COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-151/CENIPA/2016

OCCURRENCE:	**ACIDENTE**
AIRCRAFT:	**PR-IDR**
MODEL:	**AS 350 B3**
DATE:	**19NOV2016**

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 considering 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 distinct 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 Final Report has been made available to the ANAC and the DECEA so that the technical-scientific analyses of this investigation can be used as a source of data and information, aiming at identifying hazards and assessing risks, as set forth in the Brazilian Program for Civil Aviation Operational Safety (PSO-BR).

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

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

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

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Considering 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 19Nov2016 accident involving the model AS 350 B3 aircraft, registration PR-IDR. The accident was typified as “[LOC-I] Loss of Control in Flight”.

The aircraft was hovering as part of a police surveillance operation. The crew lost directional control of the helicopter, which started spinning to the left around its vertical axis, losing altitude until crashing on the ground.

The aircraft sustained substantial damage.

The four occupants of the aircraft perished in the crash site on account of impact forces.

An accredited representative of the *Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile* (BEA - France) was designated to participate in the investigation since France is the State of Aircraft Design.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ADE	Category of registration for aircraft under direct State administration
ANAC	Brazil´s National Civil Aviation Agency
BEA	*Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile*
CA	Airworthiness Certificate
CENIPA	Brazilian Aeronautical Accident Investigation and Prevention Center
CMA	Aeronautical Medical Certificate
DCTA	Department of Science and Aerospace Technology
DECU	Digital Engine Control Unit
DIVOP	Operational Publication
EEPROM	Electrically Erasable Programmable Read-Only Memory
FLIR	Forward Looking Infrared
GAM	Aerial and Maritime Group of the Rio de Janeiro Military Police
HMNT	Turbine Single-Engine Helicopter Class Qualification
IPEV	Flight Testing and Research Institute
LTE	Loss of Tail Rotor Effectiveness
METAR	Meteorological Aerodrome Report
MGB	Main Gear Box
OEE	Operator of Special Equipment
PCH	Commercial Pilot License – Helicopter category
PIC	Pilot in Command
PMD	Maximum Takeoff Weight
PMERJ	Military Police of the Rio de Janeiro State
PPH	Private Pilot License – Helicopter category
SBJR	Aerodrome Designator – Jacarepaguá Aerodrome - Roberto Marinho, Rio de Janeiro, RJ
SERIPA III	Third Regional Service for the Investigation and Prevention of Aeronautical Accidents
SIC	Second in Command
SIPAER	Aeronautical Accident Investigation and Prevention System
SJPM	Aerodrome Designator - *Cap PM Cidimar Antunes de Almeida* Helipoint, Niterói, Rio de Janeiro State
SN	Serial Number
TGB	Tail-rotor Gear Box
UTC	Universal Time Coordinated
VEMD	Vehicle Engine Multifunction Display
VMC	Visual Meteorological Conditions

1. FACTUAL INFORMATION.

Aircraft	**Model:** AS 350 B3 **Registration:** PR-IDR **Manufacturer:** HELIBRAS	**Operator:** Rio de Janeiro State Military Police (PMERJ)
Occurrence	**Date/time**: 19NOV2016 - (UTC) **Location:** Jacarepaguá **Lat.** 22º57'26"S **Long.** 043º21'27"W **Municipality – State:** Rio de Janeiro-RJ	**Type(s):** [LOC-I] Loss of control - inflight

1.1. History of the flight.

At about 1800 UTC, the aircraft took off from SBJR (*Roberto Marinho* Aerodrome, *Jacarepaguá - Rio de Janeiro*), bound for SJPM (CAP PM Cidimar Antunes de Almeida Helipoint, *Niterói - Rio de Janeiro* State), on a local surveillance flight in support of police operations, with two pilots and two special-equipment operators (OEE) on board.

Approximately one hour and twenty minutes into the flight, while hovering at a height of 1,000 feet, the helicopter inadvertently yawed to the left, with subsequent loss of control, in which the aircraft spinned around its vertical axis, losing altitude until colliding with the ground.

The aircraft sustained substantial damage.

All of the 4 crewmembers were fatally injured.

1.2. Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	4	-	-
Serious	-	-	-
Minor	-	-	-
None	-	-	-

1.3. Damage to the aircraft.

The aircraft sustained overall substantial damage.

1.4. Other damage.

NIL.

1.5. Personnel information.

1.5.1. Crew's flight experience.

Hours Flown				
	PIC	SIC	OEE	OEE
Total	633:55	332:15	494:45	09:45
Total, last 30 days	17:00	14:35	02:10	02:10
Total, last 24 hours	01:20	01:20	01:20	01:20
On this type of aircraft	482:55	227:10	494:45	08:25
On this type, last 30 days	17:00	14:35	02:10	02:10
On this type, last 24 hours	01:20	01:20	01:20	01:20

NB.: Information on hours flown was obtained from the records kept by the Operator.

1.5.2. Personnel training.

Both the Pilot in Command (PIC) and the Pilot Second in Command (SIC) did their Private Pilot Course (Helicopter category - PPH) at the PMERJ, Rio de Janeiro, in 2011.

1.5.3. Category of licenses and validity of certificates.

Both the PIC and the SIC held Commercial Pilot licenses (Helicopter category - PCH), and valid Single-Engine Turbine Helicopter (HMNT) qualifications.

1.5.4. Qualification and flight experience.

The pilots were qualified and had experience in the type of flight.

1.5.5. Validity of medical certificate.

The members of the crew had valid Aeronautical Medical Certificates (CMA).

1.6. Aircraft information.

The aircraft (SN 4844) was manufactured by HELIBRAS in 2009, and was listed in the ADE (Category of registration for aircraft under direct state-administration).

Its Airworthiness Certificate (CA) was valid.

The records of the cell and engine logbooks were up-to-date.

The latest inspection of the aircraft (type 25 hours) had been carried out on 31Oct2016, by the Aero-Maritime Group of the *Rio de Janeiro* Military Police in *Niterói*, *Rio de Janeiro* State. After that inspection, the aircraft flew 50 hours and 12 minutes.

The last overhaul of the aircraft (type 600 hours) was executed by HELIBRAS on 11Mar2016, in the city of *Itajubá*, *Minas Gerais* State. The aircraft flew 277 hours and 24 minutes after the overhaul.

On the day of the accident, the aircraft logbook indicated a total of 2,692 hours and 36 minutes of flight.

The aircraft was equipped with three pieces of electronic equipment: a Digital Engine Control Unit (DECU), a Vehicle Engine Monitoring Display (VEMD), and a thermography camera.

The DECU was a two-channel digital control of the engine which regulated the fuel, and managed the engine parameters, besides recording any detected failures of relevant systems in the non-volatile inner memories, namely the Electrically-Erasable Programmable Read-Only Memory (EEPROM), installed in each channel.

The VEMD was a multifunction screen installed in the instrument panel of the aircraft, with a two-channel system. Each one of the channels had an EEPROM memory which registered messages of both failures and exceeded limits, which were utilized in the operation and maintenance of the aircraft. Despite not being the purpose of the equipment, such data, when retrieved, may prove useful in the investigation of accidents.

The thermography camera was utilized in police operations, and had the objective of capturing infrared images of the electromagnetic spectrum, allowing visualization of the radiation emitted by objects and people.

1.7. Meteorological information.

The meteorological conditions were compatible with VFR.

1.8. Aids to navigation.

NIL.

1.9. Communications.

NIL.

1.10. Aerodrome information.

The accident occurred outside of aerodrome area.

1.11. Flight recorders.

Neither required nor installed.

1.12. Wreckage and impact information.

The aircraft crashed on soft terrain on the banks of a river, near the land area where police actions were being executed. The angle of impact and vertical speed were high.

