COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A - 053/CENIPA/2017

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PR-TTH**
MODEL:	**ATR-42-500**
DATE:	**21MAR2017**

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 21MAR2017 accident with the ATR-42-500 aircraft model, registration PR-TTH. The accident was classified as "[LOC-G] Loss of Control - Ground and [RE] Runway Excursion".

During the landing, after the touchdown, the aircraft presented asymmetry in the reverse system, causing its exit from the left side of the runway.

The aircraft had substantial damage.

All occupants left unharmed.

An Accredited Representative of the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) – France (State where the aircraft was designed/manufactured) and an Accredited Representative of the Transportation Safety Board (TSB) - Canada, (State where the engines were designed/manufactured) were designated for participation in the investigation.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AFA	Air Force Academy
AFM	Aircraft Flight Manual
AGL	Above Ground Level
ALT	Altitude
AMM	Aircraft Maintenance Manual
ANAC	Brazil's National Civil Aviation Agency
AP	Auto Pilot
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CA	Airworthiness Certificate
CENIPA	Aeronautical Accident Investigation and Prevention Center
CMA	Aeronautical Medical Certificate
CVR	Cockpit Voice Recorder
CRZ	Cruise
DECEA	Air Space Control Department
DH	Decision Height
EEC	Electronic Engine Controls
EHV	Electro-Hydraulic Servo Valve
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
FI	Flight Idle
FTR	Feather
GI	Ground Idle
HDG-SEL	Heading Select
HMU	Hydromechanical Unit
IFR	Instrument Flight Rules
IFRA	Instrument Flight Rating - Airplane
IMC	Instrument Meteorological Conditions
LABDATA	Flight Data Recorders Read-Out and Analysis Laboratory
MAX PWR	Maximum Power
MDA	Minimum Descent Altitude
METAR	Meteorological Aerodrome Report
NDB	Non-Directional Beacon
NVM	Non-Volatile Memory
OVRD	Override
PAPI	Precision Approach Path Indicator
PEC	Propeller Electronic Control
PF	Pilot Flying

PIC	Pilot in Command
PLA	Airline Pilot License - Airplane
PLANG	Power Lever Angle
PM	Pilot monitoring
PN	Part Number
PPR	Private Pilot License - Airplane
PSO-BR	Operational Safety Plan for the Brazilian Civil Aviation
PVM	Propeller Valve Module
PWR MGT	Power Management
QAR	Quick Access Recorder
QRH	Quick Reference Handbook
RBAC	Brazilian Civil Aviation Regulation
REV	Reverse
RPM	Rotations Per Minute
RVDT	Rotary Variable Differential Transducer
SBEG	ICAO Location Designator – Eduardo Gomes International Aerodrome - Manaus - AM
SBUY	ICAO Location Designator - Urucu Aerodrome, Coari - AM
SIC	Second in Command
SIPAER	Aeronautical Accident Investigation and Prevention System
SLPS	Secondary Low Pitch Stop
SN	Serial Number
Fuel SO	Fuel Shut Off
TO	Take-Off
TPR	Aircraft Registration Category of Regular Public Transport
TSB	Transportation Safety Board
TWR	Aerodrome control tower or aerodrome control
UTC	Universal Time Coordinated
VDC	Voltage Direct Current
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VS	Vertical Speed
WOW	Weight On Wheels

1. FACTUAL INFORMATION.

Aircraft	**Model:** ATR-42-500 **Registration:** PR-TTH **Manufacturer:** GIE Avions de Transport Régional I	**Operator:** Total Airlines S/A
Occurrence	**Date/time:** 21MAR2017 - 0125 UTC **Location:** Urucu Aerodrome (SBUY) **Lat.** 04°52’59”S **Long.** 065°21’21”W **Municipality – State:** Coari – AM	**Type(s):** “[LOC-G] Loss of Control - Ground and [RE] Runway Excursion” **Subtype(s):** Nil

1.1 History of the flight.

The aircraft took off from the Eduardo Gomes International Aerodrome (SBEG), Manaus - AM, to the Urucu Aerodrome (SBUY), Coari - AM, at about 2355 (UTC) on 20MAR2017, in order to carry out a transfer flight, with two pilots and two flight attendants.

With approximately one hour and ten minutes of flight time, during the descent procedure, the aircraft presented an increase in the rotation of the propeller of powerplant 2 (right side). The crewmembers performed the procedures set out in the aircraft manuals and proceeded to their destination.

During the landing on threshold 09 of SBUY, the aircraft presented asymmetrical power, in the reverse system, and left the runway by its left side, at approximately 500 m after the touchdown point, traveling about 180 m through the grass.

Figure 1 – Aircraft after the occurrence.

The aircraft had substantial damage and all occupants left unharmed.

1.2 Injuries to persons.

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

1.3 Damage to the aircraft.

The aircraft had substantial damage. The most significantly affected parts were: the propeller and powerplant on the right side; the nose and main landing gears and the fuselage, mainly in the lower part of the forward sections.

1.4 Other damage.

None.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Flight Hours		
	PIC	SIC
Total	6.780:00	28.343:00
Total in the last 30 days	27:00	41:10
Total in the last 24 hours	00:00	00:00
In this type of aircraft	2.126:00	2.941:00
In this type in the last 30 days	27:00	41:10
In this type in the last 24 hours	00:00	00:00

N.B.: the data relating to the flown hours were provided by the operator.

1.5.2 Personnel training.

The PIC completed his training at the Air Force Academy (AFA), in 1974.

The SIC took the PPR course at the Ceará Aeroclub - CE, in 1965.

1.5.3 Category of licenses and validity of certificates.

The pilots had the PLA Licenses and had valid A47 aircraft Type Rating (which included the ATR-42-500 model) and the IFRA Rating.

1.5.4 Qualification and flight experience.

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

1.5.5 Validity of medical certificate.

The pilots had valid CMAs.

1.6 Aircraft information.

The aircraft, serial number 506, was manufactured by GIE Avions de Transport Régional in 1996, and was registered in the TPR Category.

The aircraft had valid CA.

Technical maintenance records were updated.

The aircraft had a total of 31,686 flight hours and 33,979 cycles.

The last inspection of the aircraft, of the "Check 1C" type, was carried out on 20JAN2004 by Total Airlines, in Manaus - AM, having flown 1,761 hours after the inspection.

The engines were manufactured by Pratt & Whitney Company. The data for each engine installed on the aircraft is shown in Figure 2, below:

Motor	Esquerdo (#1)	Direito (#2)
Modelo	PW-127F	PW-127E
Serial Number	EB0041	127204
Ciclos Totais	25.440	31.161
Horas Totais	28.700	29.331
Ciclos após inspeção	402	402
Horas após revisão geral	10.530,2	4.091,6

Figure 2 - Data of the engines installed in the PR-TTH.

The installed propellers were manufactured by Hamilton Standard Propellers, had 6 blades each, 3.93 m diameter, clockwise rotation of 1,200 RPM (corresponding to 100% Np) and pitch angle variation of 78.5° (corresponding to the feathered pitch) to -19° (corresponding to the reverse pitch angle).

The propeller data can be found in Figure 3, below:

Hélice	Esquerda (#1)	Direita (#2)
Modelo	568F-1	568F-1
Serial Number	FR20001053	FR960255
Ciclos Totais	33.574	33.514
Horas Totais	31.253,5	31.190,3
Horas após inspeção	3.120,7	496,1

Figure 3 - Data of the propellers installed in the PR-TTH.

Propeller System

The propellers were of the variable pitch type, hydromechanically controlled, ranging from flag pitch to reverse. A phase synchronization system considerably reduced the noise level in the cabin.

The control of the pitch of the propellers was carried out by the Condition Lever, the power lever and the power manager selector (PWR MGT).

The control of the propeller system could be operated in two ways:

- The predominant mode for flight operations was the Alfa or Speed Governor mode. An EHV was the main device of the PVM that modulates the hydraulic pressure to maintain a constant pre-selected propeller rotation.

The electrical signal to the EHV was provided by the PEC, and the feedback for control was provided to the PEC by the RVDT blade angle assembly contained in the PVM.

- The second mode of operation was the Beta mode. In this mode, variable rotation control for ground and reverse pitch angles was possible. The blade angle was a function of the throttle position.

If a failure caused an undesired decrease of the blade pitch in flight and resulted in an increase in the propeller speed, a mechanical overspeed governor would be selected by a PVM valve, in order to limit the propeller speed to 102.5% of Np.

In the event of a hydraulic system failure, counterweights on the propeller blades would counteract the blade loads and either fix a pitch or drive the blades into a failsafe condition.

Both propeller operating modes are presented in detail in the PEC description below. The general location of the propeller and chain of command system components are shown in Figure 4.

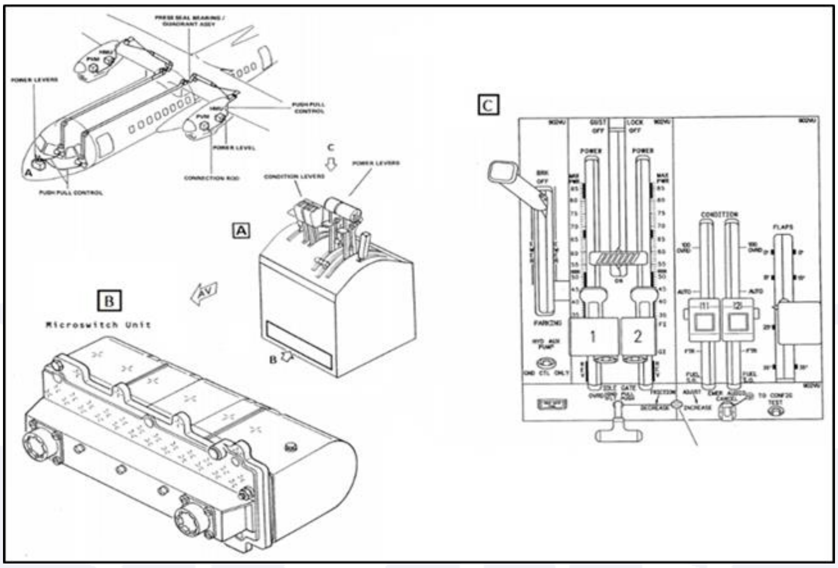

Figure 4 - Location of part of the central pedestal components.
Source: Adapted from the Aircraft Maintenance Manual (AMM).

The Condition Levers were located on the central pedestal and their functions are shown in Figure 5.

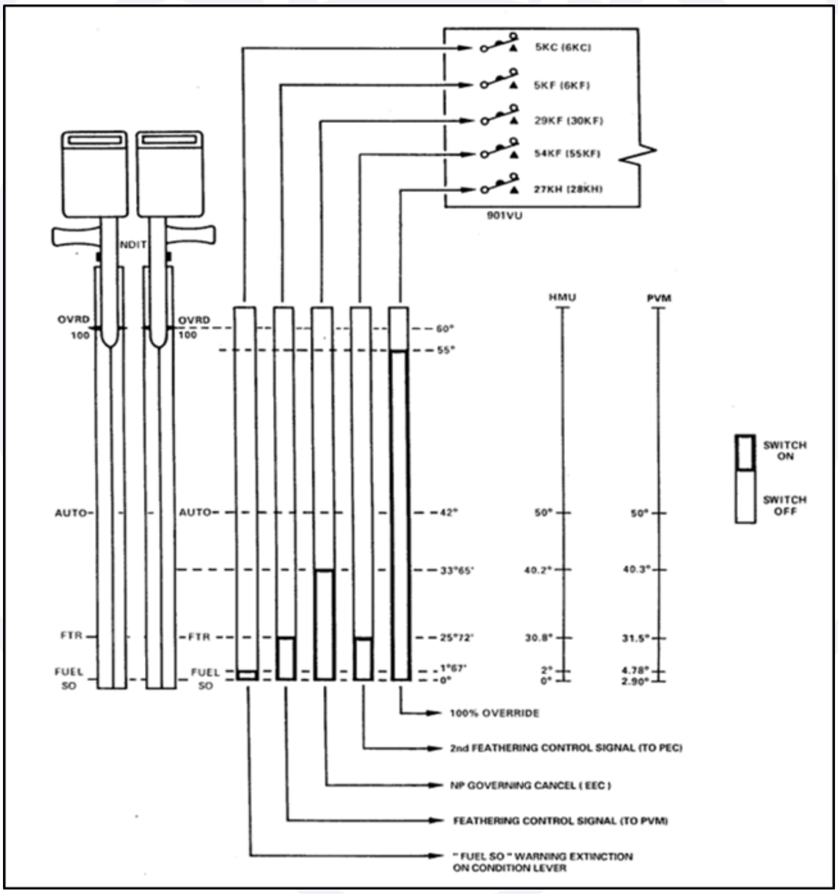

Figure 5 - Condition Lever Positions. Source: Adapted from the AMM.

The following is a brief description of the functions represented in Figure 5:

- 100% Override - Propeller rotation was forced to 100% Np regardless of PWR MGT selector position. The 100% Override position was associated with the open (off) position of the Microswitches 27KH on the right side and 28KH on the left side;

- Auto – The propeller rotation was automatically controlled and maintained between 77% and 100% Np, according to operating conditions. The Auto position was associated with the closed (on) position of the Microswitches 27KH on the right side and 28KH on the left side;

- Np Governing Cancel - Function related to the feathering of the propellers, associated with the closed position (on) of the Microswitches 29KF on the right side and 30KF on the left side;

- FTR (Feather) - Feathering position of the propellers, associated with the closed position (on) of the Microswitches 5KF on the right side and 6KF on the left side; and

- Fuel SO (Fuel Shut Off) - Engine shutdown position, associated with the closed (on) position of the Microswitches 5KC on the right side and 6KC on the left side.

