COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-011/CENIPA/2022

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PS-RAF**
MODEL:	**AT-602**
DATE:	**20JAN2022**

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 Final Report refers to the 20 January 2022 accident with the AT-602 aircraft, registration marks PS-RAF. The accident was typified as “[LOC-I] Loss of control in flight”.

Shortly after takeoff, control of the aircraft was lost, and it ended up colliding with the ground.

The aircraft sustained substantial damage.

The pilot suffered fatal injuries.

For being the USA the State of design/manufacture of the aircraft, an Accredited Representative from the NTSB (National Transportation Safety Board) was appointed for participation in the investigation of the occurrence.

For being Canada the State of manufacture of the aircraft’s engine, an Accredited Representative of the TSB (Transportation Safety Board) was also appointed for participation in the investigation of the occurrence.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AFH	Airplane Flying Handbook
AFM	Airplane Flight Manual
ANAC	Brazil's *National Civil Aviation Agency*
ANP	Brazil's *National Agency for Petroleum, Natural Gas and Biofuels*
AoA	Angle of Attack
CG	Center of Gravity
CIV	Pilot's Logbook
CMA	Aeronautical Medical Certificate
COELBA	State of Bahia's Electricity Company
CP	Pressure Center
CSN	Cycles Since New
CVA	Airworthiness Verification Certificate
DGPS	Differential Global Positioning System
FAA	USA's *Federal Aviation Administration*
FCU	Fuel Control Unit
IAC	Civil Aviation Instruction
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LOC-I	Loss of Control in Flight
MCA	Manual of the Command of Aeronautics
MNTE	Single-Engine Land Airplane Class Rating
NTSB	USA's *National Transportation Safety Board*
OM	Maintenance Organization
OS	Service Order
PAGA	Aero-Agricultural Pilot Rating (Airplane)
PCM	Commercial Pilot License (Airplane)
PIC	Pilot in Command
PMD	Maximum Take-Off Weight
PPR	Private Pilot License (Airplane)
RBAC	Brazilian Civil Aviation Regulation
RBHA	Brazilian Aeronautical Certification Regulation
SIPAER	Brazil's *Aeronautical Accidents Investigation and Prevention System*
SN	Serial Number
SSQZ	ICAO location designator - *Mimoso do Oeste* Aerodrome, *Luís Eduardo Magalhães*, State of *Bahia*
TPP	Private Registration Category – Private Air Services

TSB	Canada's *Transportation Safety Board*
TSN	Time Since New
UTC	Universal Time Coordinated
VFR	Visual Flight Rules

1. FACTUAL INFORMATION.

Aircraft	**Model:** AT-602 **Registration:** PS-RAF **Manufacturer:** Air Tractor, Inc.	**Operator:** Private.
Occurrence	**Date/time**: 20JAN2022 - 17:32 (UTC) **Location:** *Fazenda Serra Branca*. **Lat.** 08°00'43"S **Long.** 044°43'16"W **Municipality – State:** *Luís Eduardo Magalhães* – State of *Bahia.*	**Type(s):** [LOC-I] Loss of control - inflight

1.1. History of the flight.

At 17:32 UTC, the aircraft took off from SSQZ (*Mimoso do Oeste* Aerodrome, *Luís Eduardo Magalhães*, State of *Bahia*) on a ferry flight destined for the landing area of aero-agricultural use of *Fazenda Ipiranga*, *São Desidério*, State of *Bahia*, with 01 POB (pilot).

According to reports from witnesses on the ground, the aircraft got airborne and remained close to the ground until crossing over the departure end of the runway.

Then, it initiated a steep climb with a significant pitch-up angle. At the highest point of the maneuver, the aircraft made a rotation of the wings to the right until reaching an upside-down position.

Subsequently, the aircraft lost control, and impacted the ground, without horizontal displacement, at a distance of approximately 390 m past the departure end of the runway.

Figure 1 - View of the PS-RAF at the accident site.

The aircraft sustained substantial damage. The pilot did not survive the crash.

1.2. Injuries to persons.

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

1.3. Damage to the aircraft.

The aircraft sustained substantial damage to its entire structure.

There was flection of the wings, of the fuselage, as well as of the horizontal and vertical stabilizers.

The powerplant sustained serious damage resulting from the impact of the aircraft with the ground.

1.4. Other damage.

Before impacting the ground, the aircraft struck the cable of an electrical transmission line of the State of *Bahia*'s Electricity Company (COELBA), without breaking it.

1.5. Personnel information.

1.5.1. Crew's flight experience.

	PIC
Total	2.493:24
Total in the last 30 days	65:30
Total in the last 24 hours	00:00
In this type of aircraft	65:30
In this type in the last 30 days	65:30
In this type in the last 24 hours	[00:00]

N.B.: PIC's flight time data obtained through records of his Pilot Logbook (CIV) and third-party reports.