The wreckage was concentrated, and the aircraft had a 45º-angle downward attitude in relation to its lateral axis, with a bank angle of approximately 80º around the longitudinal axis. (Figures 1 through 7).

Figure 1 – Crash-site on the banks of a river, close to the area of police operations.

Figure 2 – View of the aircraft after the crash on the river bank.

Figure 3 – Wreckage seen from above, highlighting two of the main rotor blades partially buried in the terrain.

Figure 4 – View of part of the aircraft tail boom.

Figure 5 – Rear view of the aircraft.

Figure 6 – Rear of the aircraft (left side) with the third blade of the main rotor in highlight.

Figure 7 – Tail-rotor of the aircraft.

The right-hand side of the fuselage, including the cabin, the underside structure and the tail boom, had significant damage, with flattening caused by the impact forces (Fig. 8).

Figure 8 – Greater damage to the right side of the aircraft with characteristics of flattening.

The tail boom was still aligned with the structure, although disconnected in consequence of the complete shearing of the coupling.

The main rotor blades sustained significant damage, with delamination on the spar and deformations on both the leading and trailing edges of the blades, typical characteristics of impact while the main rotor was rotating.

The Main Gear Box (MGB) was rotating freely and, upon being moved, it activated the Main Rotor head. The damage identified on the Main Rotor head showed characteristics of overload.

The Main Gear Box did not present any evidence of overheating or external damage.

The magnetic plug of the filings-detection system on the MGB was clean, and free of metal particles.

Damage with rotational characteristics was identified in the coupling assembly between the engine and the MGB. The damage was compatible with a shaft that was rotating at the moment of impact (Figures 9 and 10).

Figure 9 - Evidence of rotational damage on the inner splines of the engine shaft flange.

Figure 10 - Evidence of rotational damage between the engine connection tube and the engine output shaft (freewheel assembly).

The Tail Rotor Drive Shaft assembly showed significant damage and overload-related deformations (Figures 11 and 12).

Figure 11 - General view of the tail rotor drive shaft assembly.

Figure 12 – Evidence of overload-induced damage to the remaining parts of the flexible coupling of the tail-rotor drive shaft.

The Tail Rotor Gear Box and the Tail Rotor Head showed damage consistent with deformation caused by the impact of the aircraft with the ground (Figures 13 and 14).

Figure 13 – Tail rotor gear box: damage compatible with impact of the aircraft with the ground.

Figure 14 – Tail rotor head: damage compatible with aircraft impact with the ground.

There were no magnetic particles in the magnetic plug of the TGB.

The Tail Rotor blades showed damage compatible with the impact (Figure 15).

Figure 15 – Tail rotor blades: damage compatible with impact of the aircraft with the ground.

The controls of the collective, cyclic and pedals showed numerous structural deformations, compatible with failures due to overload. However, it was possible to confirm the continuity of both the main and tail rotors' flight controls. No evidence of pre-impact failures or anomalies was observed.

The hydraulic system and the servo-actuators were severely damaged when the aircraft hit the ground. Notwithstanding, no damage, deformations or failures were found other than the ones resulting from the accident.

A locking of the tail rotor hydraulic servo-actuator was identified. The component was sent in for detailed exams to determine the reason for such locking.

Neither the SERIPA III and BEA investigators, nor the representatives of the aircraft manufacturer, found any evidence regarding the existence of failures or abnormalities prior to the accident, as well as any evidence that the aircraft could have been hit by projectiles.

1.13. Medical and pathological information.

1.13.1. Medical aspects.

There was no evidence that aspects of physiological order or incapacitation could have affected the crew's performance.

1.13.2. Ergonomic information.

NIL.

1.13.3. Psychological aspects.

NIL.

1.14. Fire.

There was no fire.

1.15. Survival aspects.

Due to the force of the impact, there were no survivors. All occupants perished as a result of polytrauma caused by blunt action.

1.16. Tests and research.

Audio Spectrum Analysis

The audio of two videos recorded by observers from a distance of the accident site were subjected to laboratory analysis by the BEA (Figures 16 and 17).

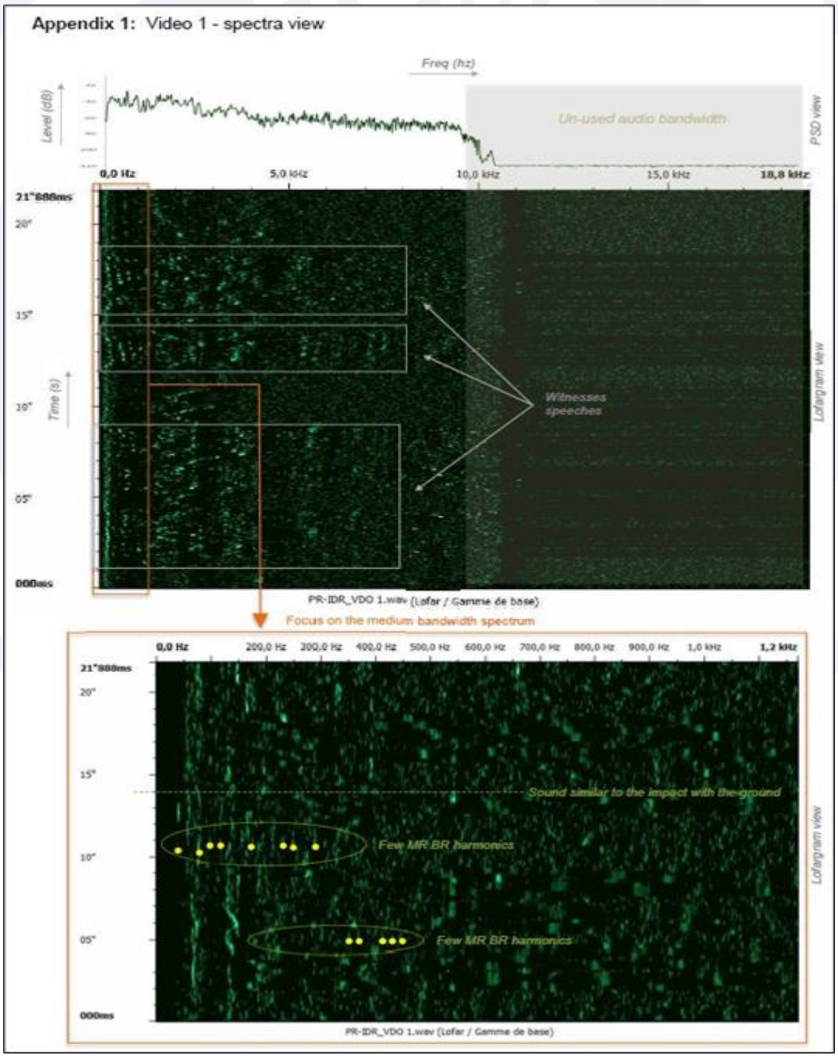

Figure 16 – Spectral analysis of the audio of the number 1 video related to the accident. Source: BEA.