The Power Levers were located on the central pedestal and controlled, through the HMU, the fuel flow from the MAX PWR position to the REV position. They also performed the functions related to propeller control in ground operations (beta scheduling and reverse) and could be placed in the following reference positions: MAX PWR; TO; FI; GI; and REV.

The 3KX Microswitches on the right and 4KX on the left were related to Low Pitch protection. Above the Flight Idle position, the Microswitches remained in the open (off) position, activating the Low Pitch protection. Below the Flight Idle position, the Microswitches remained in the closed (on) position, disabling the Low Pitch protection.

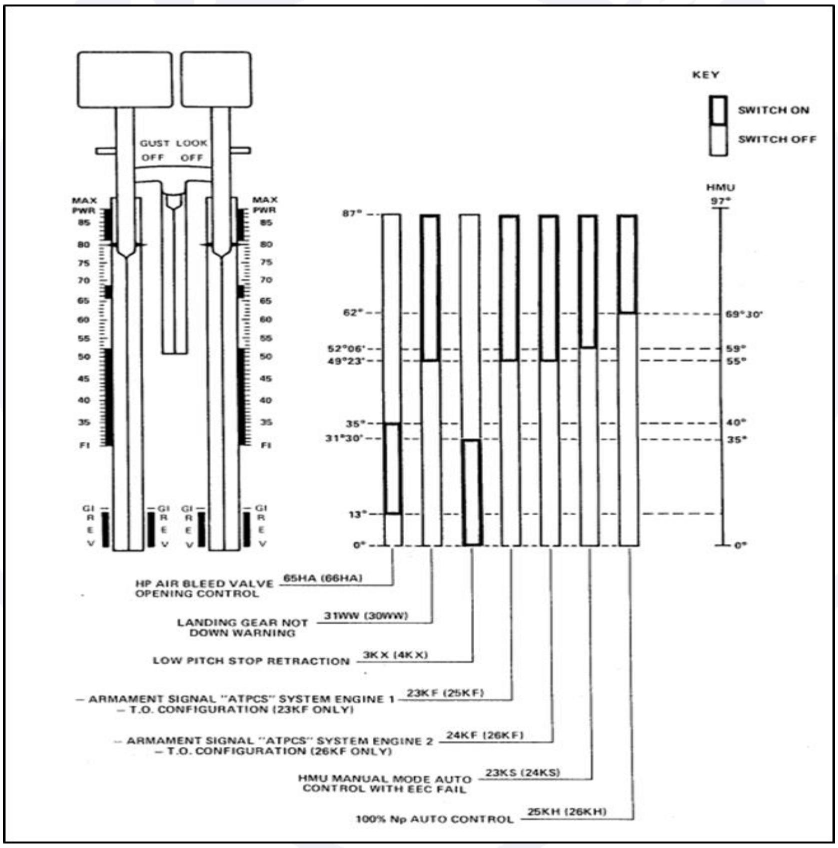

Figure 6 - Positions of the Power Levers. Source: Adapted from the AMM.

In flight, the Power Levers of the two engines were physically prevented from being pulled back to positions below Flight Idle by the device called the Idle Gate.

On the ground, the Idle Gate received signals from the aircraft's sensors on the ground, Weight on Wheels (WOW), and allowed the thrust levers to be pulled back to positions below Flight Idle (Ground Idle and Reverse).

In case of failure, the Idle Gate could be manually overridden. In this situation, the following fault messages were displayed to the crew: CAUTION light (on the instrument panel), IDLE GATE CAUTION light (on the multiple alarm panel), IDLE GATE FAIL annunciator (on the central pedestal), in addition to a signal single alert sound.

Figure 7 illustrates the operation of the Idle Gate device.

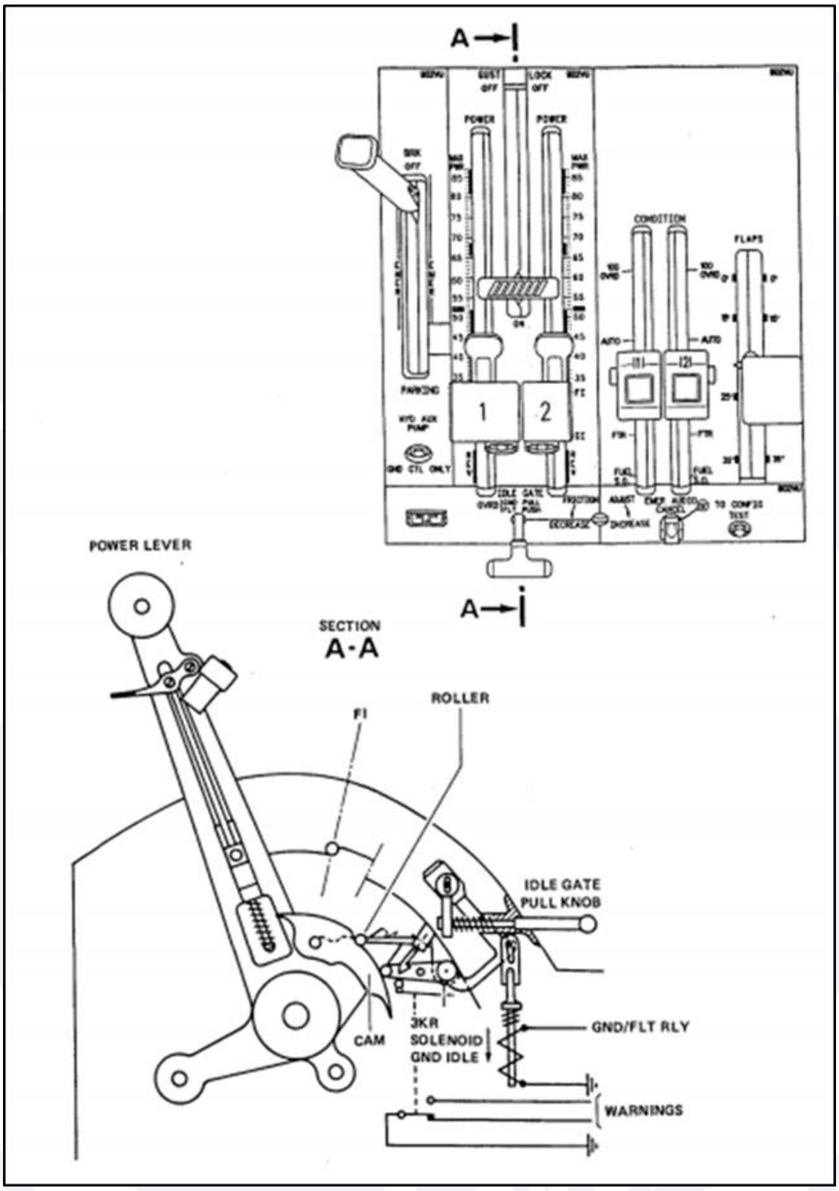

Figure 7 - Location of the Idle Gate. Source: AMM.

When the levers were retracted below the Ground Idle position, in the reverse position, springs acted to return the Power Levers to the Ground Idle position if no external force was applied to the levers.

The Microswitch Box was a unit that transmitted the positions of the Power Levers and the Condition Lever in electrical signals to a number of aircraft systems.

The Microswitch Box consisted of a series of levers and bellcranks that, according to the position of the levers, closed the contact of the Microswitches installed inside this unit.

Signals were sent to various aircraft systems through two connectors. Figures 8 and 9 below, show the position of the Microswitch Box and the details of the technical drawing of this component.

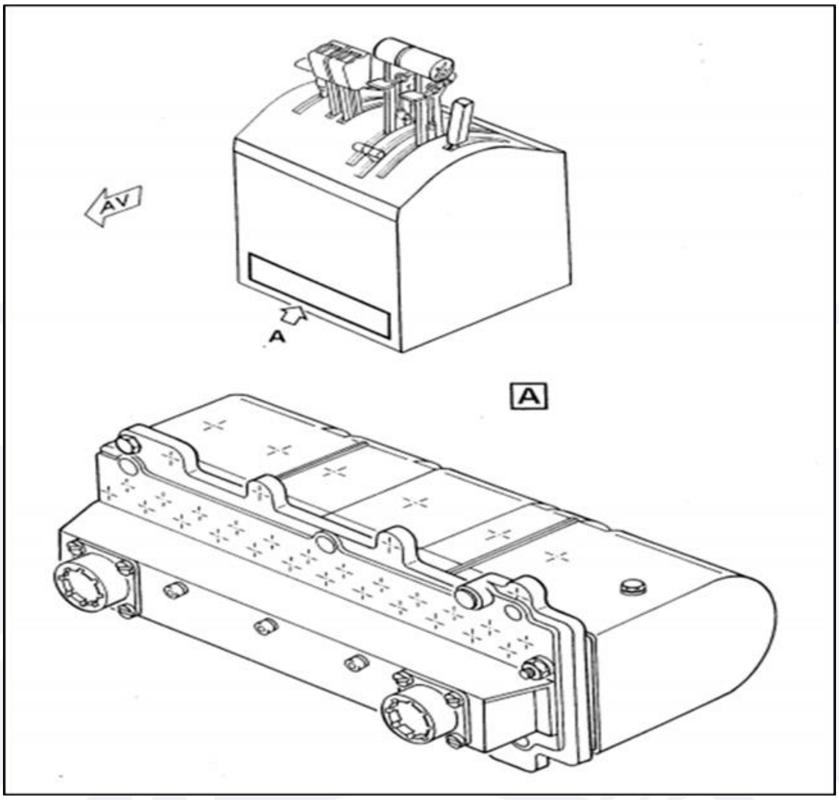

Figure 8 - Position of the Microswitch Box on the central pedestal. Source: AMM.

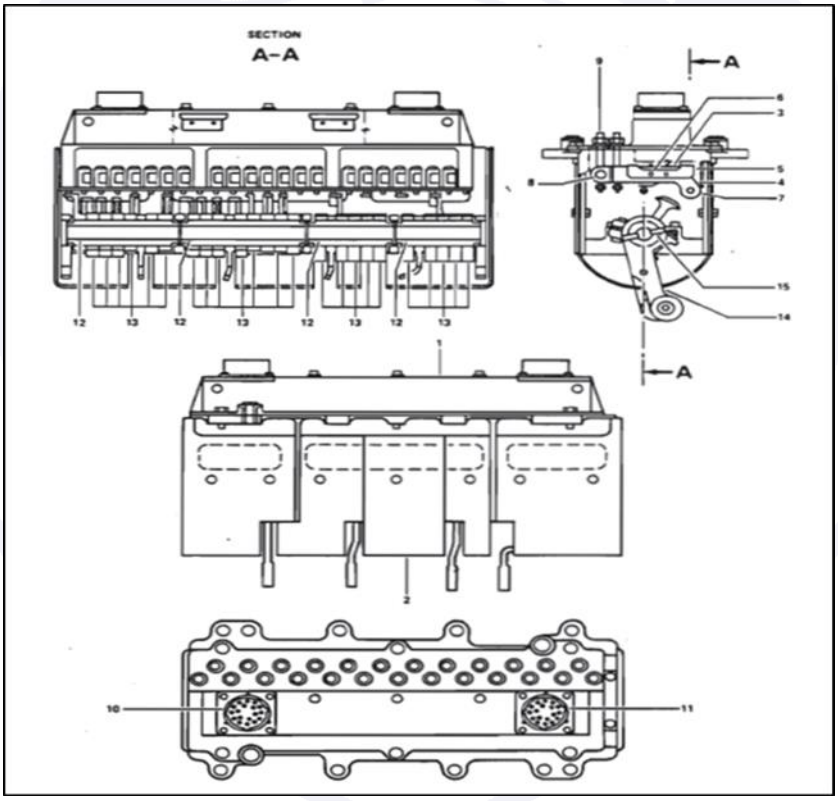

Figure 9 - Microswitch Box. Source: AMM.

The PVM were mechanical hydraulic units, installed one in each engine nacelle, which received signals from the PEC, other aircraft sensors and the overspeed governor, providing hydraulic pressure to the propeller actuator and thus varying its pitch.

The main elements of the PVM were: Propeller connection assembly, Protection Valve, Feather Solenoid, Secondary Low Pitch Stop (SLPS) and Control Levers (Input Levers).

Figures 10 and 11 show the PVM and its operation in a schematic way.

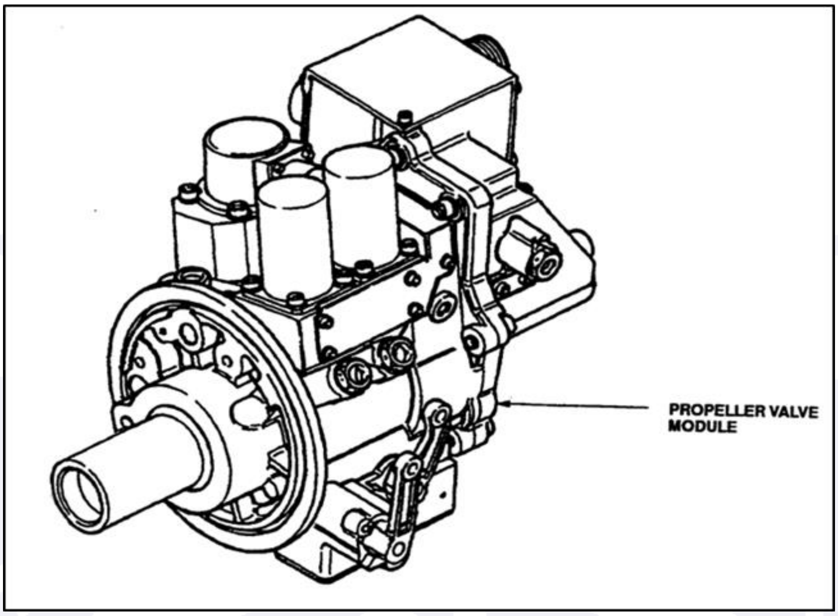

Figure 10 - Propeller Valve Module (PVM). Source: AMM.