1.5.2. Personnel training.

The PIC (Pilot in Command) did his PPR course (Private Pilot – Airplane) in 2008, at the *Aeroclube de Campo Mourão*, State of *Paraná*.

1.5.3. Category of licenses and validity of certificates.

The PIC held a PCM license (Commercial Pilot - Airplane), and valid MNTE (Single-Engine Land Airplane) and PAGA (Agricultural Pilot - Airplane) ratings.

1.5.4. Qualification and flight experience.

The pilot had qualification and experience for the type of flight.

The records of the pilot's logbook indicated that the PIC had been operating AT-602 aircraft since 30 December 2021.

Between 30 December 2021 and 18 January 2022, the PIC's Logbook had the records of 17 flights with AT-602 aircraft, all of them with the PS-RAF, totaling 65 hours and 30 minutes of flight time. Most of the flights had the objective of spraying agricultural pesticides.

1.5.5. Validity of medical certificate.

The PIC held a valid CMA (Aeronautical Medical Certificate).

1.6. Aircraft information.

The SN 602-1326 AT-602 aircraft was a product manufactured by Air Tractor Inc. in 2021, registered in the Private Registration Category - Private Air Services (TPP).

The aircraft's CVA (Airworthiness Verification Certificate) was valid.

In the aircraft logbook, no discrepancies were identified that could have resulted in malfunction of any of the aircraft's systems.

The records of the airframe, engine, and propeller logbooks were up to date.

The aircraft underwent an Initial Technical Inspection (VTI), on account of nationalization, which was completed on 18 December 2021. The aforementioned technical inspection was carried out by technicians of the ANAC's Airworthiness Superintendence, who attested the "airworthiness of the aircraft in accordance with the applicable RBHA/RBAC and IAC/IS". On that date, the aircraft had 32 hours and 6 minutes of flight time.

The last inspection of the aircraft ("100-hour" type) was completed on 20 January 2022 was carried out by *Oeste Manutenção e Reparação de Aeronaves Ltda.* Maintenance Organization (OM), in *Luís Eduardo Magalhães*, State of *Bahia*. The aircraft flew 10 minutes after the said inspection.

The OS (Service Order) nº 0016/2022, dated 18 December 2022, describing the maintenance services carried out on the PS-RAF powerplant and systems, did not contain records of repairs or interventions that could have impacted the performance of the engine. Besides, there were no records of abnormalities capable of compromising the functioning of the inspected systems.

Additionally, according to the owner of *Oeste Manutenção e Reparação de Aeronaves Ltda.* OM (maintenance organization), on the day of the occurrence and prior to the accident flight, a maintenance check flight (*aka experience flight*) was performed for verification of the systems and for receipt of the aircraft after the provision of the maintenance services.

The PIC involved in the accident was the same pilot who had performed the check flight (no discrepancies were reported in relation to the referred check flight). There were no formal records of the check flight in the PS-RAF's aircraft logbook.

In the Owners' Manual of the AT-602 aircraft, verification flights were not prescribed after completion of the first "100-hour type" inspection.

1.7. Meteorological information.

There were no restrictions of visibility at the moment of the accident. The weather conditions were consistent with the conduction of the flight.

1.8. Aids to navigation.

NIL.

1.9. Communications.

One verified that the pilot maintained radio contact with the ATC units, and that there were no technical abnormalities affecting the communication equipment during the flight.

1.10. Aerodrome information.

The aerodrome of SSQZ, located in *Luiz Eduardo Magalhães*, State of *Bahia*, was private, with operations under Visual Flight Rules, during day-time.

The runway was paved with asphalt, had the runways 10/28, measuring 1,300 m x 28 m, at an elevation of 2,543 ft.

1.11. Flight recorders.

Not required and not installed.

The aircraft was equipped with an AGNAV DGPS (Differential Global Positioning System). However, on account of damage to the equipment, it was not possible to retrieve the stored data pertaining to the accident flight.

1.12. Wreckage and impact information.

The first impact of the aircraft (with its right-hand wing) was against an electrical transmission-line cable, when the airplane was already in abnormal attitude. The collision

with the terrain occurred with high energy on the margin of a dirt road at a distance of approximately 390 m from the threshold 10 of SSQZ.

There were no reports of explosions or fire at the crash site.

None of the control surfaces detached from the aircraft. However, due to the extent of the damage, it was not possible to accurately determine the position the flaps.

The position of the elevator trimmers, identified in the wreckage, was compatible with the selection on the trim control lever, between the green operating range and the nose-up range.

Considering the extent of the damage, the deformation pattern of the fuselage and of the wings, as well as the specific concentration of debris, the aircraft impacted the ground at a high sink rate, slight wing banking, fairly pitched-down attitude, and at an upside-down position, aligned with the azimuth 110º. There was no longitudinal displacement after the collision.

1.13. Medical and pathological information.

1.13.1. Medical aspects.

There was no evidence that issues of physiological nature or incapacitation might have affected the pilot's performance.