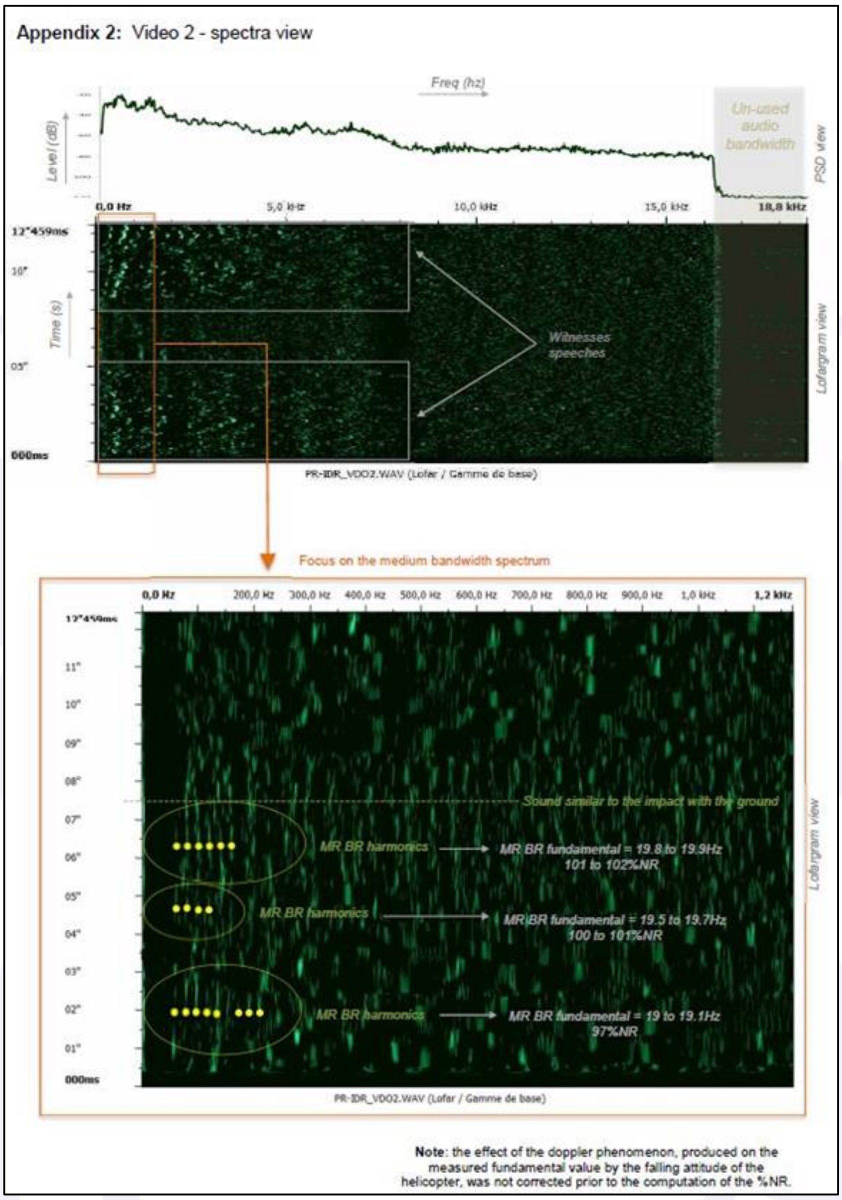

Figure 17 – Spectral analysis of the audio of the number 2 video related to the accident.
Source: BEA.

In the videos, it was possible to notice that, during the last thirteen seconds of the flight, the helicopter was rapidly descending in a state of continuous left rotation.

The frequency of the main rotor blades was the only information that could be obtained from the audios of the videos. The spectral analysis revealed that the harmonic frequencies of the main rotor blades were compatible with a rotor ranging between 97% and 102% of NR.

<u>Aircraft engine</u>

The aircraft engine was disassembled at the headquarters of SAFRAN Turbomeca *Brasil*, located in *Xerém*, *Rio de Janeiro* State, for analysis of damage to internal parts and components, in the presence of manufacturer representatives, engineers of the Department of Aerospace Science and Technology (DCTA), and investigators of the SERIPA III.

With the disassembly, it was possible to verify that the engine was in good condition, despite the damage and lockings caused by the impact. The analysis made it possible to confirm that the engine was developing high power at the moment of impact.

<u>DECU and VEMD</u>

The aircraft's DECU and VEMD were analyzed at the BEA laboratories.

The flight data retrieved from the non-volatile memories (EEPROM) of these devices were consistent and compatible with the event.

The analysis of the data retrieved from the VEMD showed that no failures associated with the event had been recorded, except for a recording of overtorque (for a period of less than one second), which reached a value between 105% and 107%.

The analysis of the data recovered from the DECU showed that several failures were recorded in the equipment memory at the exact moment at which the aircraft reached 1 hour, 18 minutes and 21 seconds of flight. Recording multiple failures at the same time is consistent with a situation of an aircraft impact against the ground.

No records concerning equipment failures were found prior to the aircraft impacting the ground.

The analysis of the data also made it possible to conclude that the aircraft engine was developing power at the moment of impact with the ground, with NG equal to 94.84%.

Tail rotor hydraulic servo-actuator

The tail rotor hydraulic servo-actuator was disassembled and analyzed at the UTC Aerospace Systems, manufacturer of the component, in the city of Vernon, France, in the presence of SERIPA III investigators.

In the analysis of the internal parts of the servo-actuator, no abnormalities were found that could have caused a failure or malfunction of the component.

The analysis revealed that the internal mechanisms were intact, with normal operation at the time of the accident. However, a dent in the control rod was identified, compatible with damage caused by impact, which made the servo-actuator get locked. The investigators also identified that the position in which the servo-actuator control rod got locked was equivalent to the one of a fully applied pedal position to the right.

Flight Tests

The SERIPA III investigators participated in a flight test with pilots and engineers of the Research and Flight-Testing Institute (IPEV) of the DCTA, making use of an AS-350 aircraft of the Brazilian Air Force (FAB).

The objective of the test was to demonstrate the flight qualities of the aircraft during a simulated loss of control of the tail rotor, when the characteristics of loss of directional control, as well as its recovery, were similar to the ones faced by the PR- IDR aircraft.

Under the conditions of the test, the investigators verified that the influence of the loss of efficiency of the tail rotor on the helicopter's yaw varied in function of the translation speed (forward speed) of the aircraft. When starting the simulated failure at speeds of 100 kt, 40 kt and 20 kt, a damped left yaw movement occurred.

In the 20-kt condition, the most critical situation of the ones mentioned above, the aircraft turned 20º to the left, and remained in a skidded flight with a 20º-yaw, that is, it was possible to verify that, with forward displacements, the aerodynamic surfaces (drifts and fuselage) were efficient to prevent loss of control of the aircraft.

Simulated failure tests were also performed in the tail rotor drive with the aircraft hovering outside of ground effect. In this condition, an undamped left yaw occurred, with the aircraft entering a continuous rotation condition, with an average rate of 33º/s. The maneuver ended after 1.5 laps, with the reduction of the collective pitch and application of the cyclic forward, in order to increase the forward speed.

The simulation was repeated under the same aforementioned conditions, but the position of the collective control received an increment of 0.5 inch as soon as the helicopter started to yaw. It was verified that, when applying the collective, the left turn rate increased from 33º/s to 57º/s, requiring interruption of the test in order to not exceed the aircraft directional-turn limit of 60°/s.

Based on the tests performed, the test flight let to the conclusion that, in the event of a tail rotor drive failure, the helicopter would enter a fast turn (yaw) to the left, in a way that the turn rate would increase considerably, on account of the collective inputs.

On the other hand, the test flight report highlighted those short forward displacements, at around 30 kt, would be enough to mitigate the yaw, allowing recovery of helicopter control, and the opportunity to take it to an area favorable for an autorotation landing.

Subsequently, another test was carried out to verify the workload required for regaining control of the helicopter after the failure simulation. For that purpose, the Bedford Workload Scale was chosen as a reference, since it is used in test flights, with the purpose of identifying the workload of a pilot when performing a task, assigning levels that vary from 1 (workload negligible) up to level 10 (pilot unable to apply required effort).