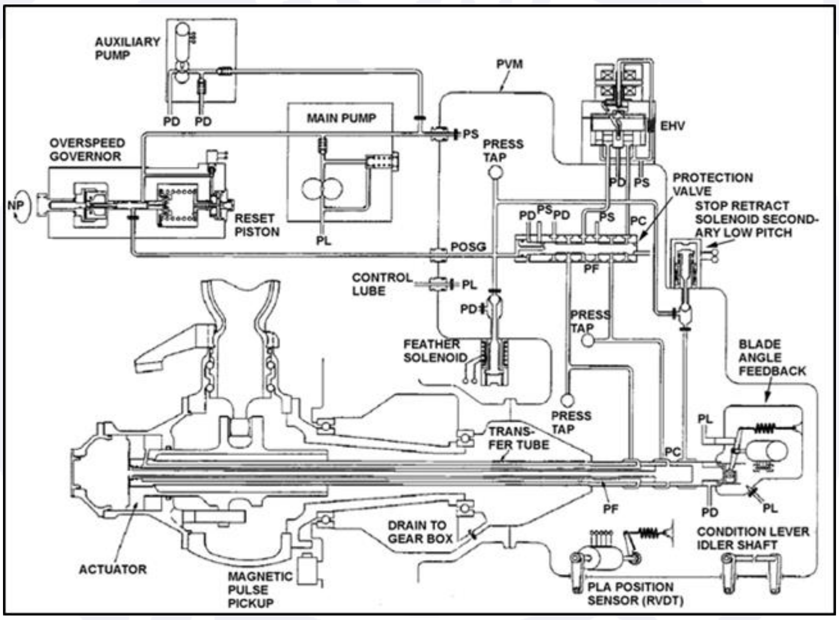

Figure 11 - Schematic drawing of the PVM. Source: AMM.

The PEC was an engine nacelle-mounted, dual-channel, microprocessor-based electronic unit. The PEC was responsible for controlling the rotation of the propellers, synchronism, beta and reverse angle, feathering and unfeathering.

Among the functions of the PEC, the following are highlighted below, the propeller rotation control and the beta and reverse angle operation.

Regarding the propeller rotation control, the PEC compared measured RPM to predicted RPM, making corrections for RPM difference errors, RPM error rate of change, Power Lever angle changes, and engine operating condition aircraft (speed and altitude).

The EEC interfaced with the PEC, making the aircraft's engine and operating data available to the PEC to perform the gain calculations for the control.

The PEC provided the command current for the PVM's EHV to change the propeller pitch through the oil pressure that moved the transfer tube, as shown in Figure 11.

In cases where the Power Lever was moved to a position below Flight Idle and the pitch angle of the propellers did not follow this command, the PEC recognized a fault situation called Reversing Fault that was recorded in its NVM.

When the Reversing Fault occurred, a signal called Np Cancel was sent to the EEC, limiting the rotation of the propellers and minimizing the effects of an asymmetric reverse situation.

Low Pitch Protection

The logic of protection for low pitch angle was given according to the schematic drawing shown in Figure 12.

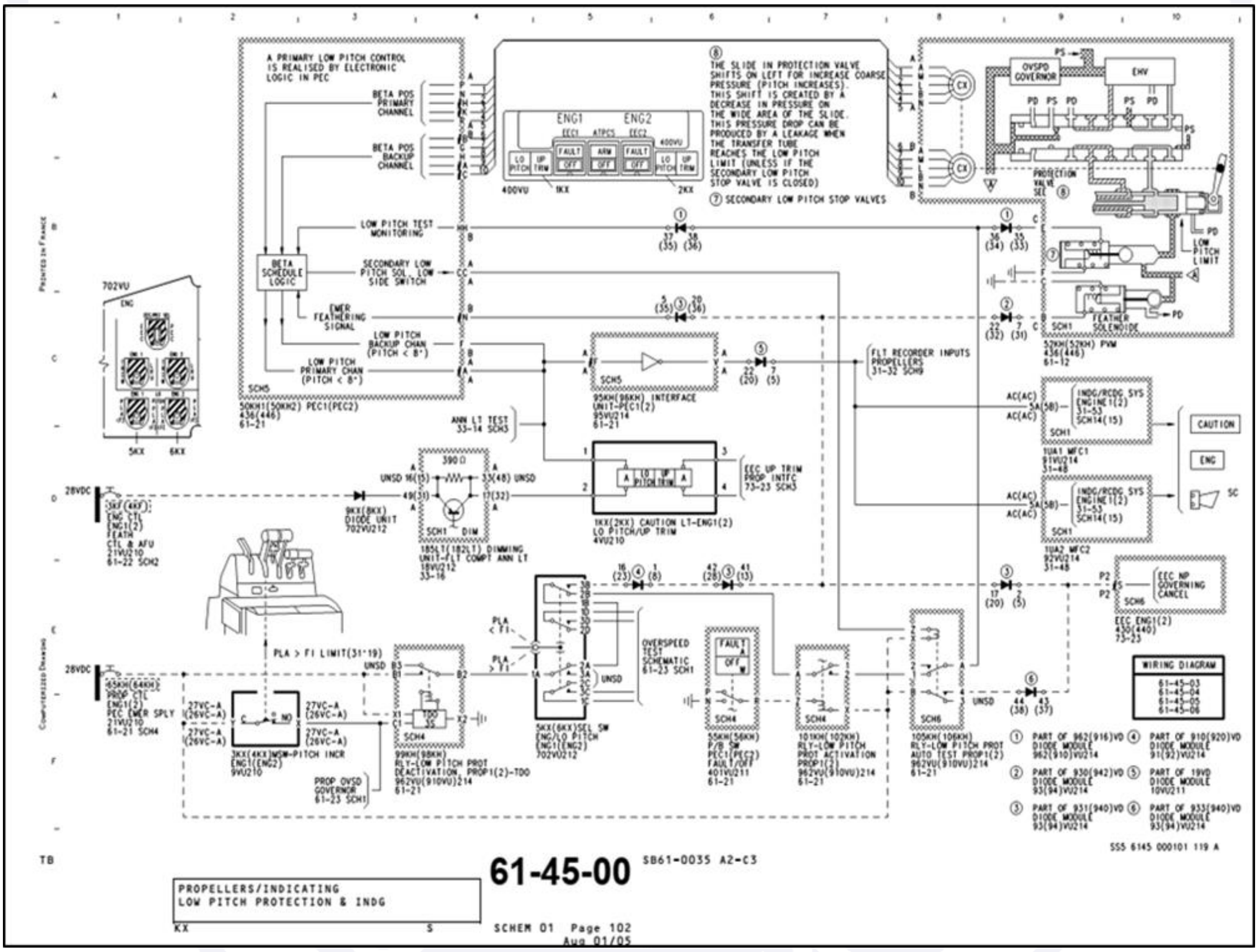

Figure 12 - Schematic drawing of the Low Pitch protection. Source: AMM.

When the Power Levers were above Flight Idle, the SLPS was de-energized (condition shown in Figure 12). In this condition (flight configuration), the transfer tube could be moved to a certain point called Low Pitch Limit. From that point, the SLPS (de-energized) allowed the hydraulic fluid to be diverted. In this way, the propellers were protected from assuming a Low Pitch condition.

When the throttles were below the Flight Idle (ground setting), the SLPS was energized, and the Low Pitch protection was disabled. The Low Pitch Protection Schematic has been adapted to show the path of the electrical current in this case (Figure 13).

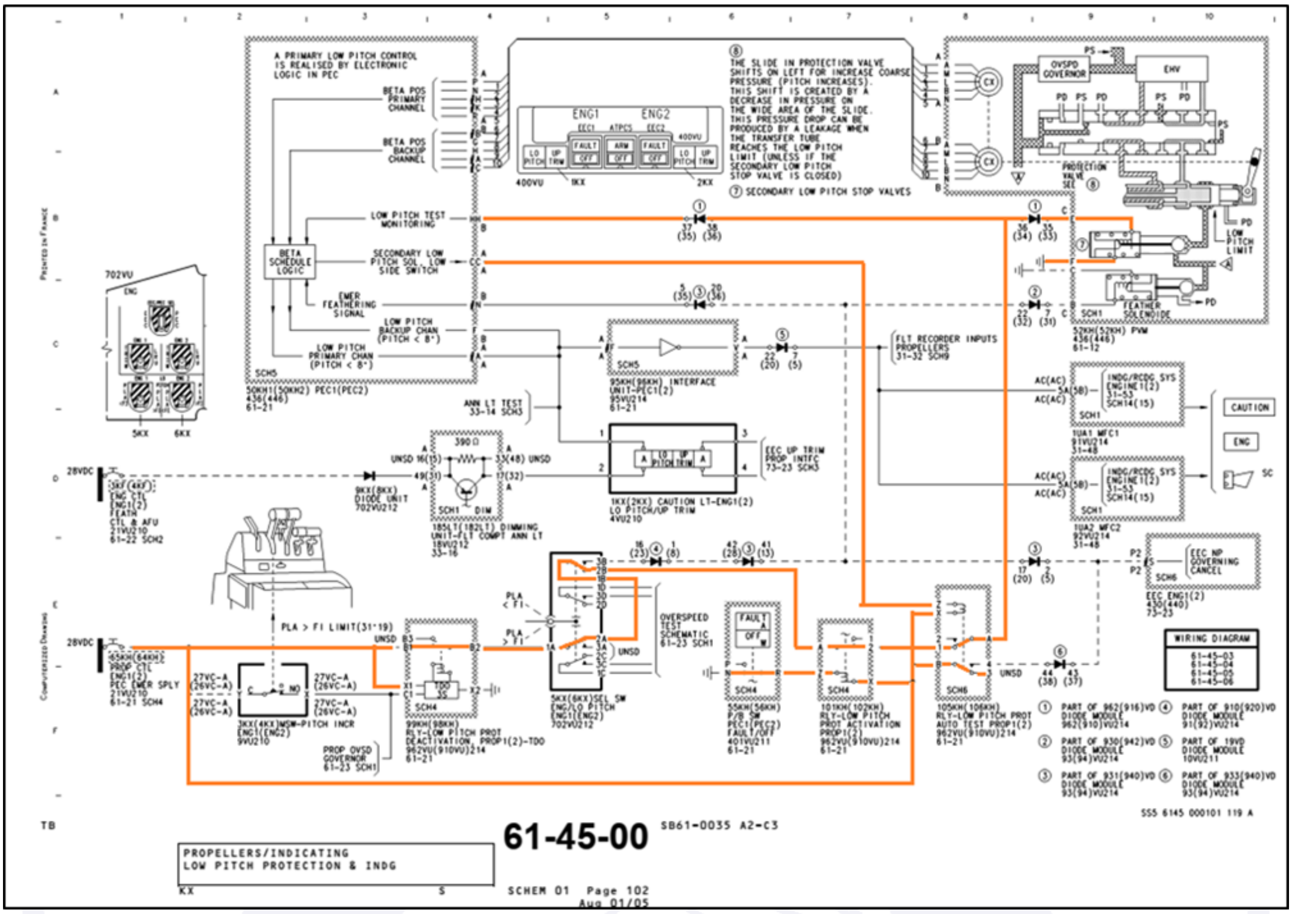

Figure 13 - Schematic drawing adapted to show the Low Pitch protection deactivation.
Source: AMM.

As for the right side of the aircraft, to energize the SLPS, the thrust lever should be reduced to a position below Flight Idle. This position was felt by the Microswitch 4KX (located inside the Microswitch Box) which closed the electrical contact providing 28V voltage at pin X of the 26VC connector.

The 26VC connector pin X was connected to the 98KH relay input C1, which closed the circuit with the X2 output connected to the aircraft grounding. The 98KH relay solenoid closed the contact between input B1 and output B2. The 98KH relay had a 3-second de-energization timer, that is, when the relay was energized and the power lever moved to a position above Flight Idle, there was a 3-second delay for changing the relay position.

The 6KX relay was used only for ground maintenance procedures and the position of its contacts was manually modified via a switch. This switch was protected by a security guard that prevented its movement during the flight.

The 56KH relay contacts were modified by the PEC fault push-button. When the PEC was OFF, the P pin was connected to the R pin of the 56KH relay and not connected to the aircraft grounding. When the PEC was working, the R pin connected to the N pin of the 56KH relay and provided the ground signal to the circuit.

When the PEC was working properly, the 102KH relay was energized closing the contact between pins A and 2 of the same relay, allowing current to flow between these two pins.

The 106KH relay corresponded to a self-test performed by the system when the engine was in the unfeathering sequence (normally associated with the start of the engines) commanded by the PEC. Under normal flight conditions, pin 1 was connected to pin A of the 106KH relay allowing current to flow.

Finally, the 28V voltage arrived at pin E of the PVM connector C providing electrical power for the SLPS to disable the Low Pitch protection.

The Low pitch indication was presented to the crew on the panel shown in Figure 14, below, adapted from FCOM.