1.13.2. Ergonomic information.

NIL.

1.13.3. Psychological aspects.

The PIC’s colleagues described him as a person of good sociability in his group of work, and as someone who did not have a show-off profile. He was familiar with the type of operation.

The PS-RAF, which had recently been purchased by the operator, was equipped with a more powerful engine than the usual one for the model, something that was considered a novelty. According to reports, there was a lot of curiosity among the accident pilot's colleagues in relation to the performance of the aircraft in question.

On the day of the accident, observers who were in an aircraft maintenance workshop in the heritage area of SSQZ, and who were preparing other aircraft for flight, saw the PS-RAF takeoff.

In fact, a pilot, who would take off shortly later, sent a photo of the PS-RAF taxiing towards the threshold 28, via the messaging application.

Before taking off, the pilot of the PS-RAF responded to the message by briefly thanking the sender for the photo, without continuing the exchange of messages.

1.14. Fire.

There was no fire.

1.15. Survival aspects.

NIL.

1.16. Tests and research.

- Analysis of the Powertrain:

The SN PCE-PN0466 PT6A-65AG Pratt & Whitney engine, which equipped the PS-RAF, was disassembled and inspected, with the objective of determining a possible failure of the component.

The engine's TSN (Time Since New) was 97 hours and 36 minutes, with 8 CSN (Cycles Since New).

The engine logbook did not have records of repairs or interventions that could have affected the engine's performance.

Initially, one observed that the engine had sustained major damage resulting from the impact of the airplane against the ground.

The analysis of the engine revealed rubbing marks on the compressor turbine, on the power turbines, as well as on the anterior and posterior sides of the turbine interstage baffle. (Figure 2).

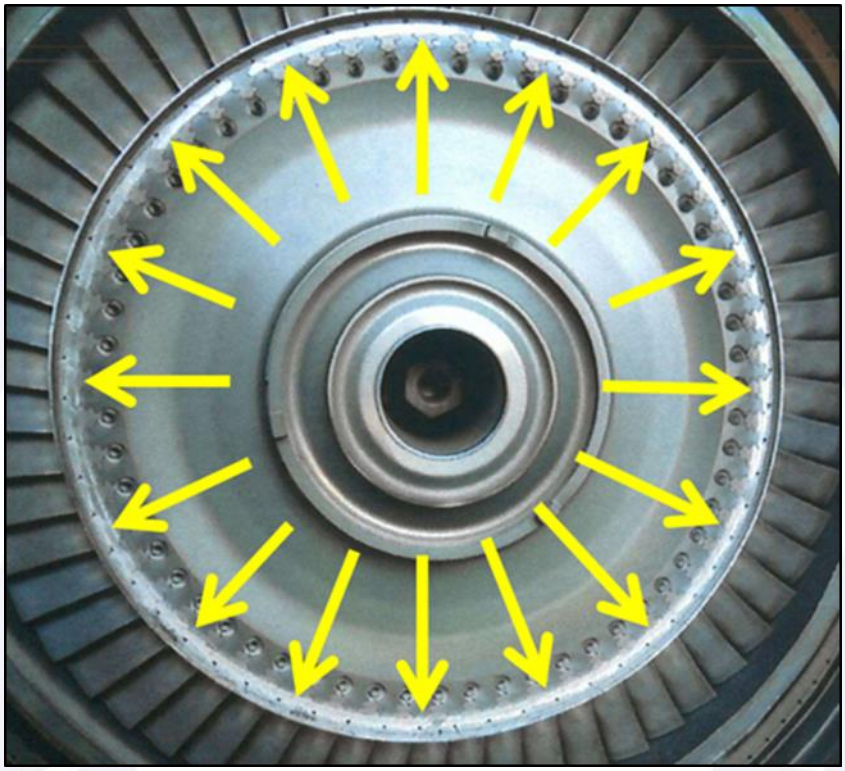

Figure 2 - Rubbing marks on the roots of the compressor turbine blades.

No abnormalities were detected in the engine lubrication system capable of compromising its functioning.

The high-pressure fuel filter was clean, and the remaining fuel in the tank did not contain any contaminants.

The Figure 3 shows a view of the engine Ng indicator. It was examined, and one found that the pointer was stuck in the position of almost 100%, something indicative of the operating condition of the component at the moment of the collision with the ground.

Figure 3 - Engine Ng indicator.

Due to the extent of the damage, it was not possible to bench test the performance of the engine's FCU (Fuel Control Unit).

Thus, the analyses of the SN PCE-PN0466, PT6A-65AG Pratt & Whitney engine, which equipped the PS-RAF aircraft, revealed that it had an operating condition, judging from the observed internal signatures. They also showed that the engine was developing power at the moment of the impact with the ground.

- Examination of the flight control system:

Visual examinations of the primary flight control cables revealed the spreading of the wires that composed the cables, breakage of the wires, and strictures at several points; such aspects were indicative of overload resulting from the impact of the aircraft.