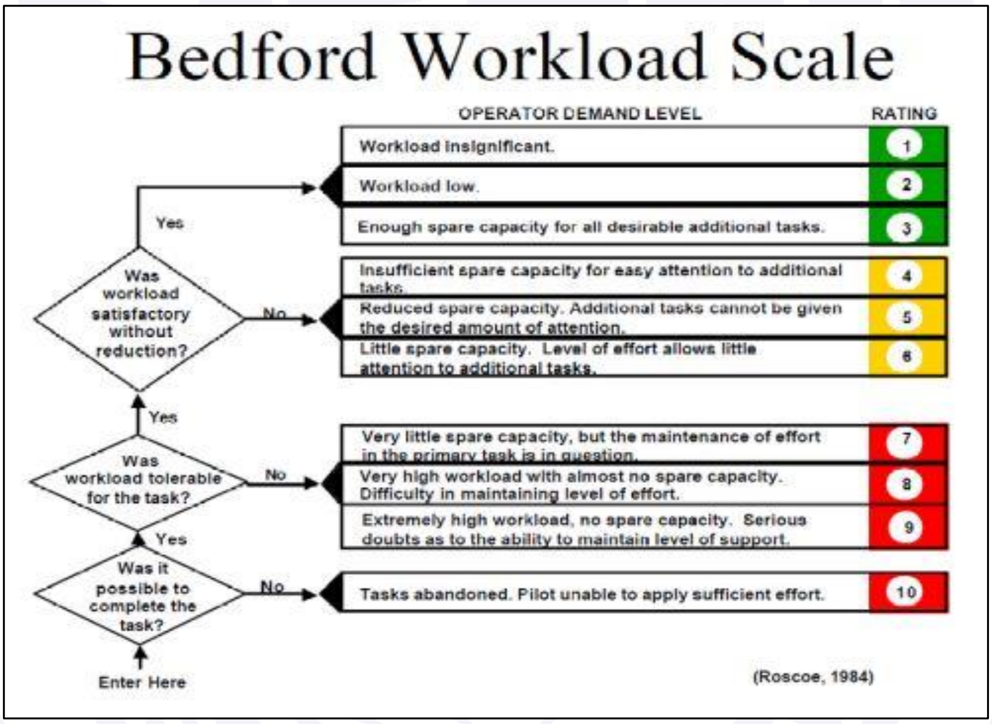

Figure 18 - Bedford Workload Scale.

In this simulation, two complete turns were executed before the start of recovery, followed by the lowering of the collective to the minimum, and application of the cyclic forward. After the maneuver, the rotation was stabilized in 3 seconds, at a speed close to 50 kt, while the aircraft continued to increase speed and lose height. From the beginning of the simulated failure, until the end of the recovery, when the aircraft leveled off at a speed of 80 kt, there had been a loss of 1,000 ft. in height.

For the execution of the aforementioned recovery procedures, the Bedford Workload Scale grade 7 was assigned, corresponding to "little ability to perform extra tasks, but without difficulties in maintaining the effort on the primary task (recovery and stabilization of the aircraft without using the pedals)."

1.17. Organizational and management information.

NIL

1.18. Operational information.

The aircraft was performing a local surveillance flight, in support of police operations in the vicinity of the site where the crash would occur sometime later. The crew consisted of two pilots and two OEE, who operated the Forward Looking Infra-Red (FLIR) equipment on board of the aircraft.

No records were found of any information given by the crew to the ATC control agencies concerning any kind of abnormality or emergency on board during the accident flight.

Based on the data presented below, it was possible to estimate the weight of the aircraft at the takeoff was 2,247 kg and, therefore, within the maximum takeoff weight limit of 2,250 kg, established by the manufacturer. Considering the data of fueling, consumption and fuel density, along with the duration of the flight recorded in the DECU, it was possible to estimate that the weight of the aircraft at the time of the accident was approximately 2,050 kg. The following data was collected:

Aircraft Basic Weight: 1,428 kg.

2 pilots + 2 armed OEE: 180 kg + 200 kg = 380 kg.

FLIR equipment: 94 kg.

Aviation Kerosene Density (QAV-1): 0.8 kg/l.

Fuel (80% or 432 liters): 345 kg.

Flight duration: 1 hour and 18 minutes.

Average engine fuel consumption: 190 l/h.

Fuel consumption during the flight: 247 liters (197 kg).

Weight at the time of crash: Takeoff Weight - Fuel Consumption = 2,049 kg.

There was no detailed operational standard established by the GAM for surveillance flights in support of police operations, with parameters for height and translational speed, for example, with the purpose of guiding the planning of flights.

The aircraft was hovering at an altitude of approximately 1,000 ft. when it suddenly started a yaw motion to the left with subsequent loss of control, and remained rotating to the left around its vertical axis, losing altitude until colliding with the ground.

1.19. Additional information.

Thermography camera (FLIR) video

The thermography camera installed on the aircraft was being operated at the time of the accident, and its memory data was later recovered. Besides images captured by the camera, it was also possible to obtain information on the aircraft's heading, speed, height and geographical position. However, there were not any audio recordings.

The SERIPA III investigators analyzed the video recorded by this camera, and concluded that, as the aircraft initiated the left yaw, the rate of rotation increased rapidly and, in about four seconds, exceeded the aircraft's limit of 60º/s in a continuous acceleration until stabilizing at a rate of about 360 degrees every 1.5 seconds (around 240º/s).

Loss of Tail Rotor Effectiveness (LTE)

LTE is a critical aerodynamic phenomenon characterized by a sudden un-commanded yaw around the vertical axis of the helicopter, which does not cease without proper pilot intervention, and may potentially cause loss of control of the aircraft.

LTE is not related to failures of the equipment or maintenance, and may happen with all types of helicopters equipped with a main rotor and a tail rotor operating at low speeds (generally less than 30 kt).

In this kind of phenomenon, the tail rotor does not “stall”, but becomes inefficient and does not produce the necessary traction to prevent the yaw.

Several factors may contribute to the occurrence of an LTE, including:

a) Variable and turbulent airflow from the main rotor blades, particularly in high power configurations;

b) Environment conditions;

c) Operations at low translational speeds (below 30 kt);

d) Operations at high altitudes, with aircraft weight close to the Maximum Takeoff Weight (PMD);

e) Operations near large constructions or large natural obstacles, which may cause turbulence; and

f) Intensity and direction of the relative wind.

In helicopters with rotors that rotate counterclockwise, the torque produced by the rotor causes, in the fuselage, a clockwise rotation tendency, that is, a nose-turn to the right.

Inversely, with helicopters that have a clockwise rotation of the main rotor, the effect on the fuselage is a tendency of rotation in a counterclockwise direction, that is, a nose-turn to the left.

As shown in Figures 19 and 20, the following wind conditions may favor the emergence of an LTE:

a) Operations with relative wind direction within ±15º of the 10 o'clock position (counterclockwise main-rotors) or within ±15º of the 2 o'clock position (clockwise main-rotors) generate swirly winds that blow directly on the tail rotor, and may drastically decrease its efficiency;

b) Tailwinds hitting a helicopter at angles between 120º and 240º may increase the pilot's workload and drastically reduce the tail rotor's efficiency

c) Crosswinds between 210º and 330º (counterclockwise main rotors) or between 30º and 150º (clockwise main rotors) may cause the development of a vortex ring in the tail rotor, which will produce a non-uniform and unbalanced air flow that will be sucked by the rotor. The direct consequence is the oscillation of the tail-rotor thrust, i.e., loss of its efficiency.