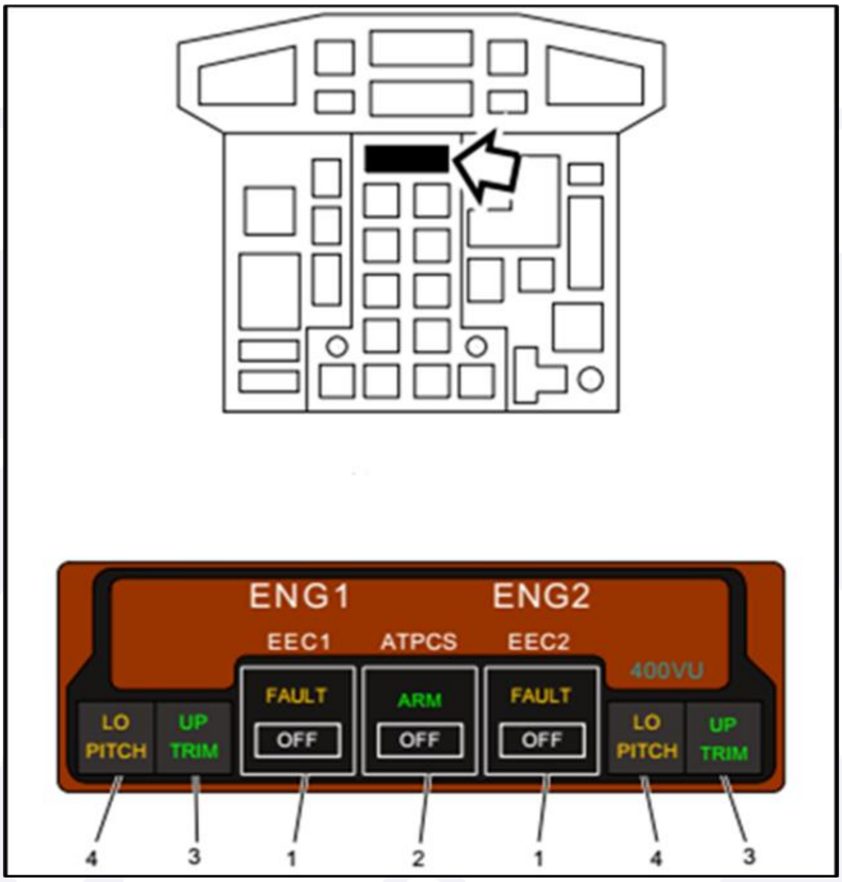

Figure 14 - Position of the Low Pitch indicator lights on the aircraft's front panel. Adapted from Total's FCOM.

In the condition of landing with both engines operating normally, if the two Low Pitch lights were verified on, the throttles could be moved back to the reverse position. If only one Low Pitch light, on either side, was verified to be lit, the reverses could not be used on landing, and the aircraft would have to be decelerated using only the brake system.

<u>Flight Commands - Elevator</u>

The elevator control columns operated the respective side of this control surface by means of rods, levers, bellcranks, cables and tension regulators. The elevator controls on both sides were linked by a mechanism called Pitch Uncoupling Mechanism, located on the horizontal stabilizer.

The Pitch Uncoupling Mechanism was installed between the two sides of the last elevator bellcranks. A linking device connected the left bellcrank to the right bellcrank by means of a torsion spring that held them together.

If the external forces applied to the elevator or control column generated a counter torque in the mechanism, the coupling of the two shafts would disconnect.

Figure 15 shows the Pitch Uncoupling Mechanism.

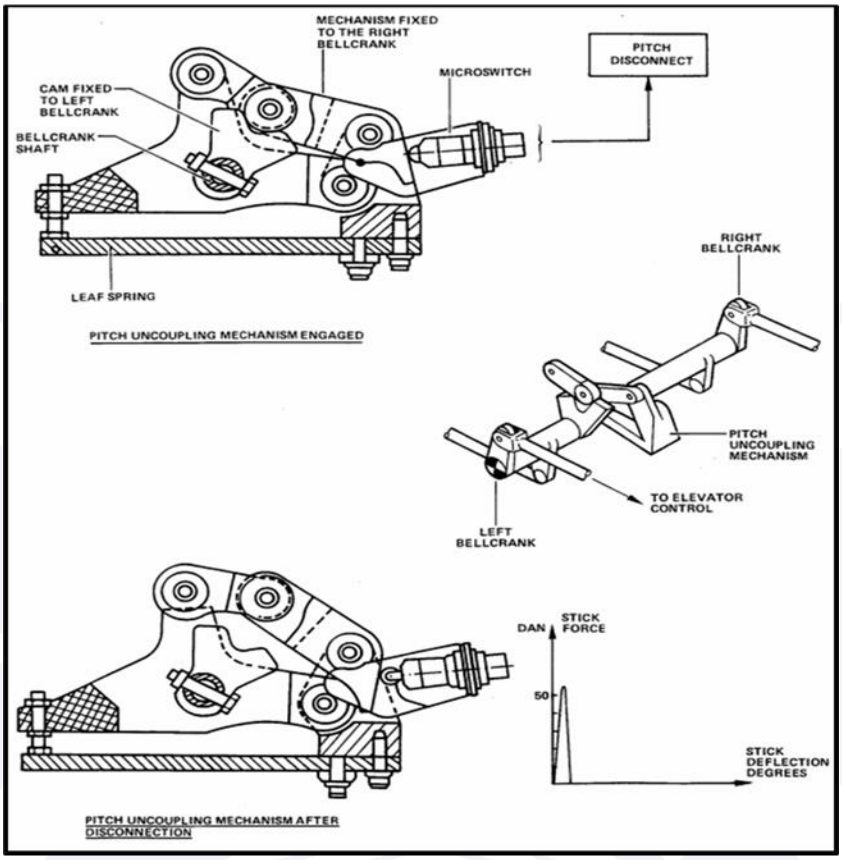

Figure 15 - Pitch Uncoupling Mechanism. Source: AMM.

If the coupling of the two axes were disconnected, a microswitch would be activated and the following information would be displayed to the crew:

- MASTER WARNING light illumination;
- illumination of the PITCH DISCONNECT light on the crew alert panel; and
- repetitive signal activation.

Through the CVR audio and the FDR parameter, it was verified that, at the moment the landing gear legs touched the runway, the repetitive audible warning associated with MASTER WARNING was activated.

These indications could be associated with the elevator's Pitch Uncoupling Mechanism function, since, during the field investigation, it was found that the only warning that remained lit on the alarm panel after the occurrence, and which could trigger MASTER WARNING, would be that light.

The intermittent character of the MASTER WARNING observed in the FDR (Figure 17) could be associated with an incorrect adjustment of the Microswitch located in the elevator (Figure 15).

1.7 Meteorological information.

The METAR of the Urucu Aerodrome (SBUY) brought the following information:

METAR SBUY 210149Z 00000KT 3000 -RA FEW010 BKN100 23/23 Q1012

The Aerodrome operated under IMC.

According to reports from the crewmembers and Aerodrome employees, at the time of the occurrence, there was light rain at the site. There were no reports of strong winds in SBUY at the time of landing.

1.8 Aids to navigation.

The procedure performed by the crew was the Non-Directional Beacon (NDB) for instrument approach to SBUY, shown in Figure 16.

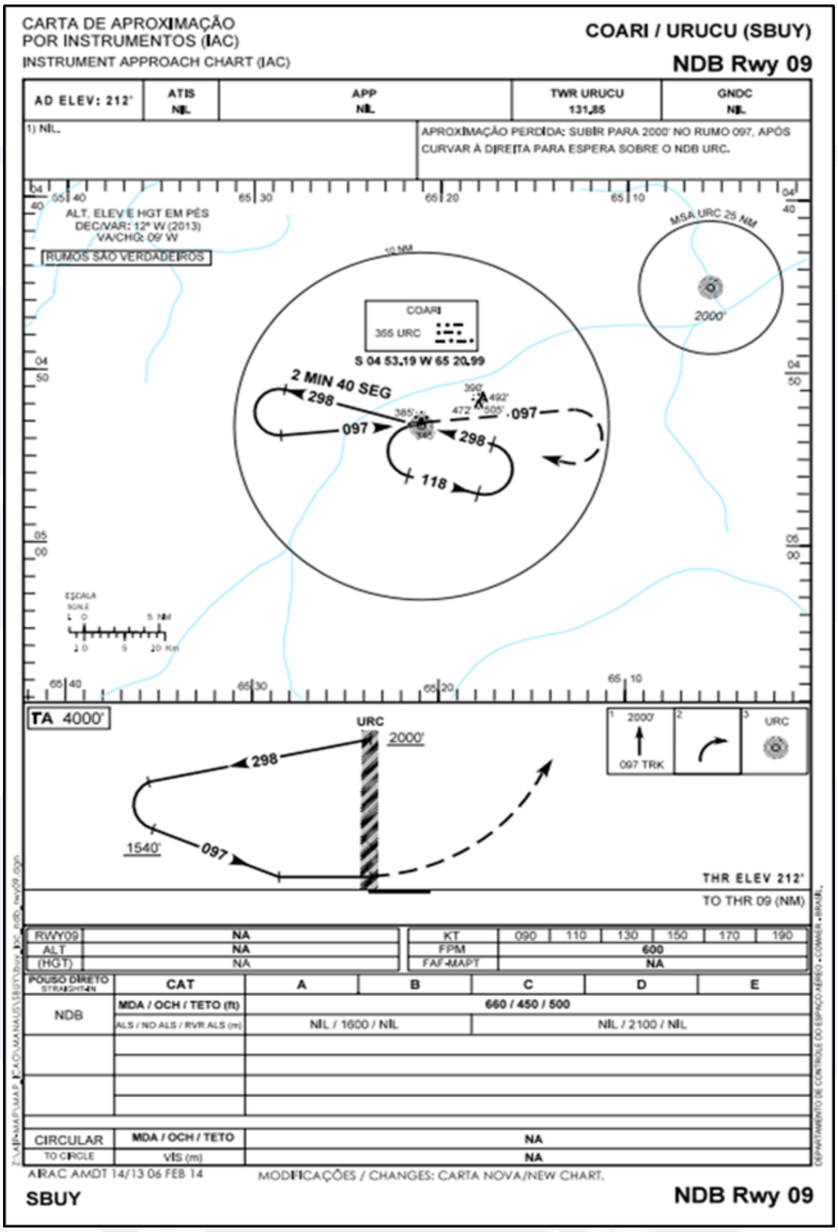

Figure 16 - NDB procedure for SBUY Aerodrome.

1.9 Communications.

The Urucu Aerodrome (SBUY) had a tower (TWR) for bilateral communications. All communications were carried out uneventfully.

1.10 Aerodrome information.

The Aerodrome was private, managed by PETROBRAS and operated under Visual Flight Rules (VFR) and Instrument Flight Rules (IFR), day and night.

The runway was made of asphalt, with thresholds 09/27, dimensions of 1,320 x 30 m, with an elevation of 210 ft.

1.11 Flight recorders.

The aircraft was equipped with a Flight Data Recorder (FDR) Fairchild model F1000, Part Number (PN) S800-2000-00, Serial Number (SN) 210 and a Cockpit Voice Recorder (CVR) L3 Aviation Recorders FA2100, PN 2100-1020-02, SN 337253.

The data contained in the FDR and CVR were extracted at the CENIPA`s LABDATA.

According to the audios extracted from the CVR, before the landing gear touched the runway, altitude callouts of 30, 20 and 15 ft were performed.

At the time of touching the runway, it was not possible to distinguish the Idle Gate and Low Pitch callouts related to the lighting of the respective lights, by the Pilot Monitoring. Simultaneously with the touch, it was possible to hear the MASTER WARNING audible alarm.

Figure 17 presents the general data extracted from the data recorder. The blue line illustrates the section in which the aircraft was in flight; the gray line shows the section in which the aircraft was on the taxiway; and the green line illustrates the section in which the aircraft left the side of the runway.

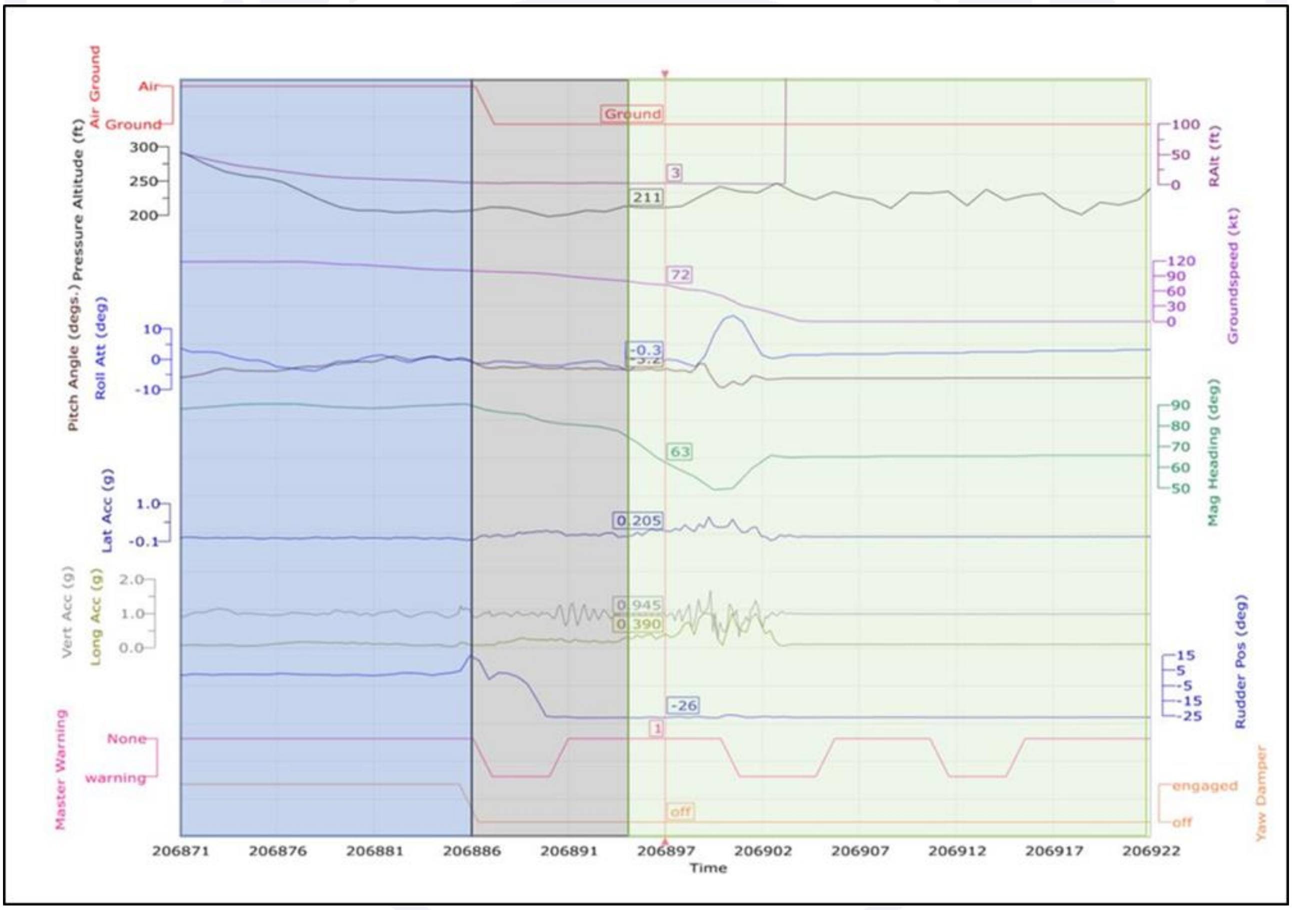

Figure 17 - General event data extracted from the FDR.