No signs of malfunction were found in the other components of the aircraft's flight control system.

- Fuel Analysis:

The aircraft's fuel tanks ruptured upon impact. In consequence, they allowed all the fuel to spill out.

The fuel sample collected from the fuel tanker, which carried out the last refueling of the PS-RAF on 20 January 2022, was sent to the ANP (National Agency for Petroleum, Natural Gas and Biofuels) for examination.

The ANP report indicated that the sample had a clear, limpid appearance, and was free of water and solid material, being, therefore, within its respective specification, showing no signs of contamination.

1.17. Organizational and management information.

NIL.

1.18. Operational information.

It was a ferry flight after a scheduled inspection, from SSQZ to the landing area for aeroagricultural use located on *Fazenda Ipiranga*, municipality of *São Desidério*, State of *Bahia*.

The aircraft was operating within its weight and balance limits. At the time of the takeoff, the aircraft's hopper was empty.

The PS-RAF took off with a weight of approximately 3,690 kg (the MTOW established by the aircraft manufacturer was 5,670 kg).

According to reports made by witnesses on the ground, the aircraft (still maintaining the takeoff axis) crossed the departure end of the runway and started climbing with a high pitch-up angle, wings level, until reaching an estimated height between 300 and 500 ft. Then, it performed a rotation of the wings to the right until reaching an upside down attitude. In that condition, according to reports, the plane began to lose height, and ended up colliding with the ground (Figure 4).

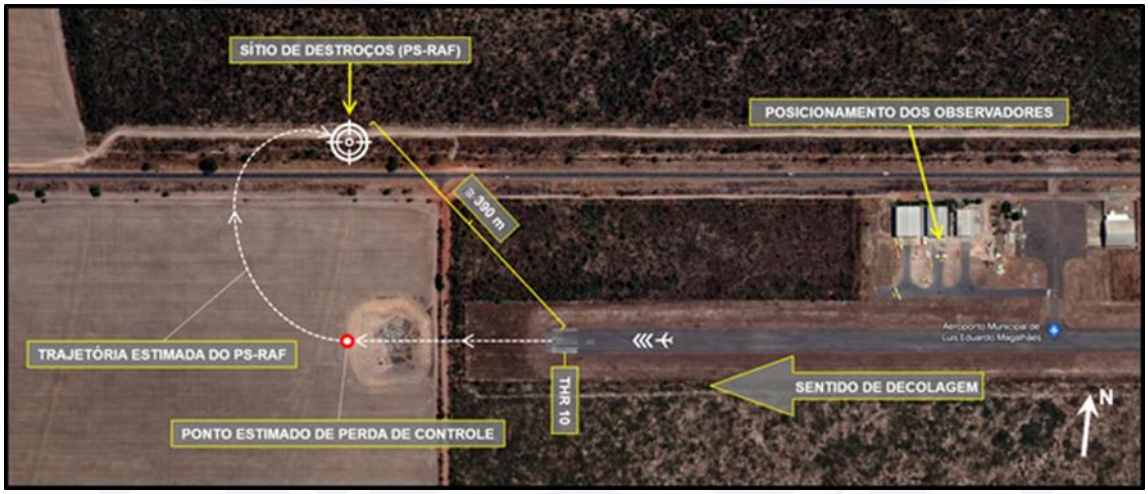

Figure 4 - Representation of the estimated dynamics of the accident, based on reports made by witnesses on the ground.

With respect to the limits for executing maneuvers, the Section 1 (Limitations) of the AT-602 Airplane Flight Manual warned that aerobatic maneuvers and spins were prohibited:

> ***SECTION 1 - LIMITATIONS***
>
> ***2.4 PLACARDS AND MARKINGS***
>
> *The following information on placards pertaining to flight and operating limitations must be displayed:*
>
> *[…]*
>
> *(c) (1) THIS AIRPLANE MUST BE OPERATED IN RESTRICTED CATEGORY IN ACCORDANCE WITH THE AIRPLANE FLIGHT MANUAL. NO ACROBATIC MANEUVERS, INCLUDING SPINS. DESIGN MANEUVERING SPEED 162 MPH [141 KNOTS] CAS. MAX FLAP DOWN SPEED 130 MPH [113 KNOTS] CAS. MAX CROSSWIND VELOCITY LANDING 20 MPH [17 KNOTS]. ALT. LOSS FROM STALL 300 FT.*
>
> *[…]*
>
> *(20) On Instrument Panel: A STALL DURING SKIDDING TURNS WILL CAUSE THE NOSE TO PITCH DOWN SHARPLY AND RESULT IN A SIGNIFICANT LOSS OF ALTITUDE. MAINTAIN COORDINATED FLIGHT AT ALL TIMES.*

According to reports, the PS-RAF performed an “American” takeoff. In this type of takeoff, after leaving the ground, the aircraft remains flying low and, at the end of the runway length, on account of the high speed obtained, it climbs at a high pitch-up angle.