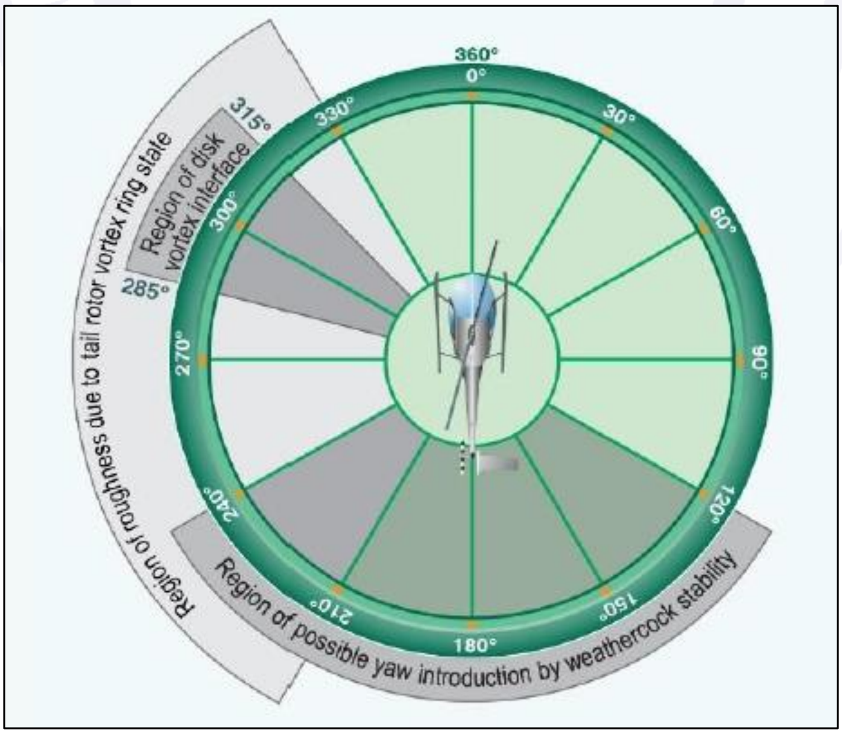

Figure 19 – Helicopter with main rotor turning counterclockwise.
Source: adapted from CENIPA, 2018 apud NTSB, 2017.

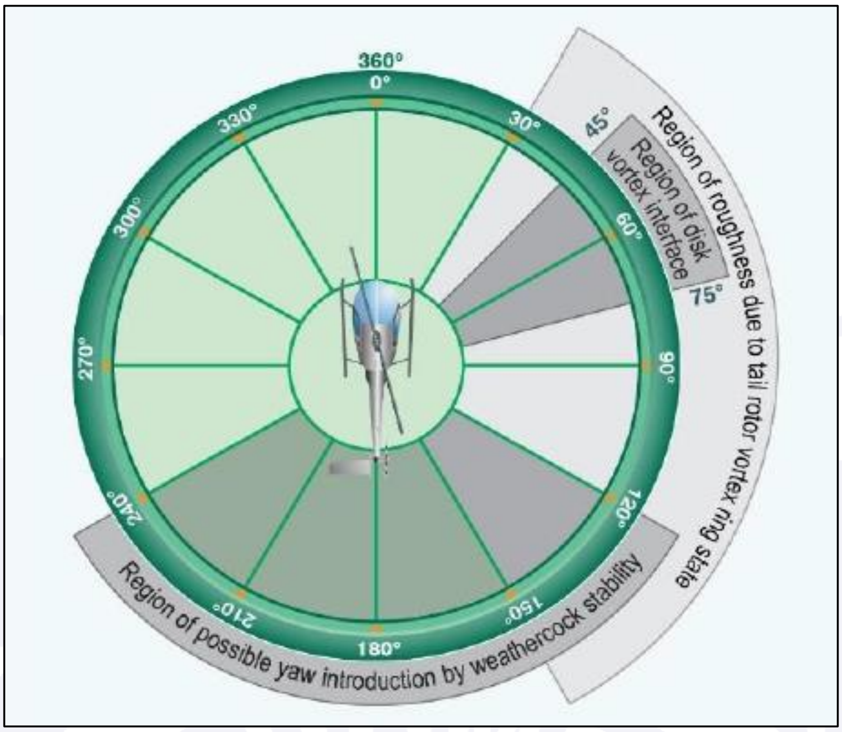

Figure 20 – Helicopter with main rotor turning clockwise.
Source: adapted from CENIPA, 2018 apud NTSB, 2017.

On tailwind approaches, when losing translational lift, or even during the initiation of a go-around at low forward speed, the sudden increase in power required to maintain the aircraft hovering may exceed the anti-torque capability of the tail rotor, especially with high values of weight and altitude.

In hovering flights outside of ground effect, for example, there may not be enough pedal travel to counteract the main rotor torque, so an inadvertent yaw may occur, especially in cases of high values of weight and with a torque close to the limit.

Although some simulators allow pilots to practice recovery, the phenomenon is not realistically reproduced. In addition, real flight training is rarely carried out due to the risk involved and the high costs charged by Civil Aviation Instruction Centers offering such service. Therefore, as a consequence, pilots may not respond with the necessary expertise to identify the LTE condition and, consequently, may not be able to properly regain control of the aircraft.

There was not any specific training in the instruction program for the PMERJ (GAM) helicopter pilots concerning the adoption of adequate procedures in emergency situations originated by aerodynamic phenomena, such as the LTE, either in simulators or in real flights.

Typical civil aviation operations in which LTE events have a higher possibility of occurrence include inspections of power transmission lines, electromagnetic surveys, rescue and air ambulance services, police operations, press reporting and filming services.

AIRBUS HELICOPTERS published the Safety Information Notice n° 3297-S-00 - Unanticipated Left Yaw (main rotor rotating clockwise), commonly referred to as LTE. The document addressed, from another point of view, the inadvertent yaw to the left of a helicopter with a clockwise-rotating rotor.

The Safety Information Notice mentioned above reported that the unanticipated yaw was a flight characteristic to which all types of single-rotor helicopters (regardless of anti-torque design) may be susceptible at low speed, generally depending on the direction and intensity of the wind relatively to the helicopter.

According to the publication, such characteristic was initially identified and analyzed in relation to OH-58 helicopters by the US Army, which coined the description "loss of tail rotor effectiveness" (LTE), although the tail rotor always remained fully operational. It is important to clarify that the phenomenon is not associated with any material failure and has nothing to do with the total loss of thrust of the tail rotor.

The unanticipated yaw may be swift and occurs in a direction opposite to the rotation of the main rotor blades (i.e., a left yaw where the blades rotate clockwise). Immediate corrective action must be taken. Otherwise, loss of control and a possible accident could occur.

The document warned that the fact that the application of the pedal for correction, at first, did not guarantee that the yaw would immediately decrease, could lead the pilot to suspect that the effectiveness of the tail rotor was compromised, when, as a matter of fact, the availability of the tail rotor thrust still remained unchanged.

Thus, the publication pointed out that the term "Loss of tail rotor effectiveness" was therefore not the most efficient description, as it mistakenly implied that the efficiency of the tail rotor was reduced under certain conditions.

Therefore, understanding the nature of an unanticipated yaw is critical for its avoidance, mainly because it constitutes a contributing factor in a number of accidents.

In this regard, the Safety Information Notice No. 3297-S-00 provided detailed information on when the situation might arise, why the tail rotor could seem ineffective, and how to react to maintain or regain full control of the equipment.

The apparent inefficiency of applying the pedal to avoid an unexpected yaw may lead to the misinterpretation of a total loss of the tail rotor thrust (for example, as would be the case after failure of the tail rotor drive). The symptom (intense inadvertent left yaw) is similar, and the short-term response to a late and ineffective pedal input is almost zero in both cases.

Only the immediate application of the right-hand side pedal in all its amplitude and in a timely manner will be able to counteract the rotation, and allow the pilot to identify whether he is experiencing an unexpected yaw or a total loss of thrust of the tail rotor due to malfunction.

If full use of the right-hand side pedal has no effect on the yaw after a timely correction, an immediate landing is required, due to a failure in the tail rotor drive system. If, however, full application of the right pedal slows the yaw, it is clear that the problem is an inadvertent yaw, which requires staying well clear of the ground and obstacles until full recovery is achieved.

The most likely reason for accidents following unanticipated yaw events is a late and very limited application of the pedal.