Engine parameters are shown in Figure 18, using the same color pattern as in Figure 17.

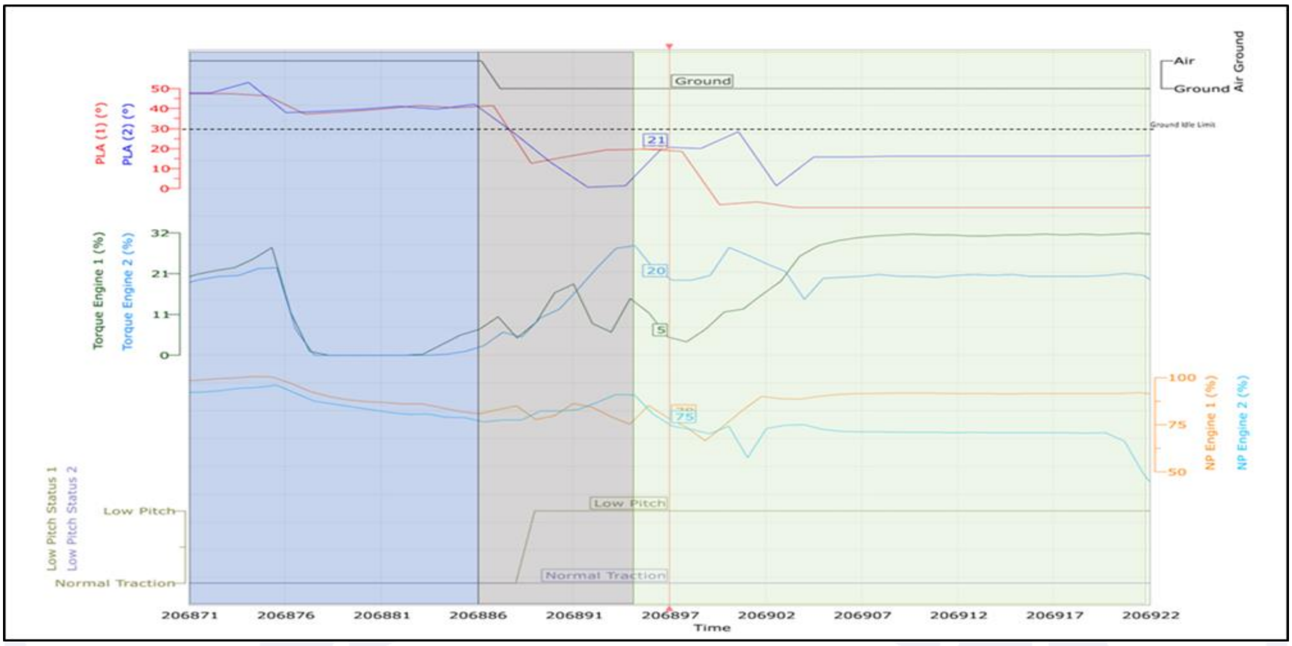

Figure 18 - Engine parameter data extracted from the FDR.

The power lever parameters recorded in the FDR were obtained through the RVDT. The throttle angle corresponding to each engine power rating range is shown below:

- Reverse: from 0° to 18°;
- Ground Idle: from 18° to 31°;
- Flight Idle: from 31° to 67°;
- Take-off position: 67° to 85°; and
- Max PWR: above 85°.

The position of the two Power Levers is shown in detail in Figure 19. The blue line at the top indicates that propeller nº1 has entered reverse pitch, following the movement of the corresponding lever. The yellow line (upper) indicates that the nº2 propeller remained in flight pitch during the entire trajectory of the aircraft on the ground and did not follow the movement of the respective lever.

The blue and orange lines (marked with dots) inside the graph represent the positions of the thrust lever angles nº1 and nº2, respectively.

Figure 19 - Recorded parameters of the throttle position.

The graph in Figure 19 shows the instant at which each PLANG value was recorded. The recording frequency of the PLANG parameter is 1.0 Hertz.

The parameter that registers the Low Pitch condition also has a frequency of 1.0 Hertz. There is a lag of 0.2 second between the time of recording the Low Pitch parameter and the time of recording the PLANG parameter of the respective engine on each side of the aircraft.

Figure 19 highlights that, after the landing gear touched the runway (gray strip of the graph), the two Power Levers left the Flight Idle position for the REV position in a predominantly continuous movement, since the recorded parameters were in a straight line.

The Low Pitch indication of the nº1 engine was recorded when the Power Levers were already in the reverse range, however the time interval in which the lever was in the position below Ground Idle was less than 1.0 second and there was no recording of the parameter of the Low Pitch condition in that time interval.

Figures 20 and 21 show the parameters of the throttle position (PLANG), engine torque, propeller rotation (Np), high power turbine rotation speed (Nh) of each of the two engines.

The vertical axis on the left of Figures 20 and 21 refers to the parameters PLANG, Np and Torque, while the vertical axis on the right presents the values referring to the parameter of Nh.

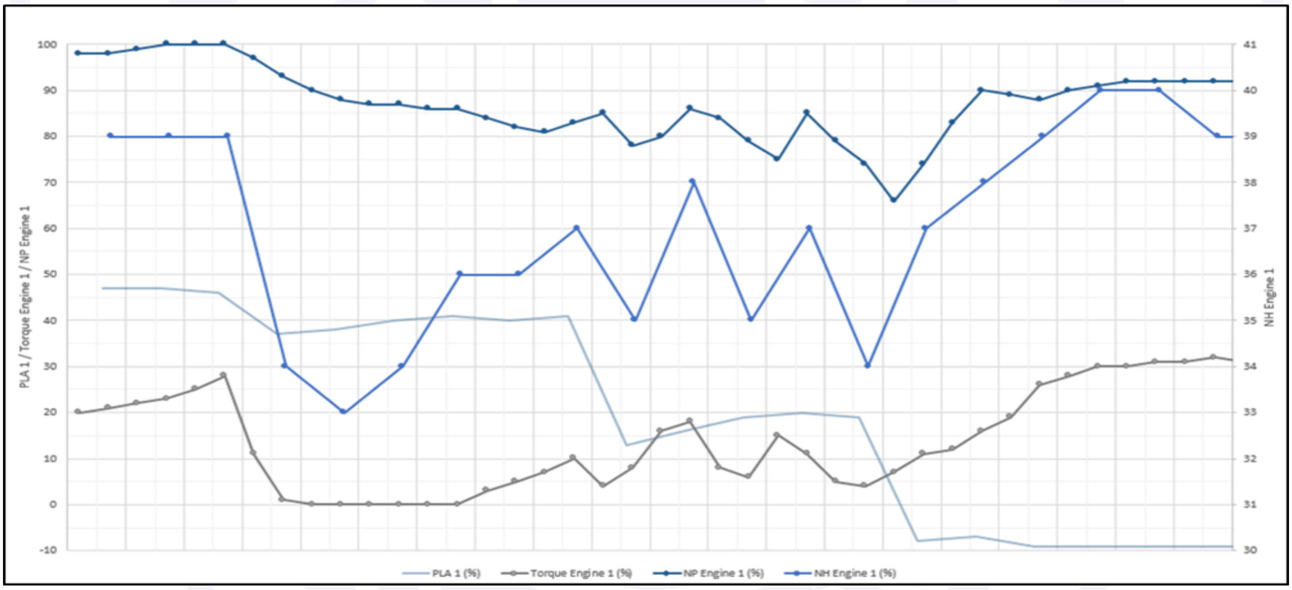

Figure 20 - Powertrain parameters nº1.

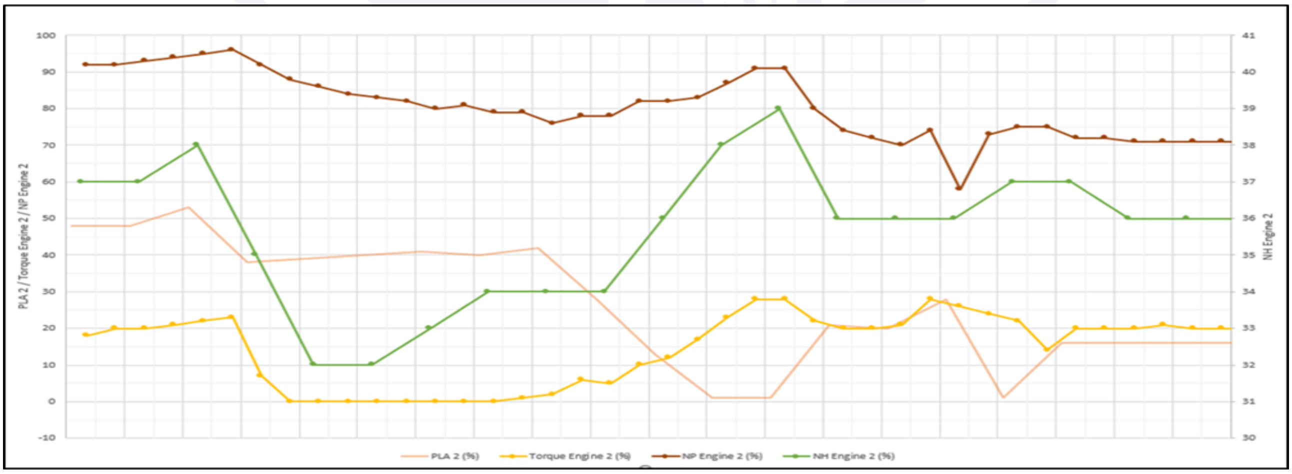

Figure 21 - Powertrain parameters nº2.

The aircraft was equipped with the QAR system which had the functionality to record various system data on a memory card in addition to that recorded on the FDR. This system was not working properly, and it was not possible to obtain any parameters for the investigation.

In addition to the data from the flight recorders, the aircraft also had electronic units that recorded specific parameters of its operation. The failure messages of the two PECs were extracted.

Reading the fault codes did not allow knowing when they were registered. Figures 22 and 23 show the codes for each fault on the left and right PECs, respectively:

Código de Falha	Fault Name
0027	SLPS enabled Fault
0025	Backup channel failed discrete wrap
0024	Primary channel failed discrete wrap
0032	Sensed propeller speed fault
0031	Sensed propeller speed fault
0066	Sensed PLA Fault
0065	Sensed PLA Fault

Figure 22 - PEC nº1 - Left side.

Código de Falha	Fault Name
0027	SLPS enabled Fault
0025	Backup channel failed discrete wrap
0024	Primary channel failed discrete wrap
0032	Sensed propeller speed fault
0031	Sensed propeller speed fault
0003	Reversing Fault

Figure 23 - PEC nº2 - Right side.

1.12 Wreckage and impact information.

The estimated touchdown position on the runway occurred at about 245m from threshold 09. The aircraft left the runway by its left side at about 500 m after the touchdown point.

After leaving the runway, the aircraft traveled about 180m in a side area covered by grass. The aircraft stopped at a lateral distance of 60m from the center of the runway.

Figure 24 - Top view of the trajectory traveled by the aircraft on the ground.

During the field investigation, the warning lights presented to the crewmembers were verified, as shown in Figure 25.

Figure 25 - Indications shown on the aircraft panel after the occurrence (highlighted).

The position of each of the alarm panel lights is shown in detail, schematically in Figure 26.

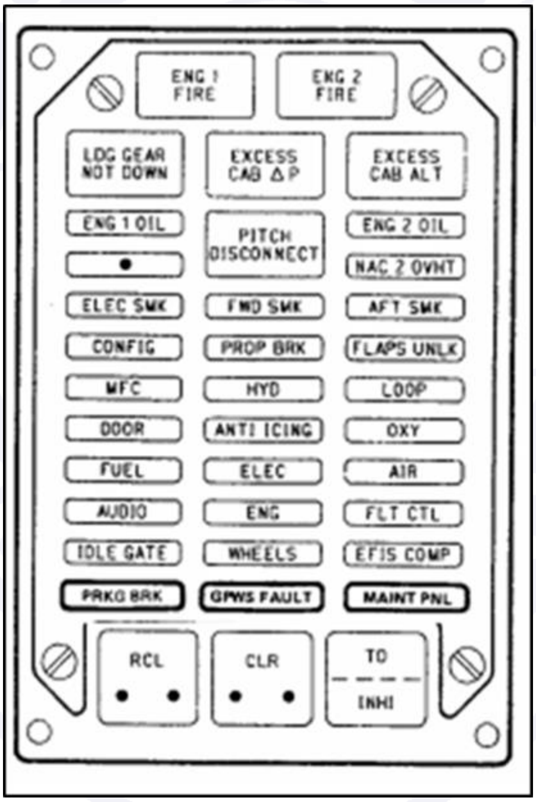

Figure 26 - Alarm Panel Alert Lights. Adapted from the ATR manuals.

