COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A - 128/CENIPA/2015

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PP-ELA**
MODEL:	**206L-3**
DATE:	**23SEPT2015**

NOTICE

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

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

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

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

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

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

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

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

SYNOPSIS

This is the Final Report of the 23SEPT2015 accident with the BELL 206L-3 aircraft, registration PP-ELA. The accident was classified as “Loss of Control In-Flight”.

During a go around procedure with left turn, there was loss of control of the aircraft. The helicopter crashed into a low voltage power grid and then it crashed into the ground.

The aircraft was completely destroyed.

All the occupants of the aircraft perished at the accident site.

An Accredited Representative of the NTSB - National Transportation Safety Board, USA (State where the aircraft was manufactured) and an Accredited Representative of the TSB - Transportation Safety Board, Canada (State where the engine was manufactured) were designated for participation in the investigation.

CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AC	Advisory Circular
ADE	State Direct Administration
AGL	Above Ground Level
ANAC	(Brazil's) National Civil Aviation Agency
CA	Airworthiness Certificate
CENIPA	Aeronautical Accident Investigation and Prevention Center
CG	Center of Gravity
CHT	Technical Qualification Certificate
CMA	Aeronautical Medical Certificate
CRM	Corporate Resource Management
DCTA	Aeronautics' Science and Technology Department
GOA	Air Operations Group
FAA	Federal Aviation Administration
FTD	Flight Training Device
FFS	Full Flight Simulator
FSTD	Flight Simulation Training Device
IAC	Civil Aviation Instruction
IAE	Aeronautics and Space Institute
ICA	Command of Aeronautics' Instruction
IGE	In Ground Effect
INVH	Helicopter Flight Instructor License
KT	Knots
LTE	Loss of Tail Rotor Effectiveness
LAT	Latitude
LONG	Longitude
METAR	Aerodrome Routine Weather Report
MGSO	Operational Safety Management Manual
MOP	Operations Manual
N1	Gas Generating Turbine
OEE	Special Equipment Operators
PCH	Commercial Pilot License - Helicopter Category
PMC	Maximum Continuous Power
PMD	Maximum Takeoff Power
POP	Standard Operating Procedures
PPH	Private Pilot License - Helicopter Category
PPSAC	Small Civil Aviation Service Providers
PTO	Operational Training Program

RBHA	Brazilian Aeronautical Homologation Regulation
RS	Safety Recommendation
SBMO	ICAO location designator - Zumbi dos Palmares/Maceió Aerodrome
SERIPA II	Second Regional Aeronautical Accident Investigation and Prevention Service
SGSO	Operational Safety Management System
SIPAER	Aeronautical Accident Investigation and Prevention System
SNGS	ICAO location designator - Alagoas Aeroclube
TQ	Torque
TOT	Turbine Temperature
UTC	Universal Coordinated Time
VAC	Visual Approach Chart
V_0	Speed Ahead
V_I	Induced speed

1. FACTUAL INFORMATION.

Aircraft	**Model:** 206L-3 **Registration:** PP-ELA **Manufacturer:** Bell Helicopter	**Operator:** Government of the State of Alagoas / Military Cabinet
Occurrence	**Date/time:** 23SEPT2015/1400 UTC **Location:** Santa Lúcia Neighborhood **Lat.** 11º53'46"S **Long.** 44º17'40"W **Municipality – State:** Maceió - AL	**Type(s):** Loss of Control In-Flight **Subtype(s):** NIL

1.1 History of the flight.

The aircraft took off from the Maceió International Airport - Zumbi dos Palmares (SBMO), at 1350 UTC, to conduct a training at the Alagoas *Aeroclube* (SNGS) and a flyover above the city of Maceió. During training, the aircraft took off with a left turn. With approximately 10 meters of altitude, the helicopter defined a downward trajectory, until colliding against a low voltage power grid and then against the ground.

The aircraft was completely destroyed.

All the occupants of the aircraft perished at the accident site.

1.2 Injuries to persons.

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

1.3 Damage to the aircraft.

The aircraft was completely destroyed.

Part of the aircraft's structure was consumed by fire. There weren't found marks of firearms on the analyzed parts.

1.4 Other damage.

A car that was parked on the street was totally carbonized.

There was a breakdown of a low voltage power grid and the breaking of four tiles of a residence.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Hours Flown	
	Pilot
Total	680:00
Total in the last 30 days	05:00
Total in the last 24 hours	00:10
In this type of aircraft	350:00
In this type in the last 30 days	05:00
In this type in the last 24 hours	00:10

N.B.: The Data on flown hours were obtained from a third party statement.

1.5.2 Personnel training.

The pilot took the Private Pilot course - Helicopter (PPH) at EDRA Aeronautics – *Escola de Aviação*, Ipeúna - SP, in 2010.

The occupant of the left front seat was a helicopter pilot, but was not qualified to operate the crashed model.

1.5.3 Category of licenses and validity of certificates.

The pilot had the Commercial Pilot License - Helicopter (PCH) and had valid aircraft technical qualification in BH06.

1.5.4 Qualification and flight experience.

The pilot was qualified and had experience on this kind of flight.

1.5.5 Validity of medical certificate.

The pilot had valid Aeronautical Medical Certificate (CMA).

The Special Equipment Operator (OEE) was with his CMA expired since 07JUN2014

1.6 Aircraft information.

Bell Helicopter manufactured the aircraft 51536, in 1991, and it was registered in the State Direct Administration Category (ADE).

The aircraft had valid Airworthiness Certificate (CA).

The airframe and engine logbooks records were up-to-date.

Oficina FLYONE - *Serviços Aéreos Especializados, Comércio e Serviços* Ltd. (GOA), in Maceió – AL, did the last inspection of the aircraft, the “100h” type, on 11SEPT2015. The aircraft flew 13 hours and 10 minutes after the inspection.

The aircraft had a total of 3,339 hours of flight and the airframe had 25 minutes.

1.7 Meteorological information.

The conditions were favorable for the visual flight.

The closest Aerodrome to the accident site was the Zumbi dos Palmares Airport (SBMO), distant about 6km. The SBMO Regular Aeronautical Meteorological Report (METAR), referring to the estimated time of the accident indicated the conditions described as follows:

METAR SBMO 231400Z 12015KT 9999 SCT020 29/21 Q1017

1.8 Aids to navigation.

Nil.

1.9 Communications.

Frequencies of the Air Traffic Control Agencies were available at the time of the accident. The bilateral communications between the pilot and the ATC took place normally.

1.10 Aerodrome information.

The occurrence took place outside the Aerodrome.

1.11 Flight recorders.

Neither required nor installed.

1.12 Wreckage and impact information.

The accident took place about 150 meters to the left of the Alagoas Aeroclube landing runway (SNGS), taking as a reference the takeoff axis from the threshold 14.

The distribution of the wrecks was linear. Several people observed the collision.

The first impact occurred between the blades of the main rotor of the helicopter and a low voltage power grid, when the aircraft was in a curve to the left. Then there was the collision of the front end of the left ski against the ground, followed by the rear of the same ski.

The impact with the power grid launched the aircraft approximately 30 meters ahead. The total stop occurred with the helicopter lagged about 45º in relation to the runway axis (SNGS), according to Figure 1.

The degree of destruction and carbonization of the aircraft impeded the verification of some equipment and instruments**.**

Figure 1 - Sketch of the accident.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

Nil.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

The Commander of the aircraft had more than 650 hours of flight time and was preparing to start the flight instructor course. He was considered studious, methodical and had a cautious profile in aerial activity.

At the time of the accident, he was going through a divorce process. He seemed to be particularly sad about that phase of life. His co-workers were worried about his behavior and they tried to support him in what was possible.

This fact led him to be dispensed from exercising air activities for 15 days, and this initiative was considered as a measure of support from his bosses, because of the difficulties he was experiencing.

Responsible for the Operational Safety sector, the pilot was in charge of updating the various manuals and programs established by the National Civil Aviation Agency (ANAC), as well as acting as a link between the GOA and the technicians of that agency and the System of Investigation and Prevention of Aeronautical Accidents (SIPAER). It was notorious his strong concern about GOA's internal procedures, particularly with the operational aspects and infrastructure provided for the operation of the air unit.

Onboard the aircraft there was another helicopter pilot, who occupied the left front seat and was not qualified to operate the wrecked model

According to information collected during the investigation, this second pilot presented a different behavior from the Commander of the aircraft. He had a more daring profile and was eager to perform the role of the Commander in the operational missions within the scope of the GOA.

Although this second pilot had started the commercial pilot course in 2010, his SHP training was only completed in 2015. He had approximately 500 flight hours and showed difficulty in meeting the operational requirements demanded to become a Commander within the scope of the GOA.

The second pilot attributed the delay in his evolution as a police pilot to the fact that he devoted himself more to the career of military policeman. Despite this, he showed some dissatisfaction with the requirements imposed by the organization in relation to the progression of the co-pilots, believing that, particularly in his case, the time of action in the GOA was not taken into account.