During an unanticipated yaw event, the tail rotor remains fully effective and offers the best chance of recovery. The yaw rate and wind conditions reduce the rotor's effectiveness if it maintains a constant pitch. This must be counteracted by substantially increasing the tail rotor pitch.

The only early sign the pilot may receive of a possible loss of control is the onset of an unexpected yaw.

For this reason, the Safety Information Notice recommended the actions below:

- Be especially careful when the wind comes from the right side or from the front-right quadrant. Do not fly unnecessarily under such conditions;
- Choose turns to the right as much as possible, especially in limited performance conditions. It is easier to monitor the torque demand at the beginning of the maneuver than when responding to an inadvertent and abrupt yaw;

- When making a tail turn, do it with a low yaw rate; and
- If an unanticipated yaw occurs, react immediately and with great amplitude, using the pedal opposite to the direction of rotation. Be ready to use the pedal to its full range if necessary. Don't limit yourself to what you think is enough, your feeling could be wrong. Never place the pedal in neutral before the yaw is stopped.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

The aircraft was performing a local aerial surveillance flight, in support of police operations in the vicinity of the site where it crashed sometime later, with two pilots and two OEE, who operated the Forward Looking Infra-Red (FLIR) equipment on board the aircraft.

The pilots were qualified and experienced in the type of flight.

Meteorological conditions were compatible with VFR flights. No records were found that the crew informed the control agencies of any abnormality or emergency on board during the accident flight.

The AS 350 B3 aircraft was operating within the weight and balance limits specified by the manufacturer. Based on technical information about the aircraft, as well as fueling, density of the aviation kerosene (QAV-1), and approximate weight of occupants and equipment, the weight of the aircraft at takeoff was estimated to be approximately 2,247 kg, a value very close to the MTOW value of 2,250 kg prescribed by manufacturer.

Similarly, the weight of the aircraft at the time of the occurrence was estimated at 2,050 kg, considering the data on average fuel consumption and flight time.

At that moment (approximately 1 hour and 20 minutes into the flight), while hovering at an altitude of 1,000 ft., the helicopter unexpectedly yawed to the left and, shortly thereafter, the pilots lost control of the aircraft, which remained in a state of continuous rotation to the left, around its vertical axis, losing height until the collision with the ground.

Observers located at a distance from the crash site recorded the last thirteen seconds of the flight in two videos, when the helicopter lost altitude with a continuous left yaw movement. The videos were analyzed at the BEA laboratories. On account of the distance and quality of the video recording, the frequency of the main rotor blades was the only piece of information that could be obtained.

Nonetheless, by means of a spectral analysis, this piece of information revealed that the harmonic frequencies of the main rotor blades were compatible with a rotor varying between 97% and 102% NR. In other words, values compatible with a main rotor operating normally.

The conclusion of the aforementioned spectral analysis was consistent with the result of the analysis of the engine by the investigators, since at the disassembly of the component, it was possible to confirm the presence of damage and lockings caused by the impact. Additionally, the investigators concluded that the engine was developing high power at the moment of collision with the ground. Such conclusions were also compatible with the data retrieved from two electronic devices installed on the aircraft: DECU and VEMD.

The aircraft's DECU and VEMD were analyzed at the BEA laboratories, resulting in the verification that the data retrieved from the EEPROM memories of these pieces of equipment were consistent and compatible with the event.

The analysis of the data retrieved from the VEMD showed that no failure associated with the event was recorded, except for an over torque recording for a period of less than one second, which reached a value between 105% and 107%, not compatible with the event and, therefore, not considered in the analysis.

On the other hand, the data recovered from the DECU showed that there was a recording of several failures in the equipment's memory at the exact moment when the aircraft completed 1 hour, 18 minutes and 21 seconds of flight, allowing investigators to conclude, based on the experience acquired in analyses from previous catastrophic events, that these failure messages were related to the impact of the aircraft against the ground, with the aircraft engine still developing power, at an NG equal to 94.84%.

Based on the aforementioned analyses (spectral and electronic equipment), the conclusion was that the aircraft did not present any abnormalities that could explain the loss of control until the impact with the ground. Such conclusion was supported by the detailed examination of the wreckage, which did not identify any evidence of pre-impact abnormalities that could explain the sequence of events, nor any evidence that the aircraft could have been hit by projectiles.

Mechanical continuity was verified between the aircraft engine and the main transmission, as well as between the engine and the tail rotor. As the spectral analysis concluded that the main rotor was rotating at a nominal speed, it is possible to state, on account of the confirmed continuity cited above, that the tail rotor was also rotating at a nominal speed until impact.

The main rotor blades sustained significant damage, with characteristics of being the result from impact with the ground while rotating. Examination of the main and tail rotor components also confirmed continuity of controls from the cockpit to the respective rotor blades and that all damage and failures observed were the result of the impact with the ground.

The examination of the hydraulic circuit and of the servo-actuators did not reveal any damage or failure other than the ones resulting from the accident, but it was necessary to deepen the examinations of the hydraulic servo-actuator of the tail rotor, in order to clarify the reasons for its locking.

Therefore, the tail rotor servo-actuator was disassembled and analyzed at the manufacturer's headquarters in the presence of CENIPA and BEA investigators.

During the disassembly and analysis of the internal parts of the tail rotor hydraulic servo-actuator, no abnormalities were found that could have caused a previous failure or malfunction.

The analysis concluded that the internal mechanisms were intact, indicating normal operation until the moment of the accident. However, a dent on the control rod was identified, compatible with damage caused by impact, which caused the servo-actuator to lock in that position. The investigators further identified that the locking position corresponded to a full application of the pedal to the right.

The above finding, consistent with the uncontrolled left turn, indicates the possibility that one of the pilots tried to regain directional control of the aircraft at some point of the descent before the crash, because at that precise moment, the pedal control was in a position of full application to the right. It also showed that, possibly, one of the pilots was aware of the aircraft rotation to the left during the crash. However, a few seconds after the start of the unexpected yaw, the aircraft was already stuck in an uncontrolled rotation.

From the recordings of the thermography camera (FLIR) installed on the aircraft, which was operating at the time of the accident, it was possible to obtain aircraft data such as heading, speed, height, geographic position, in addition to images of the location of the operation. The data showed that, shortly after starting the unexpected left yaw, the aircraft rate of rotation increased rapidly and, in about four seconds, exceeded its limit of 60º/s.

Then it kept accelerating until stabilizing at about one 360-degree-turn every 1.5 seconds (i.e., about 240º/sec). In other words, four times above the aircraft limit prescribed in the manual.

Since no evidence was found of failures or malfunctions capable of elucidating the onset of the event, this investigation considered the hypothesis of occurrence of an aerodynamic phenomenon, known as Unanticipated Left Yaw, commonly referred to as LTE, which is not associated with failures of equipment or maintenance, and may occur on all helicopters with one main rotor and a tail rotor.

This aerodynamic phenomenon is characterized as a sudden and uncontrolled yaw (a turn around the vertical axis of the helicopter) that will not cease without correct intervention by the pilot, and may result in loss of control of the aircraft.

In helicopters with a clockwise rotation of the main rotor, as is the case of the AS 350 B3, the torque produced by the rotor causes, in the fuselage, a tendency to rotate in a counterclockwise direction, that is, nose-turn to the left.

During the occurrence of an Unexpected Yaw, although not “stalling”, the tail rotor becomes inefficient and does not produce enough thrust to counteract the tendency of the helicopter to yaw due to engine torque, resulting in a tail turn not commanded by the pilots.

Several factors may contribute to the occurrence of an Unexpected Yaw (also known as LTE), such as variable and turbulent airflow from the main rotor blades, particularly in high power configurations, operations at low translational speeds (below 30 kt), and operations at high altitudes with aircraft weight close to MTOW.