The alert messages (red color) that were illuminated were:

- LDG Gear not Down - Warning light related to landing gear not down;

- Eng 1 Oil - Warning light for engine 1 oil level;

- Eng 2 Oil - Warning light for engine 2 oil level; and

- Pitch Disconnect - Warning light related to the Pitch Uncoupling Mechanism, described in Section 1.6.

The warning messages (amber color) that were illuminated were:

- Prkg Brk - Parking brake warning light; and

- Wheels - Warning light concerning the failure or shutdown of the Antiskid system or overheating of the brakes.

In addition to these messages, the Fault light was observed on PEC nº1 (left) and the PWR MGT power selector in the CRZ (Cruise) position.

Throttle levers and condition levers were locked due to impact damage. Engines shutdown was carried out by the fire handles.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

No evidence was found that problems of physiological nature could have affected the flight crew performance.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

The PIC, who was the Pilot Flying (PF), reported that he came from a flight pace that he considered calm, due to the number of passengers having decreased and, consequently, the number of flights as well. He was flying less than 40h/month. On Thursday and Saturday, before the occurrence, he was on call and on Friday he was off duty.

Regarding the flight, he informed that it was not a type of customary operation, since night flights were not frequent. According to him, during the descent, he noticed something different. There was a lot of noise and the aircraft seemed to have more power. He said he tried to make a long landing, as usual, and used little braking.

The PIC also reported that he did not feel the aircraft skidding, that it left the runway very fast, but that he tried to slow it down, using the brakes and throttles.

He had been operating on that runway since 2012 and had already experienced two episodes of tire blowouts in the region.

The SIC reported that, in his role, he was the professional with the longest time in the company at the time and that he already had the command course.

Regarding the flight of this occurrence, he said that it was the first time he had gone through this type of situation. He also informed that on the final approach, there was light rain with calm wind and that the aircraft was light, as there were no passengers on board. He said he had informed the PIC about the speed, which was above the expected.

In the SIC's view, the touch was further ahead and later than usual. He considered the landing as “technical”, which would not be a “hard” landing in the jargon used by pilots. The SIC reported that, when he realized that they were going to leave the runway, he applied a pedal to try to avoid it.

Based on the data obtained through the CVR, the crewmembers commented on the relationship between the length of the runway and night time, which could generate visual illusions. Also, at times, they did not understand the attitude of the plane and commented on some parameter that was different for each of them, however, they did not identify which would be wrong.

The pilots considered that there was a good interaction in the cabin, with a calm and professional environment.

In the perception of the commercial crew, the relationship between the pilots was based on formality, since the PIC had a more formal and reserved posture. The SIC was described as a more communicative person.

Regarding the operation with the PAPI at SBUY, the crew reported that, according to the perception of the group of pilots that operated at that Aerodrome, of which they were part, the normal condition of the PAPI (two white lights and two red lights) slowed down the touchdown point on the runway, reducing the remaining stop length.

Therefore, they adopted an approach procedure for landing in which the PAPI had three red and one white lights.

The length of the runway for braking was also a concern for the crewmembers, especially at night and in the rain.

1.14 Fire.

There was no fire.

1.15 Survival aspects.

All occupants left the aircraft through its service doors. It was not necessary to use the emergency exits.

The engine shutdown was carried out by the aircraft's fire handle.

1.16 Tests and research.

Electrical tests and breakdown research were carried out on the aircraft on 11AUG2017 and 12AUG2017. The PVM components, PN C146440-2, SN 229, and Microswitch Box, PN 11S76180650-10, SN 0199, were removed from the aircraft and taken in for examination.

The test consisted of a continuity check of the electrical system regarding the aircraft's Low Pitch protection. The schematic diagram, shown in Figure 12, was used as a reference for carrying out the test.

Failures in continuity were observed at the following points:

- continuity failure between EEC nº2 Connector P2, pin S and Microswitch 30KF pin C (related to the “Np Cancel” logic); and

- continuity failure between Relay 106KH pin B and Microswitch 4KX pin Y (related to the self-test function of the unfeathering logic).

After checking the electrical continuity of the Low Pitch protection system wiring, a breakdown search was performed for fault codes 0027 (SLPS Enabled Fault) and 0003 (Reversing Fault).

The breakdown search for fault code 0027 was carried out partially due to the preservation of aircraft evidence. The crash survey did not indicate an active PEC failure.

Carrying out a breakdown survey referring to fault code 0003 (Reversing Fault) indicated the need to carry out a more detailed examination of the PVM components and the Microswitch Box, since the tests carried out indicated an inconstant electrical voltage in the protection circuit of Low Pitch.

The following tests on the PVM unit, PN C146440-2, SN 229, equipped in the aircraft's nº2 (right) engine, were performed at the component manufacturer's facilities:

- External Component Inspection: the equipment had an external appearance without relevant observations, only with marks consistent with the number of hours and cycles of normal operation;

- Mass: the mass was within the specified limits;

- External Flange Leakage Test: not performed, so that the initial characteristics of the component would not be altered;

- Beta RVDT Feedback calibration and accuracy: all parameters were within limits;

- Activation of the SLPS Solenoid: the activation of the SLPS occurred, as foreseen in the test protocols;

- Power Lever RVDT angle calibration and accuracy: all parameters were within limits; and

- Resistance Measurement: all parameters were within limits, except the resistance measurement between the front surface of the flange and the PVM connector, which was above the specified.

Tests on the Microswitch Box unit, PN 11S76180650-10, SN 0199, installed on the aircraft's central pedestal at the time of the occurrence, were carried out at the component manufacturer's facilities. The tests performed were:

- External Component Inspection: the equipment had several non-standard conditions:

1. Non-standard component connector and brake wires placed differently than expected (Figure 27).

Figure 27 - Brake Wire placed inside the housing and connector in a different pattern than expected.

2. Misalignment of the adhesive markings on the Microswitch Box fixing screws (Figure 28).

Figure 28 - Misalignment between the adhesive markings on the Microswitches screws and nuts.

3. Damage to the Microswitch Box protective cover (Figure 29).

Figure 29 - Damage to the Microswitch Box protection cover.

4. Missing brake wire (Figure 30).

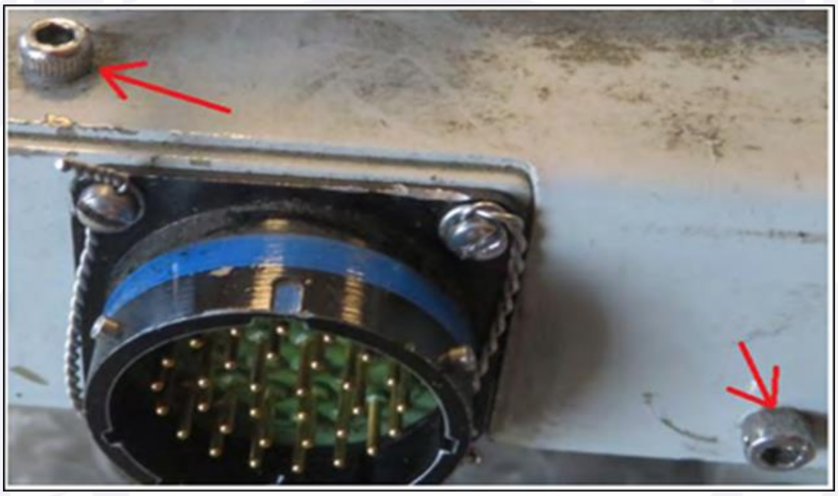

Figure 30 - Missing brake wire.

Visual inspection showed signs that the Microswitch Box, PN 11S76180650-10, SN 0199, installed on the aircraft at the time of the occurrence, had been serviced outside the standards established by the component manufacturer.

No records of services performed on this component were found. The following tests were carried out:

- Component Continuity Test: all parameters tested were as specified. Without changes.

- Functional Test of the Microswitch Box: the functional test consisted of installing the Microswitch Box on a calibrated bench with measurements of lever angles, reference positions and with a device that allowed simulating the movement of the lever. This test was performed for the two power levers and for the two condition levers. The activation of each microswitch was indicated by lighting in the bench test and the value corresponding to the PLANG was recorded. According to the test protocol, the switching range should be observed within values of ±1° from the reference angle and, additionally, specifically for the 3KX and 4KX microswitches there was a tolerance of -0.2° to - 1st. The functional test values are shown in Figures 31 and 32, below. Results that were outside the tolerance margins are highlighted. The first column of the table is relative to the tested microswitch, the second column corresponds to the values of reference angles, the third and fourth columns correspond to the values of switching angles, in direct movement (increasing angles) and indirect (decreasing angles), respectively, obtained for the Microswitch Box, PN 11S76180650-010, SN 0199, installed in the crashed aircraft.

Microswitch	Ponto de Comutação	Movimento Direto	Movimento Indireto
65HA	13°	13°45’	13°
3KX	31°16’57”	31°10’	29°40’
65HA	35°30’	35°30’	**34°**
23KF	49°20’	49°15’	48°30’
24KF	49°20’	49°45’	49°
31WW	49°23’	48°50’	48°30’
23KS	52°40’	52°30’	52°
25KH	62°	62°10’	61°30’

Figure 31 - Throttle Lever nº1.

Micro	Ponto de Comutação	Movimento Direto	Movimento Indireto
66HA	L 13°	**14°40’**	13°50’
4KX	SC 31°16’57”	30°	**28°**
66HA	M 35°30’	35°35’	**38°50’**
25KF	H 49°20’	49°30’	49°
26KF	H 49°20’	49°30’	48°50’
30WW	T 49°23’	49°50’	49°40’
24KS	R 52°40’	52°30’	51°40’
26KH	O 62°	61°50’	61°20’

Figure 32 - Throttle Lever nº2.

The 3KX and 4KX microswitches were directly related to Low Pitch protection. Regarding these microswitches, it was observed that the 4KX (Low Pitch protection referring to power lever nº2) was activated at a smaller angle than expected during the indirect movement considering the switching range and tolerance values.

The Condition Levers Microswitches did not have a function directly related to Low Pitch protection, so only the results obtained in the bench test will be shown (Figures 33 and 34).

Micro	Ponto de Comutação	Movimento Direto	Movimento Indireto
5KC	P 1°40’44”	1°40’	1°20’
5KF	U 25°42’40”	25°30’	**24°10’**
55KF	U 25°42’40”	25°20’	**23°30’**
29KF	V 33°39’04”	**32°00’**	**30°40’**
27KH	Z 55°	**53°20’**	**52°30’**

Figure 33 - Results obtained from Condition Lever nº1.

Micro	Ponto de Comutação	Movimento Direto	Movimento Indireto
6KC	P 1°40’44”	2°00’	0°50’
6KF	U 25°42’40”	26°40’	25°00’
54KF	U 25°42’40”	**27°15’**	25°40’
30KF	V 33°39’04”	**35°25’**	34°10’
28KH	Z 55°	**56°10’**	54°30’

Figure 34 - Results obtained from Condition Lever nº2.

- Additional tests on the Microswitch Box: additional tests were carried out on the Microswitch Box, PN 11S76180650-010, SN 0199, simulating a quick movement of the power levers from positions close to Flight Idle to positions in the reverse and maximum reverse range, in order to check for interruption in the electrical contacts provided by the

Microswitch Box. No interruptions were found in the electrical signals nor were any other significant conditions observed that would represent a malfunction.

Then, the Microswitch Box, PN 11S76180650-010, SN 0199, was dismantled in order to check the internal condition of the component, as shown in Figures 35, 36 and 37, below:

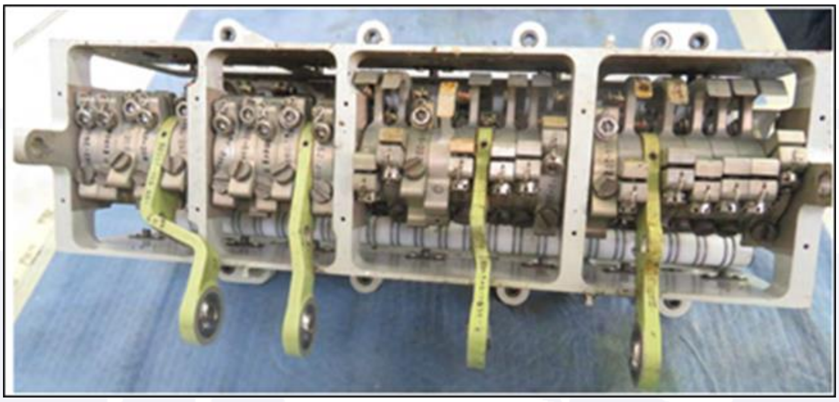

Figure 35 - Top view of the Microswitch Box disassembly.

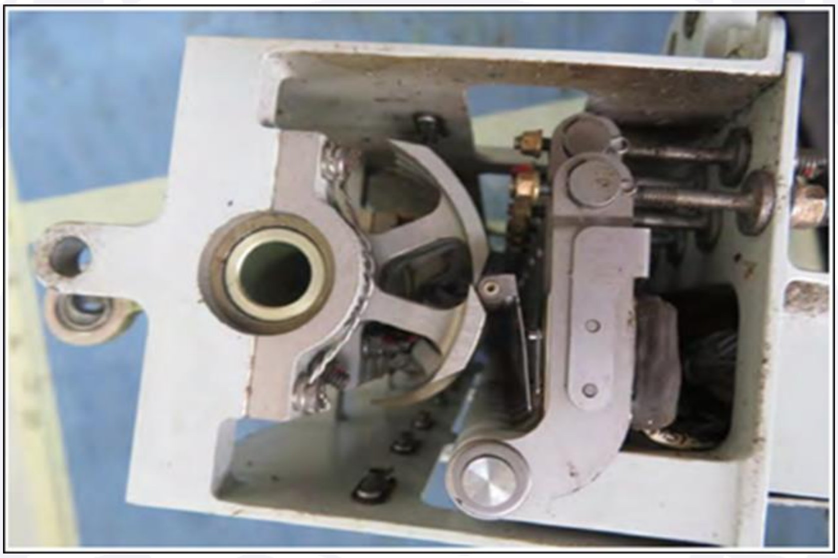

Figure 36 - Right lateral view of the Microswitch Box disassembly.