In the psychosocial context, there was evidence that communication among the members of the organization was characterized by informality. The lack of use of the appropriate instruments for the transmission of guidelines had an impact on the conduct and supervision of technical and operational routines. This case contributed, for example, for training flights characterized by informality, without adequate planning or even monitoring of assessment sheets.

Regarding the leadership processes, it was observed that the management model adopted presented characteristics not only of informality, but also of little transparency for the technical staff. The organizational group saw this administration format as a management with slow decision making and at the same time perceived as somewhat distant from the operational / technical group.

This scenario coincides with the suspicions raised among the various crew members of the GOA, leading to the assumption that the accident could have occurred with the aircraft under the operation of the occupant of the left seat. The facts led to the hypothesis that, because of the friendship bonds existing between the pilots and, contrary to all indications, the Commander may have allowed the other pilot to conduct the helicopter during the training flight, believing that this would be contributing to his friend’s training.

1.14 Fire.

The fire started immediately after the aircraft full stop. The combustion material was the fuel in the aircraft and the source of ignition was probably originated as a result of the strong friction of the helicopter parts with the ground (Figure 2).

Figure 2 - Aircraft destroyed by fire.

The fire spread quickly. The situation was aggravated by the fact that the tanks were stocked with about 480 pounds of fuel.

1.15 Survival aspects.

There were no survivors.

1.16 Tests and research.

Technicians from the Department of Aerospace Science and Technology (DCTA) and from Bell Helicopter, in the presence of representatives of the Second Regional Aeronautical Accident Investigation and Prevention Service (SERIPA II) and also the aircraft operator, examined the wreckage of the aircraft. The activities were done in the hangar of the Government of the State of Alagoas, at Maceió Airport, where the headquarters of GOA operated.

The engine analyzes, conducted in laboratory, concluded that the Rolls Royce / Allison, model 250-C30P, No. CAE 895611, which equipped the PP-ELA aircraft, had normal operation and was developing power at the time of the accident.

The analysis of the wreckage, conducted in the laboratory, concluded that there were fractures and damages with overload failure characteristics. In other words, the fractures found in the analyzed parts occurred due to the impact against the ground or against obstacles found in the ground at the time of the fall. No fatigue fractures were found in the analyzed components.

Technical analyzes were performed focusing on the performance of the aircraft and its characteristics related to flight qualities, considering the following boundary conditions:

- The engine that equipped the aircraft, Rolls Royce / Allison, model 250-C30P, n / a CAE 895611, was in normal operating conditions and was developing power at the moment the helicopter was involved in the accident;
- No fatigue fractures were found in the analyzed components that could indicate failure in service within the normal load of operation;
- the operation of the aircraft was within the limits approved in the flight manuals;

- the aircraft did not show any degradation in performance compared to the one provided in the flight manual; and
- The weather conditions at the place and time of the accident were those recorded in the METAR of SBM.

The analysis methodology followed the study of the performance characteristics and flight qualities of the aircraft, considering the information of weight, temperature, pressure, intensity and wind direction present at the time of the accident.

The study of the performance took into consideration the analysis of the influence of the inclination and the speed of the aircraft, according to the available power in the instants before the accident.

Performance study

From the performance point of view, the reconstitution of the aircraft's flight conditions prior to the accident was based on data from the following manufacturer's technical publications: In Ground Effect (IGE) Hover Ceiling (Figure 4-6), Section 4 Performance, and Fuel Flow (Figure 4-2), Section 4 Expanded Performance.

The data contained in the pages of these manuals were adjusted to a theoretical model based on the main power consuming components. According to the theory of flight mechanics of rotary wing aircraft, used to predict the power required in terms of the indicated torque, under the main atmospheric conditions at the Aerodrome and the aircraft's estimated weight at the time of the accident.

The model was also used to measure the power required for the aircraft to maintain the altitude in relation to the ground, even when in a curve, for different slope patterns and limited to 60º.

Because it was an adjustment model, it was subject to the same restrictive hypotheses described in the references, and it was only a prediction, requiring experimental proof by means of in-flight tests.

Also, the power limitations related to the speed of rotation of the gas generating turbine (N1) and the temperature of the turbine (TOT) were disregarded.

It is important to emphasize that within the methodology proposed in this study, these simplifications did not alter the presented result.

With this information, it was possible to perform the mathematical treatment of the data related to the performance of the aircraft moments before the accident, and to present them as shown in Figure 3.

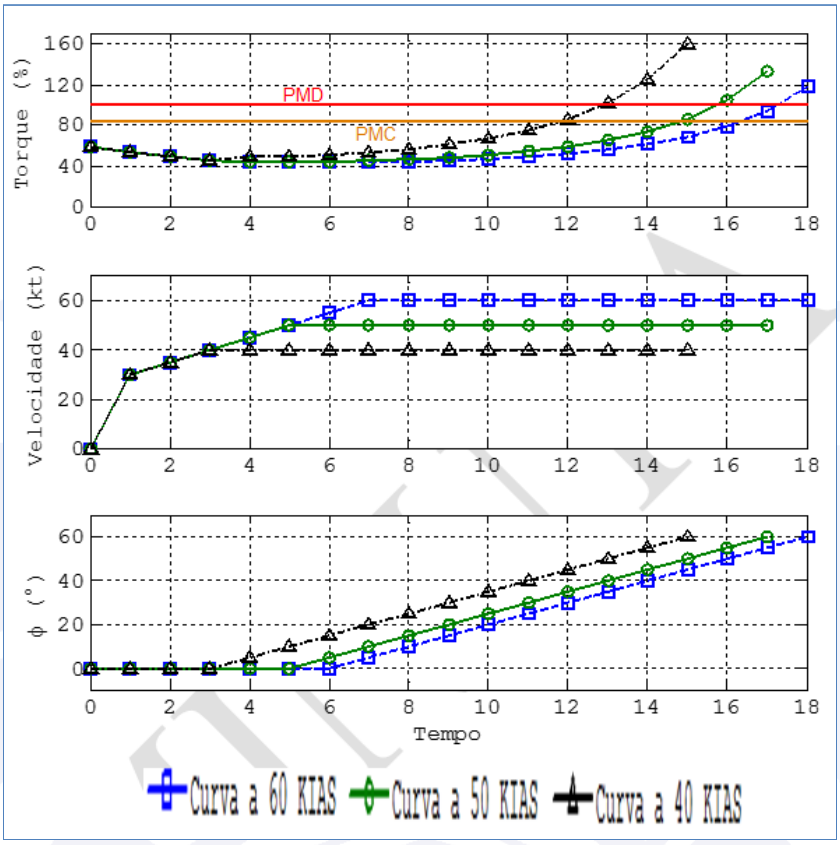

Figure 3 - Take off profiles with curve at 60KT, 50KT and 40KT.

In Figure 3, it is possible to verify the results of the performance related to several and possible takeoff profiles that the pilot could have adopted, depending on the speed ahead, applied torque (power) and bearing angle (Φ), considering the conditions of Weight of 1,520 kg, altitude of 387ft and temperature of 29 ° C. The first line of the graphic refers to the variation of torque over time. The second line represents the variation of speed ahead over time. The third line illustrates the variation of the aircraft's lateral slope according to the time. The red curve represents the Maximum Takeoff Power (PMD) and the orange curve represents the Maximum Continuous Power (PMC) of the helicopter.

The torque parameter reflects the power required to maintain level, non-skidding flight in the specified condition of weight, altitude, temperature, speed and bearing angle. Thus, since the typical takeoff profile requires a slight rise gradient, any application of power higher than the torque values presented in the curves would guarantee a positive climb rate. As a reference value, by simple energy analysis, variations up to 2% of torque would allow climb rates up to 300ft / min.

In addition, the proposed take-off profile starts from a hovering flight within the ground effect and accelerating up to a certain speed (40KT, 50KT or 60KT), in which a curve starts and may have reached up to 60° of slope, during a certain period of time.

For all the graphics shown in Figure 3, it can be observed that both the hover phase and the acceleration phase (takeoff) occur with a large extra margin of power. The smallest extra power margin reached during the flight is ΔTQ = 26%, relative to the maximum continuous power (PMC), which is TQ = 85%. This condition is observed during the hover phase.

As the aircraft is accelerated, there is a reduction of the induced power portion, one of the main power consumers. This reduction causes a decrease in the total required power, attenuates the need for torque application to maintain level flight, or even allows a positive gradient to be obtained.

The minimum power required to maintain level flight in all cases is obtained at the speed at which the curves start. Thereafter, there is a new power demand to keep the flight level in turn, due to the inclination of the lift component.

The graphics in Figure 3 show that the required torque increases as the lateral slope of the aircraft also increases. The required torque and PMC curves are found when the lateral slope of the helicopter reaches values of the order of 50º in relation to the horizon. The highest required power values are found on the 40KT curve (black).