Relatively to this subject, the Section 2 (Normal Procedures) of the AT-602 aircraft flight manual described the technique for normal takeoff for weights of up to 4,173 kg as follows, noting that the speed to be used for the best climb rate would be 89 kt:

> ***TAKE-OFF: (Normal - Up to 4173 kg (9,200 lbs.) Gross Weight)***
>
> *1. With power still approximately 1500 lbs.-ft torque, check Np at 1700 RPM, release brakes and as aircraft moves forward, gradually advance Power Lever to provide a smooth and continuous acceleration of the engine to maximum take-off power.*

2. As Power Lever is advanced, make sure temperature and torque limits are not exceeded.

3 Allow the tail to come up to the desired take-off attitude.

4. Best Rate of Climb speed at 4173 kg (9,200 lbs.) take-off weight is 89 kt (102 mph) CAS.

5. Adjust trim lever for climb and check temperature and torque limits. If desired, reduce propeller RPM to approximately 1550 RPM for climb.

CAUTION: Reduction of prop RPM will increase Torque and can cause Torque limit to be exceeded when already operating at maximum Torque.

In relation to agricultural operation flights, the Section 2 (Normal Procedures) of the AFM reinforced the need to perform coordinated turns, monitoring the quality with the use of the turn and slip indicator:

[…]

AGRICULTURAL FLYING:

[…]

Turns:

[…]

3. Make coordinated turns. Use the slip indicator as a means of determining whether or not you are carrying bottom rudder. The AT-602 has excellent stall characteristics and if the aircraft is inadvertently placed in an impending stall situation, it is only necessary to relax some back pressure on the stick to make recovery, and little altitude is lost, providing the turn is coordinated. A stall from a skidding turn will result in the nose dropping sharply with a significant loss of altitude.

[…]

In turn, the Section 3 (Emergency Procedures) warned that the rotation characteristics of this model had not been fully investigated, and the techniques for recovering from a spin had not been established, and that, therefore, there was no training planned for that condition.

In the case of an inadvertent spin, the document suggested the adoption of the following procedures to recover from that abnormal attitude: reduce power to the minimum, place the ailerons in the neutral position, apply the opposite pedal to stop the rotation, move the stick forward to make the aircraft pitch down, and make it recover from the descent:

1. Reduce POWER to idle - The torque of an engine producing power will make spin recovery more difficult.

2. AILERONS neutral - Attempting to level the wings with aileron input can actually make the spin worse.

3. Apply FULL OPPOSITE RUDDER to stop the rotation - Apply rudder opposite the rotation of the spin. If you have trouble determining which way the airplane is spinning, look at your turn coordinator or turn needle. It will indicate the direction of rotation.

4. Apply FORWARD ELEVATOR to break the stall - Immediately after applying opposite rudder, apply a quick forward motion on the control stick and hold anti-spin controls until the aircraft starts to recover.

5. RECOVER from the dive - Once you have completed the four previous steps, and the rotation stops, recover from the dive. The descent rate may be high and the airspeed can quickly exceed redline. Remember to neutralize the rudder after the rotation stops.

Relatively to the stall speed, the Section 4 (Performance), in addition to reporting that the maximum height lost in recovery with wings level was 300 ft, also mentioned the following stall speeds for a weight of 4,173 kg and with reduced power (*power idle*) (Figure 5):

Angle of Bank (Degrees)	0°	15°	30°	45°	60°
Stall Speed (MPH-CAS) FLAPS UP	87	89	93	103	123
Stall Speed (KNOTS-CAS) FLAPS UP	76	77	81	90	107
Stall Speed (MPH-CAS) FLAPS DOWN	70	71	75	83	99
Stall Speed (KNOTS-CAS) FLAPS DOWN	61	62	65	72	76

Figure 5 - AT-602 stall speeds.

1.19. Additional information.

The AFH (Airplane Flying Handbook) of the Federal Aviation Administration (FAA-H-8083-3C), version 2021, in Chapter 5: Maintaining Aircraft Control: Upset Prevention and Recovery Training, read the following:

> *To prevent LOC-I accidents, it is important for pilots to recognize and maintain a heightened awareness of situations that increase the risk of loss of control. Those situations include: uncoordinated flight, equipment malfunctions, pilot complacency, distraction, turbulence, and poor risk management. Attempting to fly in instrument meteorological conditions (IMC) when the pilot is not qualified or proficient is a common example of poor risk management. The Emergency Procedures chapter of this handbook contains specific information regarding unintended flight into IMC. Sadly, there are also LOC-I accidents resulting from intentional disregard for safety.*

The referred document informed that in order to prevent accidents caused by loss of control in flight, it was important that pilots recognize and maintain high situational awareness of situations that increase the risk of loss of control.