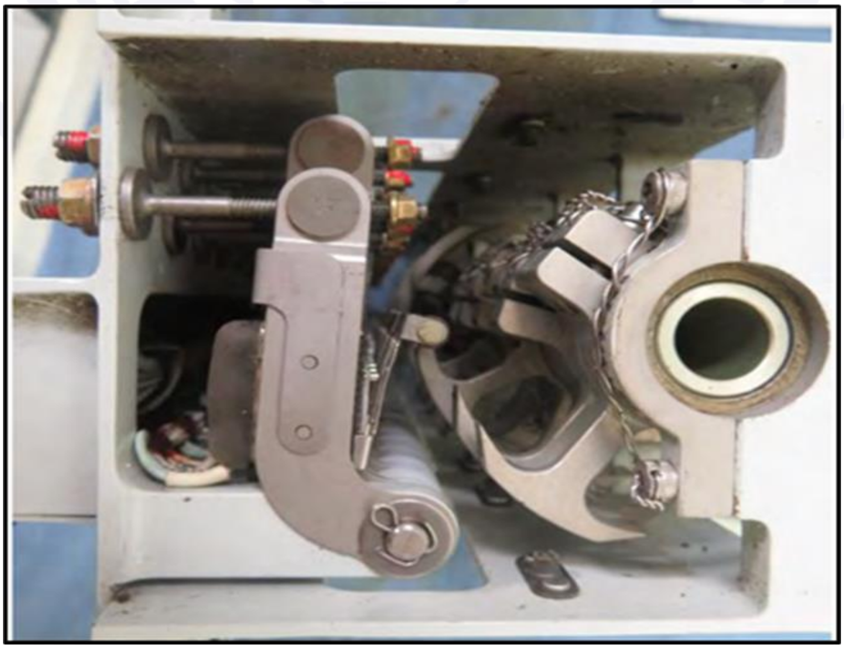

Figure 37 - Left lateral view of the Microswitch Box disassembly.

During the disassembly of the Microswitch Box, PN 11S76180650-010, SN 0199, no foreign objects or dirt were observed inside it that could indicate an intermittent operation of this component.

As shown in Figure 38, below, the presence of sealants (white color) different from the factory sealant (black color) was observed in the 25KH and 26KH microswitches.

Figure 38 - Microswitches installed in the Microswitch Box, PN 11S76180650-010, SN 0199.

The complete disassembly of the Microswitch Box, PN 11S76180650-010, SN 0199, was discontinued as the conditions observed in the electrical test carried out on the aircraft were not confirmed.

Thus, it was decided to reassemble the Microswitch Box to carry out a second electrical test on the aircraft.

Thus, a new electrical test was carried out on the aircraft on 08FEB2018. This test was intended to verify if the conflicting results between the first electrical test performed on the aircraft on the dates of 11AUG2017 and 12AUG2017 and the examination in the Microswitch Box, PN 11S76180650-010, SN 0199, would be confirmed.

The test consisted of measuring the voltage at several points of the electrical circuit, described in Figure 12, in order to verify if the voltage oscillation was measured at any other point, as observed in the first electrical test on the aircraft.

Voltage oscillation with characteristics similar to those observed previously was verified in the output B2 of the 98KH relay. The input pin voltage was constant at 28V. Thus, the grounding conditions of the 98KH relay were studied.

The 98KH relay grounding was made by installing it in the 910VU rack, located in the aircraft's electrical compartment, behind the right seat of the cockpit. It was found that the 910VU rack was not properly installed to the airframe.

During the electrical system continuity measurement process, the 910VU rack was dismantled for easy access. Thus, it is possible that, after measuring continuity, the 910VU rack was not installed correctly in the electrical compartment of the aircraft.

Therefore, it was considered that the oscillation observed in the first electrical test could not be considered valid, since the aircraft had been de-configured before it was carried out.

1.17 Organizational and management information.

Total Airlines S.A. provided services to the PETROBRAS company, being responsible for the regular transport of employees to various locations in the Amazon Region.

In 2016, the operator, as planned, submitted the pilots involved in this occurrence to periodic training in a simulator. Training was carried out under VMC, through local flights, and under IMC, through en-route flights.

In the evaluation of the VMC training, the PIC obtained a satisfactory grade in all the evaluated criteria, but with reservations to remember the “ENG STILL” checklist in the QRH and was alerted for performing a low visual approximation.

In the IMC training, the PIC had a satisfactory evaluation, with reservations about performing a procedure before flap retraction, the sequence of procedures in the go-around and the sequence of the normal, abnormal and emergency checklist.

The SIC, in turn, received a satisfactory grade in the VMC training, with comments regarding the memory items, which should be requested or remembered when relevant, in addition to improving the QRH reading, when in the PM function.

As for the IMC training, the SIC was evaluated with a satisfactory degree, with guidelines to improve the requests for memory items and remember the sequence of the normal, abnormal and emergency checklist.

1.18 Operational information.

According to the aircraft's dispatch documentation, it was within the prescribed weight and balance limits and had fuel to complete the flight leg.

The aircraft was operated by Total Airlines S.A., which had been contracted by PETROBRAS to carry out the regular transport of employees to various locations in the region.

The flight of the occurrence (TTL9915) had been requested by the contracting company to meet a demand for transporting personnel from the base in Porto Urucu - AM, to Manaus - AM. Thus, the crew, composed of two pilots and two flight attendants, was called to perform the flight at night, an unusual time condition for the SBEG-SBUY route.

At SBEG, the aircraft was fueled with 2,100 kg of fuel, totaling 3,100 kg. The take-off weight was 15,183 kg and the estimated landing weight was 14,308 kg, representing an estimated fuel consumption of 875 kg.

According to the crew, this flight condition was not usual, because due to the absence of passengers, the aircraft would be in a lighter configuration.

The take-off was carried out without intercurrences. During the beginning of the descent to landing, the propeller rotation (Np) of the right engine went to 100% in an uncommanded manner.

The crewmembers performed the checklist procedure “Uncommanded 100% Np on One or Two Propellers”. This procedure had as only action to place the two Condition Levers at 100% OVRD. This action was carried out by the crew and the Condition Levers were kept in the 100% OVRD position throughout the rest of the flight.

At SBUY, the NDB Rwy 09 procedure was performed. The Autopilot was selected in VS and HDG SEL modes, the flaps were set to the 15° position and the speed was, approximately 165 kt.

The aircraft began a continuous turn into final approach with ALT and HDG SEL autopilot modes selected. During this turn, the landing gear was down. At the end of the turn, the speed was approximately 130 kt, the flaps were set to the 25° position and then to the 35° position. The aircraft restarted the approach trajectory in the VS mode with a descent rate of 600 ft/min until reaching 500 ft of selected height.

Crossing the height of 1,000 ft AGL, the speed was at 119 kt (reference speed). On the descent, when crossing 850 ft AGL, the alignment with the runway was performed, heading 084°. At that time, the aircraft was flying under VMC.

To maintain the approach ramp, the PAPI visual references were being used. According to the CVR recordings, 4 red lights were displayed on this approach ramp, indicating that the aircraft was below the ideal ramp.

At the height of 500 ft (AGL), the AP was disconnected, and the speed was at 119 kt. In the final short, the speed had a small reduction to 115 kt. The PAPI reference at that time, as reported by the crewmembers, was three red lights and one white.

According to the perception of the company`s crewmembers who operated in that Aerodrome, the proportion of two red lights and two white lights of the PAPI would leave the aircraft with little runway for the accomplishment of the landing.

Figure 39 illustrates the vertical trajectory for the aircraft to land. The black line shows the height of the aircraft above the ground and the red line the standard reference height.

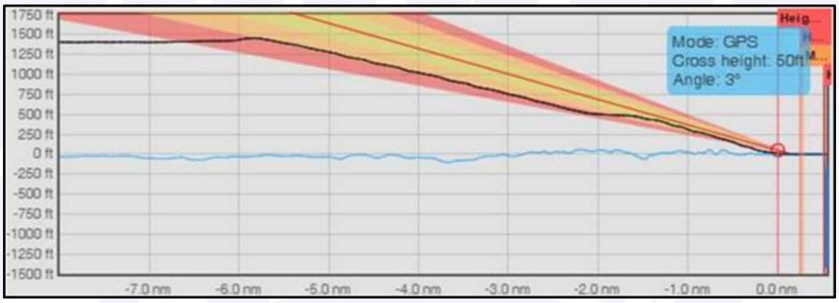

Figure 39 - Vertical trajectory for landing.

The landing distance, according to the FCOM, without the use of reverse (Power Levers in Ground Idle), was calculated using the table in Figure 40:

NORMAL CONDITIONS - FLAPS 35									
WEIGHT (1000 KG)		12	13	14	15	16	17	18	18.6
RUNWAY CONDITION	DRY	570	570	580	590	610	640	670	690
	WET	700	700	700	710	740	780	810	830
CONTAMINATED BY	WATER OR SLUSH < 1/2 in	830	840	860	880	930	970	1020	1050
	COMPACT SNOW	810	820	830	850	890	930	970	1000
	ICE	1200	1220	1250	1280	1340	1400	1460	1500

Figure 40 - Landing distance in meters. Source: Total's FCOM.

The distance corrections to be used according to the applicable situation were:

- Wind effect:

• add 10% for every 5 kt of tailwind; and

• decrease 2% for every 5 kt of headwind.

- Runway altitude:

• add 3% for every 1,000 ft above sea level.

- Reverse Effect:

• decrease 4% for dry runway; and

• decrease 5% for wet runway.

At the time of the occurrence, the following conditions existed:

- estimated weight of the aircraft: 14,308 kg;

- wind conditions: no wind;

- runway conditions: wet;

- runway altitude: 210 ft; and

- the use of the reverse was not considered for the calculation of the necessary runway length.

According to the data in Figure 40, a runway length of 707 meters was obtained.

Total Airlines' FCOM contained the company's standard procedures. Figures 41 and 42, below, show the items of the landing procedure, from the DH or MDA.

PF	PM
At DH or MDA	► MINIMUM .... ANNOUNCE
■ **If visual references acquired** ► VISUAL REF........ ....ANNOUNCE ► APPROACH.......... .... CONTINUE ■ **If visual references not acquired** ► GO-AROUND.... .... ORDER & INITIATE *"Announce, Go-around, set power, flaps one notch".* ► AP ....DISCONNECT & ANNOUNCE ► CAVALRY CHARGE.................CANCEL *Press twice AP disconnection pb to cancel* ► YD DISENGAGEMENT....... .... ORDER	► YD .... DISENGAGE & ANNOUNCE ► AFCS YD ALARM........................CLEAR ► RUD TRIM....... .... CHECK CENTERED
At 50 ft AAL	► 50 FT AAL ....ANNOUNCE

Figure 41 - Landing procedure items (part 1 of 2). Source: Total Airlines' FCOM.

CAPT	F/O
At 20 ft AAL ► PL 1+2... FI ► FLARE.................................PERFORM	► 20 FT AAL ....ANNOUNCE
On Ground ► PL 1+2... GI ► REVERSE .... AS RQRD *Reverse efficiency decreases with speed. If use is expected, it is recommended to use it just after landing. Set PL to GI before 40 kt to avoid engines ingestion and pitch disconnect.* ► BRAKES................ ....AS RQRD	► IDLE GATE RETRACTION ....CHECK *PULL if no automatic retraction* ► LO PITCH...........CHECK & ANNOUNCE
CAPT	**F/O**
Passing 70 kt ► I HAVE CONTROL ....ANNOUNCE ► N/W STEERING.....................CONTROL	► 70 KT ....ANNOUNCE ► CONTROL WHEEL....... .... INTO WIND

ENG	LO PITCH	ANNOUNCE	REVERSE
2 ENG	2	2 LOW PITCH	NORMAL USE
	1	NO REVERSE	NO REVERSE
	0	NO REVERSE	NO REVERSE
1 ENG	1	1 LOW PITCH	USE WITH CARE

Figure 42 - Landing procedure items (part 2 of 2). Source: Total Airlines' FCOM.

According to the information collected from the flight recorders, at the time of the touchdown, the aircraft had a speed of approximately 93 kt. At that moment, there was the MASTER WARNING, and the levers were moved back to the reverse position practically simultaneously.

Reportedly, upon observing the aircraft's yaw tendency and the ineffectiveness of the right engine reverse, the PF removed his hand from the nº1 (left) lever and forced the nº2 (right) lever to the REV position stop.

The landing took place with a load factor of approximately 1.3G. After touching the runway, the aircraft showed a strong tendency to exit to the left, with the rudder being applied to the right, in order to counteract the aircraft's yaw.

1.19 Additional information.

The RBAC No. 121, amendment 03, had the following requirement regarding landing distance:

> 121,195 Airplanes with turbine engines: landing limitations at the destination Aerodrome
>
> [...]
>
> (b) Except as provided in paragraphs (c), (d) or (e) of this section, no one may take off a turbine powered airplane unless, its weight on arrival, taking into account normal consumption of fuel and oil in flight (and according to the AFM landing distance data, taking into account the altitude of the destination Aerodrome and the expected wind conditions at the estimated time of landing), allows to perform a complete landing at the destination Aerodrome using 60% of the effective length of each of the runways referred to below, assuming the airplane passes 50 ft above the vertical of the intersection of the obstacle clearance plane with the runway. To determine the permissible landing weight at the destination Aerodrome, it is assumed that:
>
> (1) the airplane lands on the runway and in the most favorable direction, with calm air;
>
> (2) the airplane lands on the most convenient runway, considering the likely wind direction and speed, the ground handling characteristics of the airplane type, and other variables such as landing aids and terrain.