However, considering only the performance issues, the graphics show that up to a certain angle of slope, there would be power available to perform the curves, with a positive gradient application and also control power of the tail rotor to counteract wind gusts that would generate loss of coordination in the curves.

Even in the most critical condition (40KT), with a high bearing angle (50 °), the pilot could use an even higher power regime, maximum takeoff power (PMD, TQ = 100%) without causing engine damage or decreases of rotation in the main rotor.

The study of flight qualities considered the influence of the static stability of the aircraft, wind on the tail rotor (critical azimuth), and blade-tip vortices on the helicopter's tail rotor.

Flight Qualities Study

Bearing Effects:

The analysis of the flight qualities of the helicopter, in the moments prior to the accident, was based on the verification of the theoretical influences of each constituent element of the aircraft in the bearing response, due to static stability.

The sum of all the portions of the bearing moments that depend on the skidding of the aircraft is called the dihedral effect. Regarding the elements that influence the movement of the aircraft around its longitudinal axis, considering it in a normal configuration, we can mention the fuselage and the vertical stabilizer. (drift)

The fuselage of a helicopter in displacement, when subjected to a lateral angle of incidence (β), behaves like an aerodynamic surface, generating a certain force of “lateral support" and, consequently, a moment of bearing.

In a same skidding flight condition, the drift, which is situated above the center of gravity (CG) of the aircraft, produces a bearing restorative moment. Thus, the influence of drift on a left curve with positive β (wind coming from the right sector), as occurred in the accident situation, results in a negative (left) bearing. This effect is added to the moment produced by the "lateral support" from the aircraft fuselage, whose direction depends on the relative position of the center of pressure and the CG. Most of the times, the drift effect is more significant than the "lateral support" from the fuselage.

In a left turn, when the aircraft was subjected to a wind component of the right sector, the dihedral effect would be added to the moment of bearing, commanded by the pilot, also to the left. The result of the sum of these two effects would be a tendency to increase the lateral slope to the left.

The increasing of the bearing angle, if not counteracted or properly compensated, may decrease the vertical component of the force produced by the main rotor. Consequently, the aircraft would lose altitude.

Yaw Effects:

The analysis of flight qualities of the helicopter, in the moments prior to the accident, was based on the verification of the theoretical influences of each constituent element of the aircraft in the yaw response, due to static stability.

The sum of all portions of the yaw moments that depend on the aircraft's skidding is termed as *girouette* effect. Regarding the constituent elements of the aircraft, it should be noted that the contributions to the *girouette* effect come from three main sources: aerodynamic momentum on the fuselage, lateral forces on the drift and changes in the thrust of the tail rotor.

The presence of the drift relieves the necessary force of the tail rotor when there is flowing incident with sufficient relative velocity to produce aerodynamic forces. These forces generate moment, which contributes to the *girouette* effect. In a skidding flight condition, drift produces a yaw restoring moment.

When making a left turn with positive β (wind coming from the right sector) the surface contributes with a right turn, tending to align with the wind ("nose" to the right).

In relation to the fuselage of a helicopter in displacement, again when subjected to a lateral angle of incidence β, it behaves like an aerodynamic surface generating a certain force of "lateral support". Due to this fact, a bearing moment is created whose direction depends on the horizontally relative position of the pressure center and the CG.

A rotating rotor induces a mass flow with flow velocity through the disc. This velocity is called induced velocity (Vi). The tail rotor obeys the same laws as the main rotor, so, with respect to velocity variations induced with forward velocity (V0), we have that: Vi decreases if V0 increases.

Due to a new vector result of speeds, this condition leads to a constant pitch (for the tail rotor this corresponds to keeping the pedal stationary in one position), to increase the average angle of attack of the tail rotor blades, with the increase of the forward speed. The consequence is the increase in aerodynamic force produced by the tail rotor, which causes an additional yaw moment.

Under the conditions in which the accident occurred (helicopter with an effective translation speed, in a left turn and subjected to a wind component of the right sector), all the elements already mentioned would add up, resulting in a yaw imbalance. If the imbalance was not opposed, the curve would be performed in an uncoordinated manner.

Low Speed:

Complementing the analysis of the flight qualities of the helicopter, in the moments prior to the accident, the theoretical influences of low-speed flight were evaluated in the behavior of the aircraft.

In this flight condition, the aircraft is subjected to aerodynamic effects and distinct interactions of the flight with effective translational speed.

In low-speed forward flights within the ground effect, it is possible that the vortices produced by the main rotor are reflected by the ground, moving closer to the aircraft and inducing speeds with the rotor disk, as shown in Figure 4. So, the resulting loads on the blades affect stabilized longitudinal and lateral control conditions.

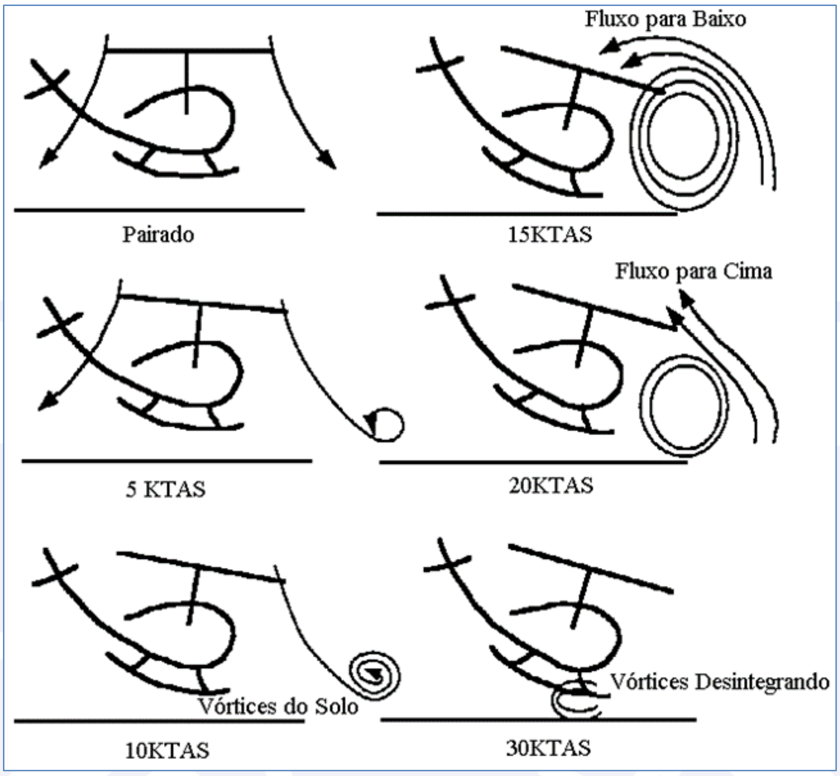

Figure 4 - Effect of ground vortices.

Another effect, in this same flight condition, is the Loss of Tail Rotor Effectiveness (LTE). This aerodynamic phenomenon occurs when the tail rotor fails to provide the necessary force to balance the torque from the main rotor. Advisory Circular (CA) No. 90-95, of 26DEC1995, issued by the Federal Administration Aviation (FAA), talks about Unanticipated Right Yaw in Helicopters.

The document describes Loss of Tail Rotor Effectiveness (LTE) as a critical, low-speed aerodynamic phenomenon that can result in an uncontrolled yaw and, if not corrected properly, can lead to the loss of control of the aircraft.

The LTE is not related to material failure. It occurs at low speeds (between 10KT and 30KT) and has no relation to deficiency in control margin, which is a certification requirement (FAR 27.143) and the reason why the flight manual of the aircraft includes the Critical Wind envelope. (Critical Relative Wind Azimuths).

This last envelope, reproduced in Figure 5, shows the relative wind limits at which the aircraft still presents satisfactory stability and control. For the case studied, this condition was demonstrated up to 26KT, under all weight conditions.