Such situations include uncoordinated flight, equipment malfunction, pilot complacency, distraction, turbulence, and poor risk management. The text concluded by stating that, unfortunately, there were also LOC-I accidents resulting from intentional disregard for safety.

- Stall

A stall is an aerodynamic condition that occurs when the airflow over the aircraft's wings is interrupted, resulting in a loss of lift. Specifically, a stall occurs when the Angle of Attack (AoA) between the wing's mean chord line and the relative wind exceeds the wing's critical AoA (Figure 6).

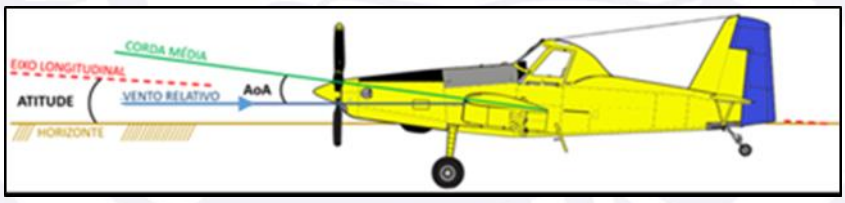

Figure 6 - Visual representation of AoA and pitch angle (attitude) definitions.

It is possible to exceed the critical AoA at any speed, at any attitude, and at any power configuration (Figure 7).

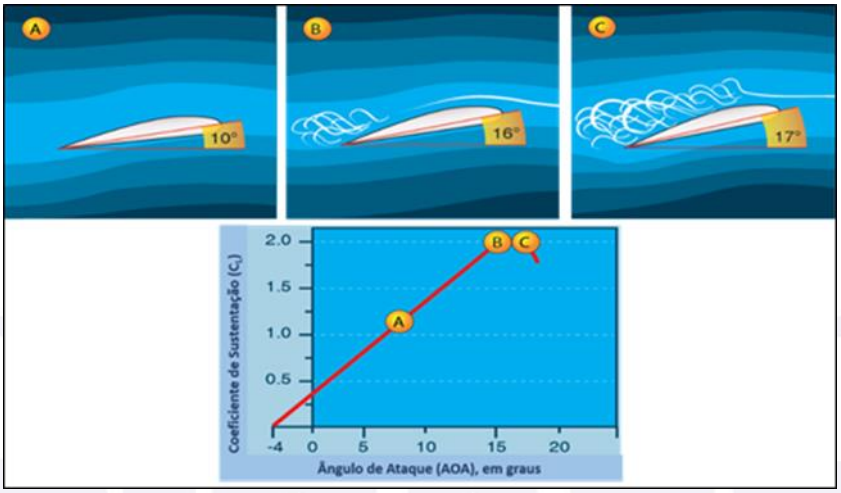

Figure 7 - Example of stall and critical AoA dynamics.
Source: Airplane Flying Handbook - FAA-H-8083-3C, 2021.

An aircraft enters a full stall condition when the critical AoA is exceeded. Indications of a full stall generally include an uncommanded *nose down (pitch down)*, which cannot be readily stopped, and may also be accompanied by an uncontrolled roll movement.

Different aircraft designs may result in different stall characteristics. Factors that may affect an aircraft's stall characteristics include its geometry, CG position, wing design, etc. Some variables may influence the stall speed of an aircraft, and the following should be noted in such case:

- Center of Gravity: in order to bring stability to the flight, aircraft are usually designed so that the Center of Gravity (CG) is ahead of the Center of Pressure (CP). The horizontal stabilizers, located at the rear of the aircraft (behind the CP and CG), are aerodynamic surfaces designed with the purpose of providing longitudinal stability (around the lateral axis - pitching) (Figure 9).

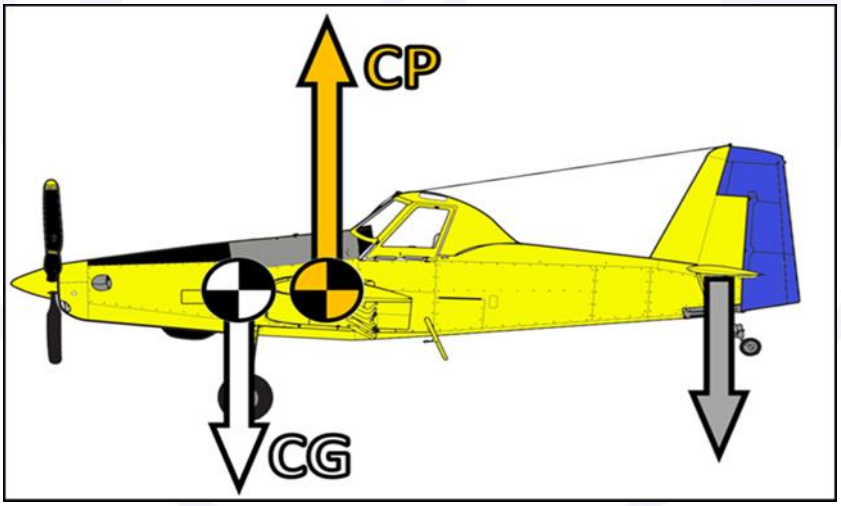

Figure 9 - Visual representation of CG and CP positioning.