On hovering flights outside of ground effect, for example, there may not be enough pedal travel to counteract the main rotor torque, so an unanticipated yaw may occur, especially in cases of high weight with torque close to the limit, as was the case of the PR-IDR.

Typical civil aviation operations with a higher possibility of occurrence of Unexpected Yaws or LTE include inspections of electrical power transmission lines, electromagnetic surveys, services of rescue and air ambulance, press reporting services and police operations.

Although a number of simulators allow pilots to practice proper recovery procedures for an Unexpected Yaw or LTE event, this type of training was not carried out by the PMERJ GAM pilots. In addition, this type of training in real flight was also not performed, due to the risk involved and the high costs charged by the Instruction Centers offering this type of service in Brazil.

Therefore, it is possible to point out that with such training condition, helicopter pilots would have difficulty responding properly with the necessary expertise to regain control of their aircraft in case of an Unexpected Yaw or LTE

As there was no possibility of simulating the phenomenon in flight or in a simulator, a test flight was carried out with two pilots and an IPEV engineer with the purpose of demonstrating the flight qualities of the aircraft during a simulated tail-rotor failure or loss of controllability, when the characteristics of loss of directional control and recovery are similar to those encountered during an Unexpected Yaw or LTE event.

Under the conditions of the test, the investigators verified that the influence of the tail rotor loss on the aircraft yaw varied as a function of the helicopter speed of translation (forward speed).

When analyzing the behavior of the aircraft at speeds of 100 kt, 40 kt and 20 kt, it was possible to see that, even in the most critical situation (at 20 kt), the aerodynamic surfaces (drifts and the fuselage itself) were efficient to prevent the loss of aircraft control.

The test flight report highlighted that small forward aircraft movements at around 30 kt would be sufficient to dampen the yaw, which would allow regain control of the helicopter and fly it to an area appropriate for a landing in autorotation.

However, for speeds close to zero, as well as on a hovering flight, the loss of directional control produced an undamped left yaw and made the aircraft enter a continuous rotation condition at an average rate of 33º/s.

In such condition (hovering outside of ground effect), two types of tests were performed:

a) Application of the collective control downwards after the start of the yaw and application of the cyclic forward (a technique recommended by the manufacturer for this type of situation); and

b) Application of the collective control upwards after the start of the yaw (a technique not recommended by the manufacturer).

When lowering the collective control after the start of the yaw at 33º/s, and applying a forward cyclic (a), the test pilots observed that they could regain control of the aircraft, with an altitude loss of 1,000 ft. and stabilization of the flight at a forward speed of 80 kt.

The pilots also sought to determine the workload needed to perform the aforementioned recovery procedures, assigning grade 7 on the Bedford Workload Scale, which corresponds to "little ability to perform extra tasks, but without difficulties in maintaining the effort on the primary task (recover and stabilize the aircraft without using the pedals)".

On the other hand, when moving the collective upward after the start of the yaw at 33º/s (b), the pilots noticed a significant increase of the turn rate from 33º/s to 57º/s, a value very close to the structural limit of the aircraft of 60º/s of directional turn.

At that moment, the test was interrupted for safety reasons, since even for the highly trained and skilled test pilots, who were in a controlled test-environment and ready for the situation to be experienced, the recovery of the aircraft required a considerable amount of workload under those conditions.

The tests showed that small variations of the collective control upward, even in the order of 0.5 inches, result in a significant increase of the aircraft's turning rate, placing the helicopter in a condition very close to its structural limits. This finding reinforces the need to follow the procedure recommended by the manufacturer to recover from situations of loss of aircraft directional control.

Relatively to emergency procedures, the technical documentation of the aircraft prescribed that in case of tail rotor drive failure out of ground effect, the pilot had to perform the actions verified and executed on the test flight, namely: decrease the collective pitch and increase forward speed. Considering that there is no way to immediately distinguish between an Unexpected Yaw and an LTE event, when there is only the pilots' perception of the loss of directional control without specification of its cause, one may say that this was exactly how the recovery attempt should have been made in this accident.

Based on the test flights, therefore, one may infer that the average pilot, with adequate training to identify and correctly handle the helicopter controls, would be able to regain control of the aircraft under the same conditions encountered in face of a loss of directional control, even with the aircraft rotating at 33°/s and with a grade-7 workload in the execution of the task performed by the IPEV.

Similarly, any increase in power after the start of the unexpected left turn would demand piloting techniques far above the average on the part of the pilot, due to the expressive increase of the directional turn speed, as encountered by the experienced test pilots, and would quickly put the aircraft in a directional turn beyond its structural limits and, consequently, in a situation of loss of control in flight.

Thus, it is likely that the PR-IDR pilots, due to lack of specific training, may have adopted inadequate reactions, such as the application of the collective control (to increase thrust) and took longer to apply the cyclic ahead in order to increase their translational speed. Such reactions would explain the acceleration of the aircraft yaw rate, which reached values above the structural limits and culminated in the loss of control of the helicopter, point of irreversibility of the accident.

In the accident in question, the video recorded by the thermography camera showed that the helicopter started a left yaw, and that the rotation rate was rapidly increasing. In about four seconds, the aircraft exceeded the limit of 60º/s, and the rotation rate continued to accelerate until reaching 240º/s, four times beyond the limit prescribed by the manufacturer.

The behavior identified in the accident is consistent with the one observed on the test flight with a raising of the collective control (b). However, due to the conditions in which the accident occurred, with a rotation rate of around 240º/s, it was not possible to measure the workload required to regain control of the aircraft, nor what aerodynamic behavior would the helicopter have in response to the inputs entered by the pilots in a situation which exceeded by far the structural limits of the aircraft.

The test flight showed that it is possible to regain control of the helicopter after a situation of loss of directional control. However, during recovery, there is a significant loss of height (1,000 ft.) before the flight can be re-stabilized at a forward speed of 80 kt.

Therefore, it may be inferred that, as the PR-IDR was on a hovering flight at about 1,000 ft. above ground level, the situation was close to the limit for recovery in case of an of an Unexpected Turn or LTE event, even if the pilots had adopted all the necessary procedures in a timely manner. In addition, one must take into consideration the aspects related to the natural time of reaction for the pilots to respond on account of the unexpectedness of what was about to happen.

The lack of an operational standard established by the GAM for surveillance flights in support of police operations contributed to the accident, as it allowed the flight to be carried out at that height, with the aircraft hovering outside of ground effect, resulting in a critical condition for recovery of directional control, either on account of the limited height for the maneuver or on account of the low forward speed (if any, at all) that increased the yaw rate and added to the workload necessary for the recovery.

Thus, the investigation committee reached the conclusion that the aircraft experienced a condition of Unanticipated Yaw or LTE, while hovering outside of ground effect. The unexpected left yaw was followed by loss of directional control of the aircraft. Then, possibly, the inappropriate actions taken by the pilot, in addition to the increased workload during the recovery attempt, may have aggravated the condition, by accelerating the rotation rate beyond the limits of the aircraft, a situation that culminated in its vertiginous fall against the ground.