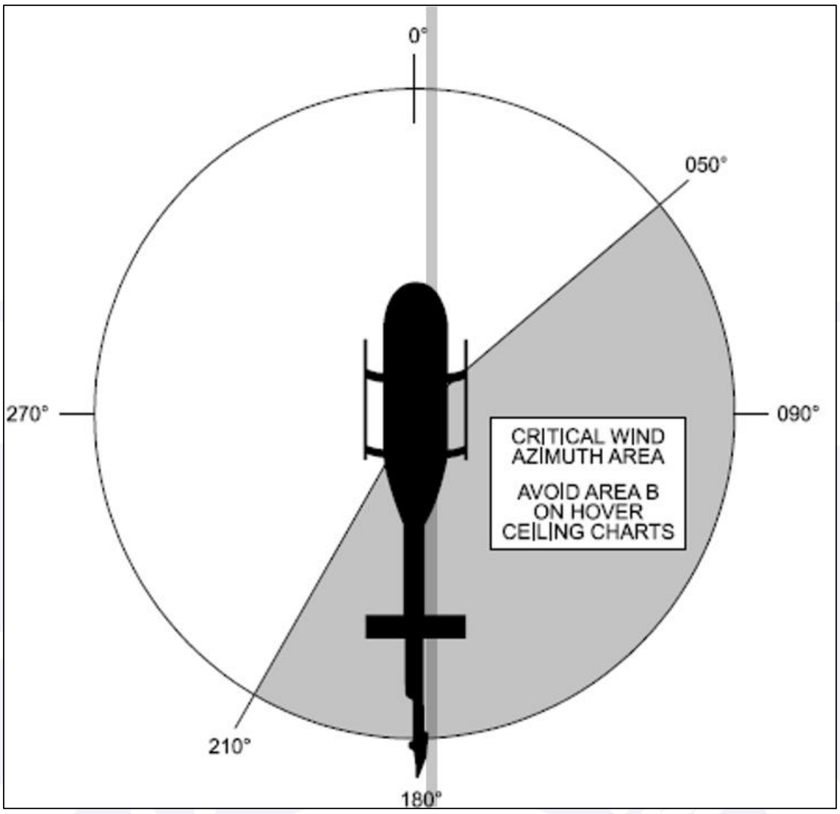

Figure 5 - Aircraft wind envelope.

The factors that contribute to the occurrence of the Loss of Tail Rotor Effectiveness (LTE) are high weight; low speed ahead, right turn (for aircraft with main rotors turning counterclockwise); crosswind; wind tail; and rapid power variations. Each of these factors will be better explained below.

To understand the wind interference in the Loss of Tail Rotor Effectiveness, the direction of the wind in relation to the direction of the helicopter in displacement is divided into azimuths, from 0 ° to 359 °.

Also according to Advisory Circular (AC) 90-95, the incidence of relative wind at azimuths between 285º and 315º (Figure 6) can generate interference between the main rotor vortex and the tail rotor. With wind focusing on this region, it is possible that the tail rotor operates within the turbulence generated by the main rotor, causing a sudden reduction of the tail rotor traction, due to the change of air flow. The pilot, in this case, must apply left pedal to prevent the aircraft from guiding to the right.

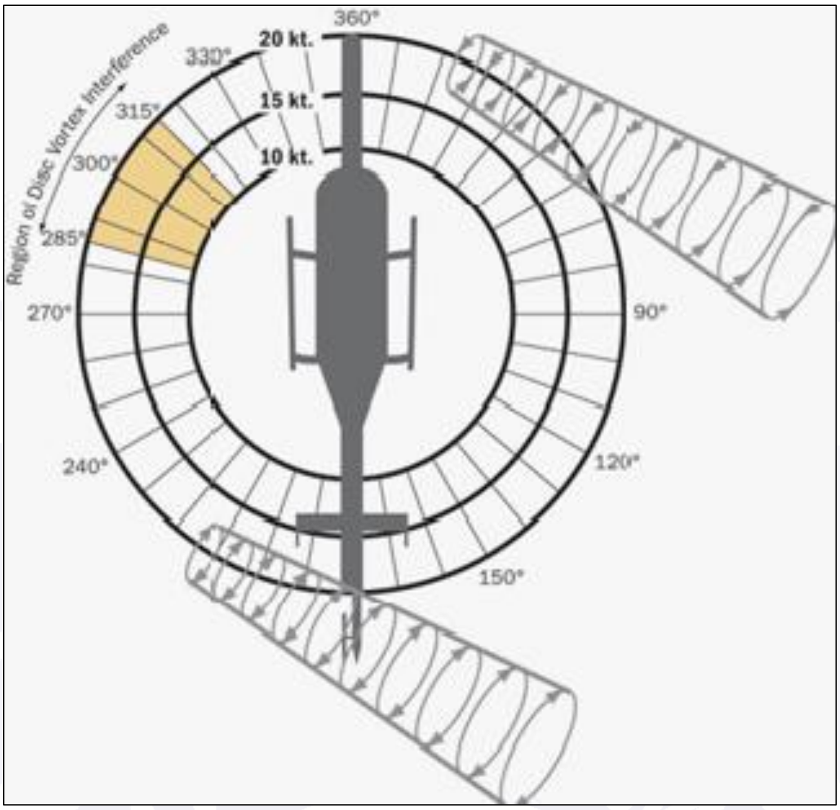

Figure 6 - Interference of the main rotor vortices on the tail rotor.

Another azimuth that can lead to loss of the tail rotor effectiveness, according to the same reference, is the one between 120º and 240º due to the *girouette* effect, (Figure 7). At low speeds, tailwinds between 120 ° and 240 ° can increase the pilot's workload. The great contribution of the winds coming from this range of azimuths is in the increase of the yaw ratio of the aircraft, which, due to the *girouette* effect tends to be with head wind.

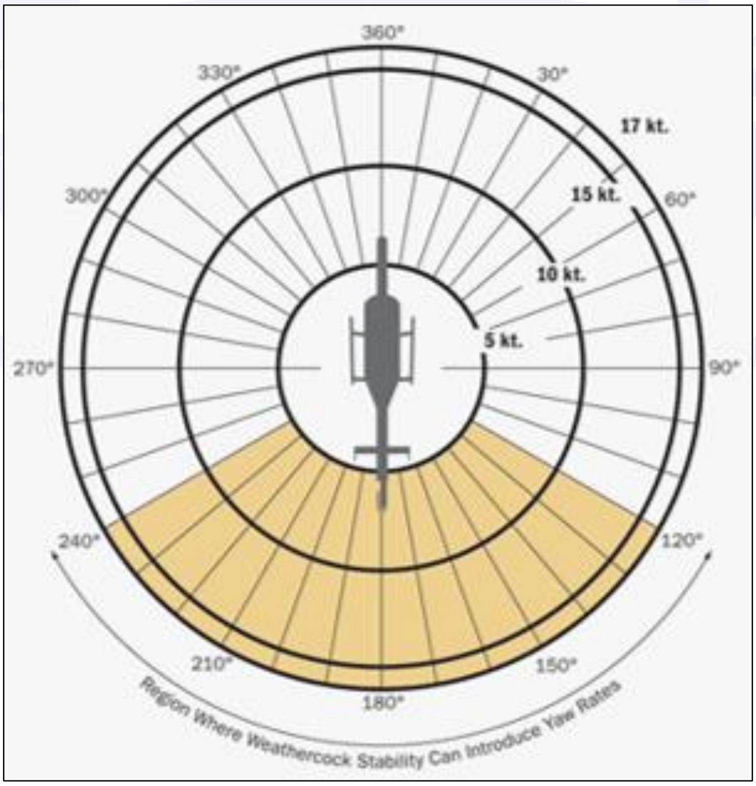

Figure 7 - Influential azimuth in the girouette effect.

A third influent azimuth in LTE is the one between 210 ° and 330 ° (Figure 8). In this situation, the velocity induced by the tail rotor has opposite direction to the relative flow incident on the left side of the aircraft, being able to develop the state of vortex rings in the tail rotor. As a result, it is assumed that the tail rotor flow will be non-stationary and non-uniform, causing oscillations in the traction produced, requiring rapid and continuous actuation of the aircraft pedals to maintain control of the flight.

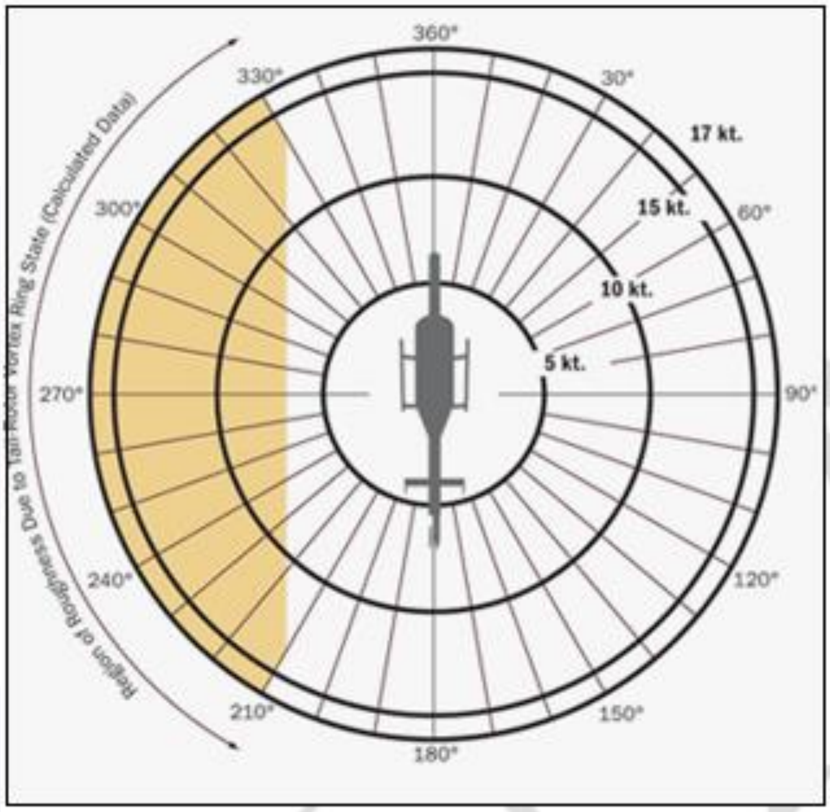

Figure 8 - State of vortex rings in the tail rotor.