- Weight: by and large, an aircraft flying with a higher weight stalls at higher speeds. As the weight of the aircraft increases, the wing loading (ratio of weight to wing area) increases. This means that greater lifting force is required to support the additional weight. To generate this greater lift, a greater angle of attack or greater speed is required.

- Coordination: when an aircraft is flying in an uncoordinated manner, that is, when there is no adequate balance between the yaw, roll, and pitch commands, the

pressure distribution around the fuselage and the wings becomes irregular, resulting in an increase of the aerodynamic drag, requiring greater power to maintain flight.

During climbs, with high power and low speeds, the effects of engine torque become more pronounced, and an imbalance between the aerodynamic forces acting on the wings and rudder may occur, leading to an uncoordinated flight condition.

- *Flat Spin*

A Flat Spin is a dangerous and potentially fatal flight condition that occurs when an aircraft enters an uncontrolled spinning motion. A flat rotation occurs when the center of gravity shifts too far back (toward the tail) and the aircraft's rotation becomes more horizontal. In this situation, the wings are not producing enough lift. Recovering from a flat spin can be extremely difficult and, in some cases, impossible.

Among the various factors that may cause a flat spin, the following ones stand out:

CG AFT: A significant factor that may lead to a flat spin is having the aircraft's center of gravity rearward (toward the tail). In this CG position, the airplane becomes more unstable and prone to going into a flat spin when “stalled” and uncoordinated.

Uncoordinated Flight: an uncoordinated flight may also contribute to the occurrence of flat spin. If the ailerons, rudder, and elevator are out of trim during a stall, the aircraft may enter a spin due to increased yaw and lack of control.

Abrupt or Aggressive Maneuver: Attempting to perform aggressive or abrupt maneuvers, especially with the CG in the rear, can lead to a flat spin. The combination of a high angle of attack and yaw may cause the aircraft to enter an uncontrolled, level spinning motion.

Flat spins are particularly dangerous because the level attitude and reduced airflow over the control surfaces make it difficult to regain control of the airplane. The flat spin occurs due to poor weight distribution in the aircraft. This travel of the CG backwards causes the aircraft to become unbalanced, leading to a more favorable condition for the occurrence of a flat spin.

The aft-shifted position of the CG prevents the nose from lowering to allow recovery of a controlled flight condition. In this way, the air (relative wind) passes perpendicularly through the control surfaces, hindering any commands on the part of the pilot (Figure 10).

Figure 10 - Illustrative image of the air flow passing vertically through the control surfaces.
Source: http://desastresaereosnews.blogspot.com/2021/12/o-que-e-um-flat-spin-e-como-recupera-lo.html

As a rule, the flat spin is an occurrence caused when the limits are exceeded with regard to minimum speeds, structural characteristics and performance of the aircraft.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

It was a takeoff for a ferry flight between SSQZ and the landing area for aeroagricultural use of *Fazenda Ipiranga*, municipality of *São Desidério*, State of *Bahia*.

Due to the extent of the damage sustained by the aircraft, one was not able to verify the position of the flaps.

There were not any records concerning abnormalities in the aircraft's systems, and examinations of the flight control system and of the engine did not reveal any discrepancies that could compromise operation.

The ANP's report indicated that the fuel sample was within the limits of the respective specifications, showing no signs of contamination.

Thus, with regard to the airworthiness conditions, no indications of failure or malfunction of aircraft systems and/or components were observed that could have affected the performance or control of the aircraft in flight. That said, no evidence of contributing factors related to the PS-RAF systems was found.

The takeoff from SSQZ was carried out with the aircraft within the weight and balance limits specified by the manufacturer. The hopper of the aircraft was empty.

According to reports from witnesses on the ground, after the rotation, the plane interrupted its initial climb and maintained a low flight over the entire length of the runway. Upon crossing the departure end, the aircraft began a sharp climb (with a high pitch-up angle), with wings level, until reaching an estimated height between 300 and 500 ft, when it began a wing turn to the right, stabilizing in an upside down flight attitude.

Subsequently, the plane lost height, maintaining a slightly pitched-down attitude, a fair banking with a high sink rate until impacting the ground, in an upside-down position and without forward displacement.

The takeoff profile performed ("American" takeoff) as well as the maneuver performed subsequently were not documented in the aircraft's flight manual. Aside from that, the Section 2 (Normal Procedures) of the AT-602 flight manual informed that for a normal takeoff for a weight of up to 4,173 kg, the speed to be used for the best climb rate would be 89 kt.

In turn, the AFM's Section 1 (Limitations) warned that aerobatic maneuvers and spins were prohibited for the AT-602 aircraft.

