoffs and landings, may have favored de pilot's spatial disorientation, leading to the accident.

- **Support systems – a contributor**

The presence of vulnerabilities in the RBHA 91.327, in the specification of the criteria regarding the operation of helicopters in non-homologated/non-registered locations, favors the execution of flights under these conditions.

- **Application of controls – undetermined**

Possibly, the lack of visual references in the departure sector caused the pilot's disorientation of the pilot, which led him to use the flight controls in an inadequate manner, exceeding an angle of bank of 30 degrees at a height of 30 meters AGL.

The acceleration of the aircraft (in 200 meters) during the night-time takeoff without external visual references may have generated in the pilot a strong sense that the nose of the aircraft was moving upward in an excessive manner, something that was not happening. Such erroneous perception may have produced a somatographic illusion, leading the pilot to command a nose-down aircraft movement, putting him in a trajectory toward the ground during the takeoff procedure.

- **Flight indiscipline – a contributor**

The pilot performed a night-time VFR operation, in discordance with the item 3.4.2 of the ICA 100-4 Special Helicopter Air Traffic Rules and Procedures.

- **Pilot judgment – a contributor**

The pilot failed to evaluate the extent to which the physical and operational features of the takeoff site might affect the safety off light, and decided in favor of a night-time operation, in a location without external visual references, with an aircraft not certified for IFR operation, in addition to the fact that he was not qualified for IFR flights in the helicopter.

4. SAFETY RECOMMENDATION

A measure of preventative/corrective nature issued by a SIPAER Investigation Authority or by a SIPAER-Link within respective area of jurisdiction, aimed at eliminating or mitigating the risk brought about by either a latent condition or an active failure. It results from the investigation of an aeronautical occurrence or from a preventative action, and shall never be used for purposes of blame presumption or apportion of civil, criminal, or administrative liability.

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 on the occasion of the publication of this report:

To the National Civil Aviation Agency (ANAC), it is recommended:

A-103/CENIPA/2014 - 01 Issued on 11/SEPT/2015

In the RBHA 91.327.a.(3), relatively to the operation of helicopters in non-homologated/non-registered locations, clearly redefine the parameters capable of guaranteeing the safety of the aircraft and its occupants, as well as of third parties.

A-103/CENIPA/2014 - 02 Issued on 11/SEPT/2015

Redefine the minimum requirements for the formation of the Brazilian civil aviation helicopter pilots so that they become fully aware of the risks associated with the spatial disorientation for the air activity.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN

None.

On September 11, 2015.