Because the aircraft crashed into a power grid before the impact on the ground, there has been a study of the height of the blade in relation to obstacles at the site. Figure 9 relates the helicopter's lateral slope to the height of the blades in relation to the ground.

Φ (°)	Altura da ponta da pá (m)
0	12,68
5	12,18
10	11,66
15	11,13
20	10,59
25	10,05
30	9,5
35	8,96
40	8,43
45	7,91
50	7,4
55	6,92
60	6,46

Figure 9 - Height of the tip of the main rotor blades in relation to the ground.

1.17 Organizational and management information.

The Air Operations Group (GOA), which operated the helicopter involved in the accident, operates under the rules established by Subpart "K" of the Brazilian Aeronautical Regulation 91 (RBHA 91), which deals with air operations of public safety and civil defense.

Created to provide administrative and operational support for preventive, as well as ostensible and repressive air policing, GOA was also active in the rescue and aero-medical transportation and civil defense actions, triggered by the organs of the Social Defense System of the State of Alagoas.

The staff of the institution was composed of members of the Military Fire Brigade and Civil and Military Police of the State of Alagoas.

This organization had an internal structure for the supervision of runway maintenance services, including daily pre-flight, post-flight and inter-flight checks. It had two Civilian Police Officers to perform the maintenance control tasks, and Sergeants and Corporals to perform daily maintenance services.

The periodic inspections and the most complex maintenance services of the aircraft involved in the accident were done by a specialized repair shop and certified by ANAC.

The operational training processes and the fulfillment of the operational training program were a responsibility of the Operations Sector.

In July 2015, the organization was submitted to a prevention activity, at the request of its own coordinator. At the date of the accident, the Recommended Actions included in the corresponding event, notably, within the scope of training/qualification and management supervision, were in the implementation phase.

At the time of the accident, the GOA operational base was installed in an old car garage, used by a company that operated at Zumbi dos Palmares Airport.

The sections worked in an improvised way. They were agglutinated in the available space, compromising routine tasks such as holding daily meetings to deal with technical and operational matters, including flight planning, monitoring, and control of aircraft maintenance activities.

The lack of space caused the transfer of the sector responsible for the control of flight hours and maintenance data to the headquarters of the Department of Social Defense, located in the city center of Maceió. This fact compromised the organizational climate, as there was a feeling that there was little evolution in solving the organization's problems.

At the same time, documents such as the Operations Manual (MOP) and the Standard Operating Procedures (POP) were in the analysis phase for approval. These documents had the purpose of establishing the necessary basis for the implementation of a standardization of procedures system, as well as to define the actions developed by that unit regarding the Operational Safety. Among other aspects, MOP also contemplated the management of aerial instruction.

This fact was reflected, momentarily, in the lack of use of important instruments to follow up on each mission accomplished, with the evaluation of the produced results.

Although, at the same time, the GOA's Operational Training Program (PTO) was valid, in fact, its faithful compliance was compromised by the lack of the crew performance assessment sheets.

The interviews with the other GOA crew showed that inside that organization there was an organizational climate influenced by the feeling of invulnerability.

It was suspected that this scenario could be caused by the informal environment in which air activities were carried out, in part, characterized by the non-establishment of objective operational criteria, such as the number of equipment that each pilot could operate. It was identified that there were co-pilots who composed crews of up three different aircraft models.

No complaints or dissatisfactions were identified regarding workload, division of tasks or duty roster.

1.18 Operational information.

The aircraft took off from Zumbi dos Palmares Airport (SBMO) at 1350 UTC, to conduct a training in the Alagoas Aeroclube (SNGS) and an overflight on the city of Maceió.

During the training in SNGS, the aircraft made a go around procedure with a left turn and reached approximately 10 meters of altitude. Soon after, the helicopter set a downward trajectory, until colliding against a low voltage power grid and then against the ground.

The Commander of the aircraft, who at the time of the accident was in the right front seat, was an officer of the Military Fire Brigade of the State of Alagoas and belonged to the GOA staff. It had over 650 flight hours experience with the Jet Ranger / Long Ranger (BH06), Koala (A119) and Hughes (HU30) helicopters. His qualification as a PCH occurred in August 2011. He did not have a helicopter flight instructor license (INVH).

The occupant of the left front seat was an officer of the Military Police of the State of *Alagoas* and also belonged to the GOA staff. It had approximately 500 flight hours of experience with the Schweizer model helicopter (H269). He had a PCH license since July 2015 and did not have a license to operate the Bell 206L helicopter. This officer, on board, was responsible of establishing coordination between the crew and the police officers who engaged in ground-based police operations.

The GOA crew reported that on the day of the accident, the aircraft had flown over a neighborhood near the Maceió Airport, before heading to the Alagoas Aeroclube (SNGS) for a Commander's training flight. After the SNGS go around procedure, the aircraft would continue towards the city center of Maceió.

The accident occurred after the go around procedure of the hovering flight at threshold 14 of the SNGS.

The sequence of procedures described above was different from that generally adopted by GOA pilots. Normally, training in SNGS was performed only after the return of the overflight of the city of Maceió, when the aircraft was with less fuel on board and presented a better yield, given the high temperatures in the locality.

Training on SNGS threshold 14, usually performed by GOA crews, consisted of performing the maneuver known as "square", usually performed from the hovered flight (Figure 10).

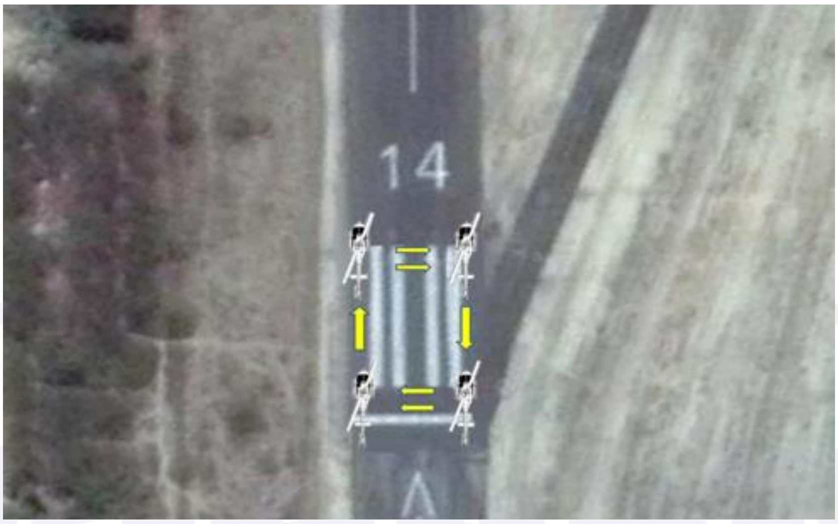

Figure 10 - Profile of the maneuver known as "square".

Just before the crash, some people spotted the aircraft performing hovering at the SNGS threshold 14.

The Alagoas *Aeroclube* was located on the route between the city center of Maceió and Zumbi dos Palmares Airport.

At the time of take-off, at Maceió Airport, the aircraft was configured for double command and presented the following weight:

Basic weight of the aircraft 940,00kgf

Fuel (500 libras) 226,80kgf

Pilots (77kgf + 90kgf) 167,00kgf

Two crew members (90kgf + 90kgf) 180,00kgf

Equipment 25,00kgf

Total take-off weight .... 1.539,40 kgf

At the time of the accident, the aircraft had completed ten minutes of flight, time between the SBMO take-off, 1350 UTC, and the time of the crash, 1400 UTC.

For the planning purpose, it was considered that the aircraft consumed 30Gal / h.

Thus, at the time of the accident, the aircraft had the following weight configuration:

Consumed fuel 18,80kgf

Total weight of the aircraft in the accident................... 1.520,60kgf

The aircraft was within the weight and balance parameters specified by the manufacturer, and its Certificate of Airworthiness stated that it could be operated by only one crewmember.

1.19 Additional information.

In response to the inquiry by the Investigation Commission (IC) of this accident concerning Bell 206 Long Ranger aircraft, the Bell Helicopter representative reported that there was a Level 7 flight simulator, Flight Training Device (FTD) , static and visual only at the Flight Safety International headquarters, located in the city of Lafayette, Louisiana / USA, and another one, level 6 FTD (static) at the facilities of the Bell Helicopter Training Academy, located in the city of Fort Worth, Texas / USA.