Even taking into consideration the reports from the PIC's colleagues that he did not have a show-off posture, a possible motivation for his choice of that takeoff profile might have been the presence of observers and their curiosity in relation to the aircraft's performance.

It is likely that, during the execution of the maneuver, the critical AoA was exceeded, causing the aircraft to stall, for lack of knowledge of the aircraft's aerodynamic behavior in that flight attitude.

By the way, uncontrolled rolling movement (wing rotation) is a characteristic of an uncontrolled stall. In such condition, the aircraft may have inadvertently entered a flat spin, in the upside-down position.

A flat spin is a dangerous and potentially fatal flight condition that occurs when an aircraft enters an uncontrolled spinning motion.

Such flat rotation occurs when the center of gravity shifts too far backwards, and the aircraft's spin becomes more horizontal. In this situation, the wings are not producing enough lift. The condition in which the PS-RAF collided with the ground, in an inverted position and without horizontal displacement, denoted a possible occurrence of a flat spin.

Among the various factors observed during the flight that may have contributed to the aircraft entering a flat spin, the following ones stand out: rolling to an inverted position (upside down) and uncoordinated flight.

Likewise, the combination of an abrupt maneuver and a yaw (uncoordinated flight) may have caused the aircraft to enter an uncontrolled rotating movement with the wings leveled in an upside down position.

As that behavior of the aircraft was not expected, in addition to the fact that the PIC did not have training to counteract the situation, it is possible that the corrections were not applied appropriately and in a timely manner to get rid from the abnormal attitude.

At the same time, due to the height at which the plane was flying, recovery from a flat spin, in that case, was rendered impossible in practical terms.

As highlighted by the FAA-H-8083-3C (*Chapter 5: Maintaining Aircraft Control: Upset Prevention and Recovery Training*) for the prevention of accidents caused by loss of control in flight, it is important for pilots to recognize and maintain high situational awareness of circumstances that increase the risk of such condition.

Furthermore, according to the publication, pilot’s complacency, poor risk management, and intentional disregard for safety are inherent elements of the loss of control in flight.

3. CONCLUSIONS.

3.1. Findings.

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

b) the pilot held valid MNTE (Single-Engine Land Airplane) and PAGA (Agricultural Pilot - Airplane) ratings;

c) the pilot had qualification and experience for the type of flight;

d) the meteorological conditions were consistent with the conduction of the flight;

e) the aircraft had a valid CVA (Airworthiness Verification Certificate);

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

g) the airframe, engine, and propeller logbooks were up to date;

h) there was no evidence of any condition of failure or malfunction of aircraft systems and/or components that could have affected the performance or control in flight;

i) there were no alterations of either medical or psychological order in the period prior to the accident that could have affected the pilot's performance in flight;

j) the pilot performed an “American” takeoff in disagreement with the recommendations of aircraft’s flight manual;

k) after crossing the threshold, the aircraft began a climb with a high pitch-up angle, wings level, until reaching an estimated height between 300 and 500 ft. Afterwards, the wings were rotated to the right until an upside-down flight attitude, followed by loss of control in flight;

l) the aircraft impacted the ground at a high sink rate, fair wing banking to the left, slightly pitched-down inverted attitude without forward displacement, aligned with the azimuth 110º;

m) the aircraft suffered substantial damage; and

n) the pilot suffered fatal injuries.

3.2. Contributing factors.

Attitude – a contributor.

The behavior observed in relation to the type of takeoff, in addition to the maneuver performed, denoted an inappropriate posture, characterized by improvisation, showiness, non-compliance with procedures, and overconfidence.

Handling of aircraft flight controls – a contributor.

A low takeoff was performed in the direction of the departure end of the runway. Upon crossing the runway's longitudinal limit, the aircraft began a climb at a high pitch-up angle, wings level, until reaching an estimated height between 300 and 500 ft. Then, an abrupt maneuver was performed until the aircraft reached an upside-down flight attitude. In that condition, control of the aircraft was lost, and the airplane lost height until colliding with the ground.

Piloting judgment – a contributor.

The recommended parameters for a normal takeoff were not observed, as well as the operating limits established by the manufacturer (abrupt maneuvers).

Motivation – undetermined.

Despite reports from fellow workers that the PIC did not have a show-off profile, it is possible that the presence of observers interested in the aircraft's performance influenced his behavior, leading him to adopt, during the takeoff, an inappropriate posture characterized by improvisation, non-compliance with procedures, and excessive self-confidence.

Perception – undetermined.

It is possible that the pilot was not able to adequately recognize the characteristics of the stall, thus resulting in late and/or insufficient actions to recover from the abnormal attitude.

Decision-making process – undetermined.

The inappropriate decision to perform a takeoff not recommended by the manufacturer, as well as the rotation of the wings at low height, may have resulted from an inaccurate analysis of the risks involved in that type of maneuver.

4. SAFETY RECOMMENDATIONS

None.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

None.

On December 29th, 2023.