1.20 Useful or effective investigation techniques.

Nil.

2. ANALYSIS.

It was a transfer flight between SBEG and SBUY.

The flight between SBEG and SBUY was carried out frequently by the operating company, but normally during the day. The mission was intended to transport passengers from the company contracting the air transport services. The flight at night and with the aircraft empty was an unusual condition for the crewmembers.

With approximately one hour and ten minutes of flight, during the descent procedure, the aircraft presented an increase in the rotation of the right propeller of the number 2 powerplant (right side).

The crewmembers performed the procedure described in the flight manual “Uncommanded 100% Np on One or Two Propellers”, which, in short, consisted of taking both Condition Levers to the 100% OVRD position, causing the propeller rotation to be maintained at 100% of Np. This condition caused a decrease in efficiency relative to fuel consumption, not generating loss of propeller functionality.

Thus, it was not possible to establish a relation between the increase in propeller rotation that occurred in flight and the failure of reverse asymmetry during landing.

The approach for landing at threshold 09 of SBUY was carried out under light rain conditions, complying with the profile provided for in the NDB Rwy 09 procedure, with flaps initially positioned at 15°, using the AP in Vertical Speed and Heading Select modes.

Upon reaching 850 ft in height, the aircraft was in visual condition, with the landing gear down and locked, flaps 35°, and the final alignment with the runway was carried out and the aircraft was below the ramp. According to the CVR recordings, the PAPI indication was four red lights, therefore, below the ideal ramp. Upon reaching 500 ft in height, the AP was disconnected.

During the final approach, there was a speed reduction from 119 kt to 115 kt. The aircraft continued below the ramp, but the PAPI began to indicate three red and one white lights.

According to the crew's report, the fact that the aircraft was empty made it more difficult to manage flight parameters such as speed and height for the flare during landing. Also, according to them, there was a shared perception among the operator's crewmembers that the SBUY PAPI, in its normal condition (two white lights and two red lights), delayed the touchdown point on the runway, reducing the length available for stop the aircraft.

Thus, an approximation with the pattern of three red and one white lights was informally adopted, which represented a low visual approximation, different from that recommended.

This type of approach, below the recommended standards, was performed on this flight and as reported, it was customary for the pilots who operated in that location.

It is noteworthy, however, that although this type of low approximation has already been an observation item in the PIC training assessment, this fact was not directly related to the events observed in this occurrence.

It was verified that the landing performance was compatible with the dimensions of the runway, since it was possible to make the landing, even with inoperative reverses, under the conditions present at the time of the occurrence. According to the data in Figure 40, a required runway length of 707m was obtained.

The Aerodrome runway had a length of 1,320 m, being, therefore, greater than the minimum length required for landing in the conditions of the aircraft at the time of the occurrence and taking into account the safety factors required by regulation, which stipulated 792m (60%).

However, despite the fact that the SBUY runway has adequate dimensions for the deceleration of the aircraft without the use of reversers, it was observed that the crewmembers showed great concern about the length of the runway for braking, since the operation took place at night under wet conditions (wet runway).

In order to minimize this concern, the approach was performed with a ramp pattern below the ideal and, as soon as the main landing gears touched down on the runway, the thrust levers were brought directly into the reverse position.

The landing took place with a load factor of approximately 1.3G, which is considered to be within the normal range.

In summary, the actions that should be taken after the aircraft touches down on the runway would be:

- check the retraction of the Idle Gate, a function that should be performed by the PM;

- move the thrust levers back to the Ground Idle (GI) position, a function to be performed by the PF; and

- check and announce the conditions of the Low Pitch lights, a function that should be performed by the PM.

In the condition of landing with both engines operating normally, if the two Low Pitch lights were verified on, the throttles could be moved back to the reverse position. If only one Low Pitch light, on either side, was verified to be lit, the reverses could not be used on landing and the aircraft would have to be decelerated using only the brake system.

This procedure aimed to ensure that the aircraft was correctly configured to apply reverse power to the engines, being essential to prevent a runway departure due to the occurrence of asymmetric reverse.

According to the CVR audio, it was not possible to identify the SIC announcing “two Low Pitch” or “No Reverse” foreseen in the landing procedure. In addition, the FDR data indicated that only propeller 1 (left side) entered Low Pitch even though both thrust levers were continuously pulled back into reverse.

Thus, it is concluded that only the Low Pitch light referring to propeller 1 (left side) has turned on. Therefore, neither of the two engines could be placed in reverse and the aircraft would have to be decelerated using only the brakes.

At the same time, it was verified through the CVR audio and the FDR parameters that, at the moment of the landing gear touching the runway, the repetitive audible warning associated with MASTER WARNING was activated.

These indications may be associated with the elevator's Pitch Uncoupling Mechanism function, where opposing forces on the control lever column would generate the decoupling of the right and left portions of this control surface. This decoupling would provide the following indications: MASTER WARNING light, Pitch Disconnect indication, and repetitive beep.

The intermittent character of the MASTER WARNING observed in the FDR (Figure 17) could be associated with the adjustment of the Microswitch located in the elevator (Figure 15).

In view of the above, it is possible that the unexpected audible warning of Pitch Disconnect may have diverted the attention of the crewmembers while carrying out the planned landing procedures, thus contributing to the non-verification of the Low Pitch lights. In this scenario, both levers have been moved back to the REV position.

Therefore, the crew's diversion of attention led to the application of the engine reverse command, with one of the Low Pitch lights on, causing only one of the propellers to go into reverse while the other remained in flight pitch. This action contributed to the exit of the aircraft by the left side of the runway.

The fact that the FDR recorded throttle positions below Ground Idle allowed us to rule out an Idle Gate failure, which would prevent the thrust levers from being pulled back to positions below Flight Idle, as well as the WOW sensor.

From the moment the left propeller entered reverse and the right propeller continued in flight pitch, the aircraft began to deviate to the left.

When the engines enter the reverse regime, there was an increase in torque and other related parameters, such as propeller rotation and high-power turbine rotation. This characteristic could be observed in both engines, as seen in Figures 20 and 21.

Thus, it was found that, although the right propeller did not change the pitch to reverse, the engine presented a behavior consistent with the position of the lever, that is, in reverse.

The increase in torque on the right engine with the propeller in flight pitch caused a rise in traction in the flight direction. On the other hand, the left engine assumed the reverse regime and the traction provided was in the opposite way to the flight direction.

In this condition, there was a large moment of lateral yaw to the left which, despite the application of all the rudder to the right, could not be counteracted and resulted in the aircraft leaving the runway.

Observing the aircraft's yaw tendency and the ineffectiveness of the reverse of the right engine, the PF removed his hand from the No. 1 (left) lever and forced the No. 2 (right) lever to the REV position stop. Lever nº1 mechanically returned to Ground Idle position due to the effect of lever box springs, as can be seen between reference times 206889 and 206895 in Figure 19.

Based on the data presented in the graph of this Figure, it is concluded that, after leaving the runway, lever nº 2 was moved to the Ground Idle position and then to Reverse, however, there was no change in the condition of the propeller pitch, which remained in flight.

Lever nº1 assumed a position below 0° of lever angle due to impacts after leaving the runway, which caused all levers to lock, both power and condition.

The engines were cut by the fire handles and the aircraft traveled about 500 m after the touchdown point and 180 m off the runway, stopping approximately 60 m perpendicularly to the center of the runway.

As for the factors that may have led to the failure of the step angle of the No. 2 engine and, consequently, to the asymmetric reverse event, the following hypotheses were elaborated:

- PVM hydraulic failure;

- Microswitch Box failure; and

- Electrical failure in the Low Pitch protection system.

Regarding a hydraulic failure of the PVM, PN C146440-2, SN 229, the unit was bench tested. It was found to have the ability to provide hydraulic power to modify the pitch of the propeller. Therefore, the PVM could be ruled out as a contributing factor to the event.

Regarding a failure of the Microswitch Box, PN 11S76180650-10, SN 0199, a series of component discrepancies were observed indicating that the unit could have been opened in an unauthorized location.

The continuity test presented all the results within the expected parameters.

In the functional test, both the microswitches of the two power levers and the microswitches of the two condition levers were tested.

Values outside the specified range were obtained in several microswitches, in particular, the Microswitch 4KX stands out, responsible for identifying that the nº2 power lever (right side) was in the Ground Idle position.

The 4KX Microswitch, among other functions, allowed the passage of 28 VDC voltage to the Low Pitch protection system. However, although a difference was observed between the activation angle of the Microswitch 4KX and its expected value, this discrepancy would not be enough to completely disable the reverse function on the right engine and could be associated with a delay in the change of the propeller pitch.

Several simulations were performed in order to verify a possible non-activation of the Microswitch 4KX. In all the simulations carried out, it was activated.

Finally, the Microswitch Box, PN 11S76180650-10, SN 0199, was opened in order to verify if there was any foreign material inside that could cause a momentary failure that could not be reproduced, since the unit had already passed through inappropriate intervention. No objects that could produce a failure in the Microswitch 4KX were found, just more evidence of performing out-of-spec services.

However, it was not possible to obtain information on the period in which the intervention in the Microswitch Box, PN 11S76180650-10, SN 0199, would have been carried out, since no records of maintenance services were found in the unit.

With regard to an electrical failure of the Low Pitch protection system, initially an electrical continuity test was performed on the entire system. This test showed that all the aircraft's wiring was intact.

However, to carry out the test, it was necessary to change the initial configuration of the system to allow access to the Low Pitch electrical protection components and measurements.

This sequence of procedures prevented a more complete assessment of the aircraft`s initial state and the verification of a possible intermittent failure of the electrical part of the Low Pitch protection system.

Thus, it was considered that a momentary electrical failure may have generated the loss of the Low Pitch protection deactivation signal, according to the schematic drawing shown in Figure 15.

This condition could possibly be associated with the grounding conditions of the aircraft's electrical components, given that this factor generated an oscillating signal, as observed in the first electrical test on the aircraft.

It was also observed that the Np Cancel signal that should be generated in cases of reverse failure registered in the PEC was not sent to the EEC, since there was no reduction in the rotation of the right propeller (Np), as shown in Figure 23 .

The Np Cancel function would limit the propeller rotation of the engine with reverse failure, thus minimizing the yaw moment effects caused by a reverse asymmetry.

The wiring referring to the Np Cancel function was verified in conjunction with the electrical test performed and no discrepancies were found, and the failure of the Np Cancel function may also be associated with an aircraft grounding condition.

3. CONCLUSIONS.

3.1 Facts.

a) the pilots had valid CMAs;

b) the pilots had valid A47 aircraft type Rating (which included the ATR-42-500 model) and IFRA rating;

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

d) the aircraft had a valid CA;

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

f) the technical maintenance records were updated;

g) the weather conditions were favorable for the flight;

h) the flight was performed at night;

i) at the beginning of the descent, the aircraft presented an increase in the rotation of the right engine propeller;

j) the condition levers were placed in the position of 100% OVRD according to the procedures foreseen in the manual;

k) the approach was performed with a ramp below the ideal;

l) the landing was performed with a load factor of approximately 1.3G;

m) in the CVR recording, it was not possible to identify the crew's announcement regarding the Low Pitch lights being turned on;

n) in the CVR recording, it was possible to identify a repetitive sound warning at the moment of landing;

o) the FDR data revealed the activation of the MASTER WARNING at the moment of landing;

p) the FDR data revealed a continuous movement of the thrust levers from the Flight Idle position to the REV position;

q) during the landing, the aircraft showed a strong tendency to yaw to the left;

r) the FDR data revealed that the right propeller did not assume the reverse pitch with the throttle in position below Ground Idle;

s) the aircraft exit the runway by its left side;

t) the Pitch Disconnect light remained on after the occurrence;

u) the tests carried out on the PVM installed on the right engine indicated that there was no contribution from this component in the event;

v) a series of discrepancies were observed in the Microswitch Box indicating that the unit could have been opened in an unauthorized location;

w) the continuity tests showed no failures;

x) the aircraft had substantial damage; and

y) the crewmembers left unharmed.

3.2 Contributing factors.

- **Attention – a contributor.**

The lack of attention to the lighting of the Low Pitch lights contributed to the application of reverse in both engines, with only one of the lights on.

Thus, this action contributed to the asymmetric reverse condition, which allowed the aircraft to exit the runway on the left.

- **Emotional state – undetermined.**

The feeling of apprehension experienced by the crewmembers in relation to the length of the runway, associated with the condition of night operation and in the rain, may have affected their performance, so that, in an attempt to anticipate the engines entering the reverse regime, the standard landing procedures were not properly performed.

- **Aircraft maintenance – undetermined.**

The series of discrepancies identified in the Microswitch Box, PN 11S76180650-10, SN 0199, indicating that the unit could have been opened in an unauthorized location, raised doubts about the quality standard of the services performed on the aircraft, which may have allowed an aircraft grounding condition fault that has affected several aircraft electrical components and caused the Np Cancel function to fail.

4. SAFETY RECOMMENDATION.

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

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of the air activity operational safety, and shall be treated as established in the NSCA 3-13

"Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State".

Recommendations issued at the publication of this report:

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

A-053/CENIPA/2017 - 01 **Issued on 09/21/2022**

Work with Total Airlines S.A, in order to verify the compliance of the maintenance services performed by that company, aiming to increase the levels of competence and operational safety required for the performance of the activities for which such organization is certified.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

None.

On September 21th, 2022.