According to information on the ANAC website, flight simulators (FSTDs) are training devices regulated by FAR Part 60 and are subdivided into:

- FTD (*Flight Training Device*) – it may represent a generic aircraft or be specific for a particular type rating, rated at levels 4 to 7, being the latter one the most advanced.
- FFS (*Full Flight Simulator*) – they are more advanced devices and reproduce certain type of aircraft. They are classified in levels from A to D, being the latter one the most advanced. Capable of performing all the maneuvers and procedures required to obtain type, as well as flights of skill check.

  - The technical limitations of the existing flight simulators for the Bell 206 Long Ranger helicopter made it impossible to carry out tests that adequately reproduced the accident scenario.

According to one of the accident observer, an experienced professional of the civil aviation, during the go around procedure, after crossing the intersection between the runway and the SNSG parking lot, the aircraft started the climb by setting a very steep left turn, approaching 90º. When it was about 10 meters of altitude, the helicopter defined a downward trajectory, until it collided against a low voltage power grid and then against the ground.

The observer added that immediately after the accident he tried to identify whether fauna or even another aircraft were present in the runway extension that might justify an evasive maneuver by the helicopter pilots, and that nothing similar had been sighted.

When interviewed about maneuvering, helicopter pilots confirmed the tendency for performing turns to the side that coincided with the side of the seat they occupied in the cockpit.

The Alagoas *Aeroclube* had its headquarters located in an area that, among other aspects, was characterized by chronic problems of public safety. The investigation has raised data that could reinforce or rule out the possibility of the accident was associated with gunfire. The reports obtained through people who witnessed the accident showed that, at that moment, no noises or visual signs that could characterize this fact have been identified. The analyzed wrecks did not show signs that firearms had hit the aircraft.

During the present investigation, the administrative process regarding the change of the operational base of the GOA was in the final phase, in the State of *Alagoas*. Among other aspects, this change aimed at avoiding the risks observed in the Aerodrome of SNGS, from the safety of the operations against illicit acts point of view.

The video images showing the wreckage of the burning aircraft (Figure 11) demonstrated, through the smoke, that at the time of the accident the wind had a lateral component (left) in relation to the SNGS runway axis, whose characteristics (direction and intensity) were similar to those reported by METAR of SBM.

Figure 11 - Scene of the accident with the presence of fire

Figure 12 - Overview of the accident site highlighting the power grid.

Regarding the qualifications of the crew members engaged in PUBLIC SAFETY AND/OR CIVIL DEFENSE AIR OPERATIONS, Subpart K of RBHA 91 provides:

> Crews of aircraft exclusively intended for carrying out public safety and/or civil defense air operations shall belong to the Authority's staff. In exceptional situations where crew members are made of persons placed at their disposal by other Organs, such persons shall be operationally subordinated to the Organ operating the aircraft. The following items must also be obeyed:
>
> The pilot in command of the aircraft must have at least a commercial pilot's license (PCA or PCH) and a certificate of technical qualification for the type or class of the operated aircraft
>
> The second-in-command pilot must have at least a commercial pilot's license (PCA or PCH) and a certificate of technical qualification for the type or class of the operated aircraft. The CHT requirement can be exempted when the aircraft's Commander has the authorization of INVH, INVA, PLA or PLH, according to item 61.95 of RBHA 61;

(a) The other crew members must have technical qualification under the responsibility of the Organ and the certificate of physical capacity equivalent to the Operator of Special Equipment, according to RBHA 67.

The GOA had a fleet of four helicopters, all of different models. Among the crew members who made up their pilots group, several ones operated up to three types of aircraft. There was no restriction for pilots, in the Civil Aviation System legislation, about the operation of aircraft from different manufacturers at the same time.

At the time of the accident, the GOA's Operational Manual (MOP) and Standard Operational Procedures (POP) were under review for approval. The information documents were approved on 06NOV2015.

The regulation of the Civil Aviation System, through ANAC Resolution 106 of 30Jun2009, established the mandatory implementation of an Operational Safety Management System (OSMS), within the scope of the airport operators, as Small Civil Aviation Service (PPSAC).

The Guide for the elaboration of the Operational Safety Management Manual (MGSO) established that:

> OSMS is a structured way of managing operational safety. It establishes the structure of the organization, points out those responsible for operational safety in its activities, and it documents the policies and procedures that allow an effective management of the operational safety.

As part of the documentation for the implementation of the Operational Safety Management System, Public Safety and / or Civil Defense air operators should prepare their own Operational Safety Management Manual, which recommended the adoption of specific programs for PPSAC, including Training in Corporate Resource Management (CRM).

The Civil Aviation Instruction - IAC 060-1002 A, which prescribes on CRM training, among other aspects, established that:

> 3.4 - The CRM training should include situations involving routine operations, through exercises, seeking to have a positive effect among the crew, in order to contribute to the reduction of stress in times of high workload. The continuous practice of CRM also allows a satisfactory performance of the group during emergency situations, when the time pressure demands a rapid response.
>
> 3-5 - The CRM training is defined by the following characteristics:
>
> - It consists on the application of the concepts of Human Factors to improve team performance.
>
> - It encompasses all personnel involved with the air activity.
>
> - It must be part of every type of flight training.
>
> - Be focused on team attitudes and behaviors and their impact on Flight Safety.
>
> - It requires the participation of all.
>
> - It provides an opportunity for each individual and his or her group to analyze their own attitudes and to promote appropriate change, in order to optimize their capacity for teamwork and decision-making.
>
> 3.5.5.1 - The correct application of the concepts in the practice sessions of CRM represents an extremely effective way to develop and to strengthen the attitudes dictated by the Philosophy of CRM.
>
> 3.5.5.2 – The success in CRM training depends on the commitment of the top management, facilitators and participants, in short, of the whole organization to be committed to the CRM philosophy.

The SGSO was still in the implantation phase, with the elaboration of the MGSO.

Regarding the operability of the Special Equipment Operators (OEE), it was observed that despite having an ANAC code, one of the police officers did not have an Aeronautical Medical Certificate (CMA), nor a qualification as OEE, according to RBHA 91 Subpart K, reason why he was considered a passenger in item 1.2 of this report.

Likewise, the other police officer on board, who had an ANAC code, did not have a qualification as OEE, and his CMA was expired since 07JUN2014.

1.20 Useful or effective investigation techniques.

Nil.

2. ANALYSIS.

The absence of projectile impact marks on the aircraft's structure, along with reports from observers who said they had not witnessed gunfire in the area, led to the dismissal of the possibility that the helicopter was shot by firearms in the moments before the accident.

The analysis of the psychological aspects, in the individual / psychosocial fields, led to observe the influence of the behaviors adopted by the crew of the aircraft, facing a specific situation, as a consequence of processes such as attitude, attention, perception, emotional state, memory and decision process.

In this context, the stage of life that the Commander of the aircraft was going through drew attention, but it was not possible to directly associate this fact with the accident.

In the same way, we tried to identify the aspects present in the integration of the crewmembers who were involved in the accident, with the work environment, taking into account factors such as communication, work group culture and leadership.

Although traces of informality in the communications used in the organization have been identified, with a possible compromise in the interpretation of the transmitted messages, the accident can’t be directly linked to this aspect.

In the organizational field, among other aspects, it was observed that some instruments that could facilitate the supervision of activities, such as MOP and POP, were not being properly used. The SGSO was still in the implantation phase, with the elaboration of the MGSO.

Although they were very deteriorated due to the severe fire action, the debris were analyzed in the laboratory. During the exams, no pre-impact anomalies were found. The damage observed was consistent with the impact of the accident. The exams concluded that there were fractures and damage with overload failure characteristics. No fatigue fractures were found in any of the analyzed components. These findings ruled out the possibility of a failure prior to the accident.

The engine analysis concluded that the component had normal functioning and that it was developing power at the moment of the accident. Therefore, it was ruled out that an engine failure occurred before the aircraft crashed.

The aircraft had a total weight of 1,520 kgf, 19% less than the maximum take-off weight. For this reason, the weight of the aircraft at the time of the accident was not considered a limiting factor to the operation.

Technicians conducted assessments in two areas of knowledge: performance and flight qualities of the aircraft. These studies supported the research findings and made it possible to establish the dynamics of the accident. The studies related the following magnitudes:

- Necessary Torque;

- Speed ahead;
- Lateral slope angle;
- Maximum takeoff power (PMD); e
- Maximum continuous power (PMC).

It is known that the aircraft performed an acceleration procedure from hovering and takeoff followed by a left turn. However, it was not possible to establish the speed that the aircraft maintained at the moment that the curve started, nor the angle of lateral slope of the curve. For this reason, the studies considered three possible takeoff regimes: 40kt, 50kt and 60kt, with lateral slopes up to 60 °.

Regarding the study of performance:

For the purpose of the performance study, it was considered that:

- the engine of the aircraft was in normal operating conditions and was developing power at the time of the accident;
- the operation of the aircraft was within the limits approved in the flight manuals;
- the aircraft did not show any degradation in performance compared to what is provided in the flight manual; and
- the take-off profile started from a hovering flight, within the ground effect, with acceleration up to a certain speed (40KT, 50KT or 60KT), in which a curve started with an angle that may have reached up to 60 °of inclination for a period of time.