3. CONCLUSIONS.

3.1. Findings.

a) The crew had valid Aeronautical Medical Certificates;

b) The pilots had valid Single Engine Turbine Helicopter (HMNT) ratings;

c) The respective licenses of the Special Equipment Operators (OEE) were valid;

d) The pilots were qualified and had experience in the type of flight;

e) The aircraft had a valid Airworthiness Certificate (CA);

f) The aircraft was within the weight and balance limits;

g) The records of the cell and engine logbooks were up to date;

h) The meteorological conditions were favorable for the conduction of the flight;

i) While hovering at a height of 1,000 ft., the helicopter unexpectedly yawed to the left and, shortly thereafter, the pilots lost control of the aircraft.

j) The aircraft remained in a condition of continuous rotation to the left around its vertical axis, while losing altitude until colliding with the ground;

k) The wreckage was concentrated, showing damage typical of overload;

l) No evidence was found of failures or abnormalities prior to the impact, nor any evidence indicating that the aircraft could have been hit by projectiles;

m) the analysis of the internal parts of the rear servo-actuator, did not reveal any abnormalities that might have caused a component failure or malfunctioning;

n) a flattening, compatible with damage caused by impact, was identified on the control rod of the rear servo-actuator, which caused the servo-actuator to get stuck in a position equivalent to that of a pedal fully applied to the right;

o) The spectral analysis of two videos recorded by observers revealed that the harmonic frequencies of the main rotor blades were compatible with a rotor varying between 97% and 102% of NR;

p) The analysis of the aircraft's engine revealed that the component was developing high power at the moment of impact;

q) The analysis of the data retrieved from the VEMD and DECU did not reveal any failures in the equipment prior to the collision of the aircraft with the ground;

r) analysis of the data concluded that the aircraft engine was developing power at the moment of impact with the ground, with NG equal to 94.84%;

s) The aircraft had a directional turn rate limit of 60°/s);

t) The analysis of the FLIR video revealed that the directional turn to the left had a high increasing rate that, in about four seconds, exceeded the helicopter's limit and continued accelerating until stabilizing at about one turn of 360° every 1.5 second (around 240°/s);

u) the investigators participated in a flight test with IPEV pilots and engineers, with the purpose of simulating a tail rotor drive failure, at which point the characteristics of loss of directional control, as well as recovery, are the same as those of an Unexpected Yaw or LTE event;

v) under the test flight conditions, it was verified that the influence of the loss of the tail rotor on the helicopter yaw varied as a function of the aircraft translation speed;

w) during the simulated failure in the activation of the tail rotor while hovering outside of ground effect, an undamped left yaw was observed, with the aircraft entering a continuous left turn condition, at an average rate of 33º/s;

x) it was verified that, upon application of the collective, the left yaw rate increased from 33º/s to 57º/s, requiring the interruption of the test in order to not exceed the aircraft limit of 60°/s;

y) the test flight led to the conclusion that, in the event of a failure of the tail rotor drive, the helicopter would enter a fast yaw to the left, with the rotation rate increasing considerably, as a result of applications of the collective;

z) The test flight report highlighted that, after the failure of the rotor drive, short forward movements at around 30 kt would be enough for a mitigated yaw to occur, enabling the pilots to keep control of the helicopter and take it to an area appropriate for a landing in autorotation;

aa) From the beginning of the simulated failures, until completion of recovery, with the aircraft leveling off and at a speed of 80 kt. there was a loss of height of 1,000 ft.;

bb) the aircraft sustained substantial damage;

cc) All of the crewmembers suffered fatal injuries.

3.2. Contributing factors.

- **Training – undetermined.**

The absence of specific training in the instruction program of the GAM helicopter pilots for the adoption of adequate procedures in emergency situations caused by aerodynamic phenomena, may have contributed to the accident, as it did not allow the crew to have the necessary knowledge and expertise to act correctly in case of an Unanticipated Yaw or LTE in order to regain control of the aircraft.

- **Handling of aircraft flight controls – undetermined.**

It is likely that the PR-IDR pilots, due to their lack of adequate training, adopted inappropriate reactions, such as the upward application of the collective control (to increase the pitch), as well as their delay in increasing the horizontal speed. Such reactions would explain the acceleration of the aircraft rotation rate, which reached values above the aircraft structural limits, and culminated in the loss of control of the helicopter, point of irreversibility of the accident.

- **Piloting judgment – a contributor / undetermined.**

Even being qualified to operate the aircraft, it is possible that the pilots of the PR-IDR, on account of lacking adequate specific training, adopted inappropriate reactions, such as the upward application of the collective control, and delayed the application of the cyclic control forward to increase the translational speed.

- **Support systems – a contributor.**

The absence of a set of standards, manuals or publications established by the GAM for surveillance flights in support of police operations, allowed the hovering phase of the flight to be carried out at a height of 1,000 ft. outside of ground effect with an aircraft that was considerably heavy at that moment.

The operation under such conditions reduced the possibility of recovering the control of the aircraft, due to the insufficient height for the maneuver and its low translational speed, which would considerably increase the crew's workload, and may have contributed to the accident in question.

- **Managerial oversight – a contributor / undetermined.**

There was inadequate supervision by the management of the organization with regard to the planning and execution of activities at an operational level, given the lack of operational standards for the accomplishment of this type of mission, which may have allowed it to take place below the height necessary for recovery in the event of an Unanticipated Yaw or LTE.

4. SAFETY RECOMMENDATIONS

A proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of 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".

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

A-151/CENIPA/2016 - 01 Issued on: 08/15/2023

Publicize the lessons learned in this investigation to Public Air Units that carry out special operations in accordance with the requirements established in the RBAC 90, so that they are disseminated and used in internal events for the Promotion of Operational Safety.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

The Center for Investigation and Prevention of Aeronautical Accidents (CENIPA) issued the Operational Publication (DIVOP) nº 001/2018, dated 07Mar2018, dealing with Tail Rotor Loss of Efficiency in Helicopters, describing the phenomenon and listing a number of occurrences that may have been caused by an LTE event.

The DIVOP aforementioned listed several actions and recommendations to rotary-wing aircraft operators and pilots, such as:

1) Include wind speed and direction in the flight planning of all phases of flight, as these factors may significantly affect the helicopter's susceptibility to LTE;

2) Get to know and meet the performance limitations of one's own helicopter, as described by the manufacturer, and as approved by the certifying aeronautical authority;

3) Be aware of one's own helicopter's flight control characteristics, particularly tail rotor pedal actuation forces, so that one can quickly recognize and act appropriately on the controls at the onset of an un-commanded yaw (LTE);

4) Carry out specific training with professionals qualified in critical emergencies, including the identification of LTE and recovery of aircraft control, taking into account that the LTE occurs unexpectedly, and that pilots, who have had this kind of experience, describe the onset of yaw as quite aggressive;

5) Give preference to making turns contrary to the anti-torque effect in operations with speeds below 30 kt, whenever possible; and

6) Acquire knowledge on the LTE phenomenon, as well as on some avoidance measures adopted through the Helicopter Flying Handbook made available on the Federal Aviation Administration website (https://www.faa.gov/), especially the ones listed below:

- be aware of possible weight changes close to the moment of takeoff and stay within the approved MTOW;

- maintain awareness of wind direction and flight speed, especially on flights with high pilot workload, when flying over mountain tops and around large buildings, and when hovering with the wind at about 8-12kt. intensity, as a loss of lift may occur;

- avoid tailwind and crosswind (crosswind direction depends on the type of helicopter being flown) when operating at speeds below 30 kt;

- avoid operations outside of ground effect and in situations of high demand for power and with a flight speed of less than 30 kt; and

- monitor the amount of pedal being applied to counteract the main rotor torque. If you are already close to the pedal backstop, you may not be able to counteract an un-commanded yaw.

The section 90.173 of the Subpart M of the Brazilian Civil Aviation Regulation (RBAC), dated 12Apr2019, which deals with “Requirements for Public Aviation Special Operations”, determined the dissemination of the LTE concepts in the ground curriculum aimed at pilots’ Initial training:

> 90.173 Initial training: ground curriculum
>
> [...]
> d) The curricular component of general knowledge shall contain:
> (i) ground resonance;
> (ii) collision with wires
> (iii) LTE;
> (iv) dynamic and static roll;
> (v) recovery from abnormal attitudes;
> (vi) mast bumping e low G;
> (vii) vortex ring;
> (viii) runway excursion and incursion; and
> (ix) deep stall.

On august 15th, 2023.