The main objective of the study was to define the limiting factors of torque, slope and speed ahead for the developed flight profile.

Figure 3 shows that the required power (torque) increases as the lateral slope of the aircraft increases as well. It can be verified that the PMC of the engine is only reached for values close to 50 ° of lateral inclination, for the three take-off profiles studied (40kt, 50kt and 60kt forward speed).

If the power applied does not match the increase in power required, in values equal to or greater than those shown in Figure 3, it would not be possible to guarantee the maintenance of the level flight. Consequently, the aircraft would lose altitude in proportion to the power deficit.

Studies have shown that the aircraft engine was able to provide sufficient power for all typical takeoff profiles, provided that the pilot started the curve at least 40kt and maneuvered the aircraft up to 50 ° lateral slope.

Even in the most critical condition (lateral slopes of up to 50º) and the speed of lower power margin (40KT), there would be conditions to perform the takeoff, to print positive gradient of rise and to counter gust of wind, from the performance point of view.

Maneuvers with slopes greater than 50 ° or the beginning of the curve with speeds below 40kt would result in a power deficit that would culminate in the impossibility of keeping the flight level (without loss of altitude). It is noteworthy that these slope and forward speed values (50 ° and 40kt) can be considered marginal to typical helicopter takeoff standards under normal operating conditions. Maintenance of parameters above these values would be related to aircraft operation outside typical known standards for which performance analyzes were not performed.

In this way, it is inferred that the performance of the aircraft did not contribute to the accident.

Regarding the study of flying qualities:

The analysis of the flight qualities of the helicopter, in the moments prior to the accident, was based on the verification of the theoretical influences of each constituent element of the aircraft, rolling response (rolling effect) and yaw (yaw effects) due to stability as well as in the theoretical influences of low-speed flight. For the analyzes that considered the wind, it was stipulated that the values of direction and wind speed would be those described in the METAR of SBMO, namely: direction 120 ° and intensity 15kt (item 1.7 of this Report).

Regarding the bearing effect, it was observed that in a left turn, when the aircraft was subjected to a wind component of the right sector, the dihedral effect would be added to the moment of the pilot's bearing, also to the left. The result of the sum of these two effects would be a tendency to increase the lateral slope to the left.

A late response to counteract this tendency could lead to unintended increase of the bearing angle (lateral slope). This could decrease the vertical component of the force produced by the main rotor and, consequently, lead to loss of altitude of the aircraft. However, a pilot that was trained and adapted to the aircraft, would be able to notice these trends and counter them, even in a mechanical and intuitive way.

Thus, taking into consideration only the dihedral effect, the bearing moments resulting from the aerodynamic response of the constituent elements of the aircraft could be counter posed by the pilot. For this reason, the rolling effects alone were not considered as contributing to the accident.

As for the effects of yaw, based on the conditions in which the accident occurred (helicopter already achieved effective speed of translation, in left turn and subjected to a component of wind of the right sector), the aerodynamic moment on the fuselage, the lateral forces on the drift and the changes in the aerodynamic force produced by the tail rotor would add up, resulting in a yaw imbalance. The consequence of this imbalance would be the realization of an uncoordinated curve. However, a pilot that was trained and adapted to the aircraft, would be able to correct these effects, even intuitively.

Thus, taking into account only the *girouette* effect, the yawing moment resulting from the aerodynamic response of the constituent elements of the aircraft could cause a yaw imbalance capable of being counter posed by the pilot. For this reason, the *girouette* effect alone was not considered a contributor to the accident.

Regarding the effects of low speed, the possible influence of the soil and relative wind effects on the control of the aircraft was analyzed. Therefore, it was stipulated that the values of direction and intensity of the wind would be those described in the METAR of SBMO, that is, wind with the direction of 120 ° and speed of 15KT.

It is known that the maximum theoretical height for influence of the ground effect on helicopters corresponds to the diameter of the main rotor. With the aircraft above this altitude, it is considered that the flight is developing out of the ground effect. According to observers, the crashed aircraft flew approximately 10 meters above the ground (AGL). This condition was considered edge for the influence of the ground effect on the flight, since the main rotor diameter of the model is equal to 11.34 meters. For this reason, the studies concluded that soil vortices (ground effect) did not influence the performance of the aircraft and, therefore, it did not contribute to the accident.

The influence of the relative wind to which the aircraft was submitted was also analyzed.

According to the meteorological information, the direction data and wind intensity at the time of the accident were 120° and 15kt, respectively. The helicopter took off from runway 14 of SNSG, therefore, with headwind component. After the takeoff, the aircraft made a left turn and from that moment, the wind came to be positioned with a right lateral component, in relation to the aircraft.

Based on the wind direction / intensity information and on the flight profile described by the aircraft, it can be stated that there was no incidence of relative wind at azimuths of 285° to 315°, azimuths in which the wind incidence could cause loss of the rotor tail, due to the turbulence from the main rotor, according to Figure 6. Thus, it can also be stated that there was no incidence of relative wind in the azimuths from 210° to 330°, favorable condition to the appearance of vortex rings in the tail rotor, (Fig. 8). This way, it can be seen that these two effects did not contribute to the accident.

It was also considered that, at some point during the curve on the left, there might have been a relative wind incidence in the azimuths from 050 ° to 210 °, a sector considered as a critical azimuth area (Figure 5). However, the envelope reproduced in Figure 5 demonstrates that the aircraft had satisfactory conditions of stability and control for winds up to 26kt of intensity.

Since the wind at the site of the accident was 15kt, if the wind affected this sector, this occurred at intensities lower than those shown. In this way, it can be assumed that the possible relative wind incidence, in the azimuths considered critical, could cause the increase of the workload of the pilot in the control of the heading of the aircraft. However, it would not be enough for there to be total loss of yaw control.

Before colliding against the ground, the aircraft collided against a wire from the local power grid. According to Figure 12, the height of the power grid poles at the crash site was 7.5 meters. Studies have shown that, for an altitude of 10 meters AGL, the tips of the aircraft's main rotor blades exceed 7.5 meters up to a 45 ° lateral slope of the aircraft. According to Figure 9, from 50 ° of slope, the tips of the blades would pass distances of less than 7.5m from the ground, making it possible to collide between the blades and the electric grid at hand.

It is worth mentioning that observers informed the flight height data of the aircraft, so they are estimated and inaccurate. Although it cannot be ruled out that a collision of the blades against the power grid has originated the sequence of events that culminated in the accident, the imprecision of the velocity, height and lateral inclination data of the aircraft made this hypothesis less probable.

The fact that there was another helicopter pilot occupying the left front seat was also analyzed. The aircraft was equipped with dual command, that is, it had flight commands in both front seats. This means that the occupant of the left front seat could pilot the helicopter as much as the pilot, who occupied the right front seat in that model.

The occupant of the left front seat was an officer of the Military Police of the State of Alagoas and was a helicopter pilot, but had no qualification in the crashed model. However, the possibility that he was flying the aircraft at the time of the accident was considered. Some aspects reinforce this hypothesis, as mentioned below:

- The officer was a helicopter pilot;

- The curve was taken from the left. Usually helicopter pilots give preference to making the curves to their side of the aircraft;

- According to reports, the curve was performed at low altitude and with a considerable slope. These maneuvering characteristics are consistent with a daring profile pilot, compatible with the occupant of the left front seat and different from the profile of the Commander;

- The GOA's psychosocial and leadership contexts were conducive to an environment of informality in the organization's training flights;

- There was a strong relationship of friendship between the pilots, which could have enhanced this informal environment;

- There was a motivation for sharing the operation of the aircraft with the use of the Commander's training flight;

- The action of theoretical influences related to flight qualities was considered unlikely for a pilot that was trained and adapted to the operation of the aircraft. However, a pilot with no experience in this model would be more susceptible to these influences;

- The left front seat occupant had experience in operating the Schweizer model helicopter (H-269), this equipment had different aerodynamic reactions from the crashed Long Ranger model; and

- The studies did not find any aspect related to the performance of the aircraft, which could contribute to the accident.

Thus, two hypotheses were considered as plausible for the occurrence of the accident:

a) The Commander of the aircraft, for some reason, left his standard of piloting and made a curve at low altitude with a high degree of lateral inclination after takeoff. During the maneuver, he did not make the necessary corrections and the aircraft lost altitude, colliding against the power grid and then, against the ground; and

b) The occupant of the left front seat was piloting the helicopter at the time of the accident. During takeoff, when performing a large lateral slope at low altitude, he was not able to perform the necessary corrections to maintain level flight. The aircraft lost altitude and crashed into the power line and then into the ground.

The "a" hypothesis was considered less likely because of the Commander's psychological profile and flying experience. The referred pilot had a cautious profile of piloting, which does not match the executed maneuver. The fact that the curve was made to the left (opposite side of the pilot's location in the aircraft cabin) was considered significant, since helicopter pilots usually give preference to turn to their side of the cabin, especially in bolder maneuvers. In addition, the performance studies and flight qualities performed showed that the maneuver could be performed with corrections and workload level considered normal for a pilot that was trained and adapted to the model of the crashed aircraft. The commander had approximately 680 total flight hours of flight experience, 350 hours in that aircraft model.

The "b" hypothesis was considered the most probable one because of the psychological profile and flight experience of the occupant of the left front seat in the aircraft model. The referred officer had a bold pilot profile, consistent with the maneuver executed. The curve was made to the left (the side where the officer was in the cabin of the aircraft), a consistent situation with what is usually done by helicopter pilots. The performance studies and flight qualities showed that the maneuver was possible, but it required some corrections and workload levels that may have exceeded the skills of the pilot, not familiar or adapted to the model. The occupant of the left front seat was a helicopter pilot, but he was not qualified in the crashed model, so he did not have previous piloting experience in that aircraft model.

3. CONCLUSIONS.

3.1 Facts.

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

b) the Special Equipment Operator (OEE) was with his CMA expired;

c) the pilot had valid Technical Qualification Certificate (CHT);

d) the pilot was qualified and had experience in that type of flight;

e) the occupant of the left front seat, despite being a helicopter pilot, was not able to operate that model of aircraft;

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

g) the aircraft was within the weight and balance parameters;

h) the airframe and engine logbooks records were up-to-date;

i) the conditions were favorable for the visual flight;

j) the accident occurred during take-off after a training flight, performed at SNSG's threshold 14;

k) the take-off profile was characterized by a hovering flight within the ground effect with acceleration on the landing / take-off runway towards threshold 14;

l) after the race on the track, a few meters after crossing the intersection with the SNSG parking area, the aircraft started curving up to the left;

m) with approximately 10 meters height (according to observers reports), the helicopter defined a downward trajectory, until colliding against a low voltage power grid and then against the ground;

n) the aircraft caught fire after impact;

o) there weren’t found marks of firearms in the aircraft structure;

p) no fatigue fractures were found in any of the analyzed components;

q) the damage observed on the skis, main drive motor system, main rotor, tail rotor, flight controls and motor were consistent with the impact resulting from the accident;

r) the analysis showed that the engine had normal functioning and it was developing power at the moment of the accident;

s) the weight of the aircraft at the moment of the accident was 1,520 kgf, 19% less than the maximum take-off weight;

t) the operation of the aircraft was within the limits approved in the flight manuals;

u) the aircraft did not present any degradation of performance in relation to that provided in the flight manual;

v) performance studies found that the maneuver was possible to be executed with sufficient power margin for curves performed above 40kt and with up to 60 ° lateral slope;

w) the studies showed that there was no incidence of relative wind in azimuths from 210 ° to 330 ° and from 285 ° to 315 °;

x) the studies concluded that the possible relative wind incidence, in the azimuths considered critical, would not be sufficient for total loss of yaw control;

y) the studies concluded that soil vortices (ground effect) did not influence the performance of the aircraft;

z) the performance studies and flight qualities showed that the maneuver was possible, but it required some corrections and workload levels considered normal for a pilot that was trained and adapted to that aircraft’s model;

aa) the loss of altitude of the aircraft, during the performance of the curve, was associated to the slope and speed used ahead, without being performed necessary corrections for the altitude maintenance;

bb) the aircraft was completely destroyed; and

cc) all the occupants of the aircraft perished at the accident site.

3.2 Contributing factors.

- **Attention - undetermined.**

It is probable that the information processing capacity of the pilot who was flying the aircraft, at the time of the accident, particularly related to the operational limits, was compromised due to some stimuli such as motivation or emotional state.

- **Attitude - undetermined.**

Performing a maneuver that may have exceeded the operational limits of the aircraft may have been an indicative of a response due to an activity designed without prior planning and supposedly performed by an unqualified person.

- **Communication - undetermined.**

The informal way in which the information was passed on, within the scope of the organization, could have compromised the clarity and interpretation of the messages, leading to the breaking of the existing rules and standards, such as the operation of the helicopter outside its operational limits.

- **Control skills - a contributor.**

Performing a maneuver with high speed and incline values would only be possible if there was adequate application on the altitude maintenance controls. If the operating limits of the aircraft have been exceeded, this condition was related to the inadequate use of the flight commands.

- **Decision-making process - undetermined.**

The possibility of the aircraft being under the operation of the occupant of the left front seat refers to a failure of the Commander's decision-making process. This aspect could be associated with the context of informality and the lack of an adequate consolidation of formal processes within the GOA.

- **Emotional state - undetermined.**

The mood of the crew was probably undergoing changes. The Commander, due to the stressful situation because of his separation, and the occupant of the left seat because of the excessive mobilization to become Commander. These aspects may have compromised the ability to react to the critical flight situation.

- **Flight planning - undetermined.**

It is possible that for the accomplishment of that flight there has not been the proper preparation of it, with the establishment of the correct distribution of the tasks onboard.

- **Insufficient pilot's experience - undetermined.**

The hypothesis that the occupant of the left front seat was in command of the aircraft, without having qualification for the model, supposes the contribution of this factor to the event.

- **Managerial oversight - a contributor.**

The informality present in the accomplishment of the air activities, within the scope of the GOA, influenced in the accompaniment of the planning phase, reinforcing the breaking of rules in the conduct of that flight, contributing to the accident.

The possible operation of the aircraft by a pilot without proper qualification and the presence of two police officers without the valid OEE authorization ratifies the contribution of this aspect.

- **Memory - undetermined.**

The possibility of the contribution of the behavior known as interference, in this case, characterized by the influence of other helicopter models in the operation of the aircraft involved in the accident, suggests the contribution of this aspect, which maintains a direct relation with the psychological phenomenon described by Piaget, called: the transfer of learning.

- **Organizational culture - undetermined.**

It is possible that the set of informal rules in use at GOA influenced the interpretation of the common facts by the commander of the aircraft, leading him to believe that the operation of the helicopter by the other pilot would only be a common action and without greater risks.

- **Organizational processes - a contributor.**

The lack of adequate tools to monitor the crew’s performance, such as assessment sheets, revealed flaws in the organization's formal processes, compromising the supervision of the training flights.

- **Perception - a contributor.**

For several reasons, the psychological state of the pilots inhibited the performance of the processes of recognition and organization of the received stimuli, which could prevent the accomplishment of a maneuver at low altitude and with great slope.

- **Piloting judgment - a contributor**

The pilot failed to assess, adequately, the theoretical influences related to flight performance and quality of flight, in performing a maneuver at low altitude and with a great slope.

- **Support systems - undetermined.**

The fact that operational models, such as the Operations Manual (MOP) and Standard Operating Procedures (POPs) were not approved at the time of the accident, may have compromised the establishment of adequate and timely supervision of the air activities, including training.

- **Work-group culture - undetermined.**

The alleged operation of the aircraft by an unqualified pilot may have been the result of a set of beliefs and values shared by the GOA crew. Since the internal culture of that organization was still influenced by the previous experiences of its components, coming from other segments of the police activity, and which did not always strengthen the safety culture of air operations.

It should also be pointed out that informality may have led to the breaking of rules, culminating in the operation of the aircraft, allegedly conducted by a pilot without the proper license.

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 prior to the publication of this report:

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

A-128/CENIPA/2015 - 01 **Issued on: 10/05/2018**

Work with the operator, aiming the execution of didactic activities directed at pilots, seeking to reinforce the need for faithful observance of the operational limits of their aircraft.

A-128/CENIPA/2015 - 02 **Issued on: 10/05/2018**

Work with the operator, to ensure the effective use of Performance Assessment Sheets for the various types of instructional flights, in line with the GOA Operational Training Program.

A-128/CENIPA/2015 - 03 **Issued on: 10/05/2018**

Work along with the GOA, aiming the execution of periodic training of CRM techniques by its crews, with the centered focus of the organization.

A-128/CENIPA/2015 - 04 **Issued on: 10/05/2018**

Work with the GOA, aiming the adoption of mechanisms of Management Supervision, in the Operational scope, in order to allow the timely identification of aspects that may compromise the safety of its air operations, notably, regarding the accomplishment of instruction flight by pilots that are not qualified to do so.

A-128/CENIPA/2015 - 05 **Issued on: 10/05/2018**

Disclose the lessons learned from the present investigation among the airport operators, seeking to emphasize the importance of faithful observance of the rules and operational norms, as well as the appropriate CRM techniques for the success of its air operations.

A-128/CENIPA/2015 - 06 **Issued on: 10/05/2018**

Work with GOA, aiming the implementation of its Operational Safety Management System - SGSO, in accordance with Resolution 106 of 30JUN2009, of ANAC.

Recommendations issued at the publication of this report:

None.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

The SERIPA II ministered a course of CRM directed to the air operators of Public Security.

On May 10th, 2018.