COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-136/CENIPA/2020

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PR-LMP**
MODEL:	**EMB-500**
DATE:	**30OUT2020**

NOTICE

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

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

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

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

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

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

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

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

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

SYNOPSIS

This is the Final Report of the 30 October 2020 accident with the EMB-500 aircraft, registration marks PR-LMP. The accident received the typification of "[RE] Runway Excursion".

At around 20:00 UTC, the aircraft took off from SBSP (*Congonhas* Airport, *São Paulo*, State of *São Paulo*), bound for SSDK (*São Pedro* Aerodrome, *Igaratinga*, State of *Minas Gerais*) on a personnel transport flight, with two pilots and two passengers on board.

The takeoff and en-route phase of the flight were uneventful. During the landing run at the destination, the aircraft suffered a runway excursion, traveling the full length of the runway and overrunning its departure end.

The aircraft was destroyed.

The two crewmembers and both passengers suffered minor injuries.

Being the USA the State of manufacture of the aircraft's components, and Canada the State of manufacture of the aircraft's engines, the NTSB (National Transportation Safety Board - USA) and the TSB (Transportation Safety Board – Canada), respectively, designated an accredited representative for participation in the investigation of the occurrence.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AFM	Aircraft Flight Manual
ALD	Actual Landing Distance
ANAC	Brazil’s National Civil Aviation Agency
BCU	Brake Control Unit
BCV	Brake Control Valve
BECMG	Becoming
BIT	Integrated Maintenance \ Built-in Test
BKN	Broken clouds (5-7 Oktas)
CB	Cumulonimbus cloud
CENIPA	Brazil’s Aeronautical Accidents Investigation and Preventio9n Center
CMA	Aeronautical Medical Certificate
CPTEC	Weather Forecast and Climatic Studies Center
CVA	Airworthiness Verification Certificate
CVDR	Cockpit Voice and Data Recorder
DECEA	Department of Aerospace Control
EPTA	Stations providing Telecommunication and Air Traffic Control Services
FEW	Few clouds (1 - 2 Oktas)
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
IAM	Annual Maintenance Inspection
IFR	Instrument Flight Rules
IFRA	IFR Flight rating (Airplane)
LABDATA	Flight Recorder Data Readout and Analysis Laboratory
LH	Left-Hand side
MCA	Manual of the Command of Aeronautics
METAR	Meteorological Aerodrome Report
MFD	Multifunction Display
NM	Nautical Miles
NSCA	System Norm of the Command of Aeronautics
OPERA	Optimized Performance Analyzer
OVC	Overcast (8 Oktas)
PAPI	Precision Approach Path Indicator
PCM	Commercial Pilot License (Airplane)
PIC	Pilot in Command
PLA	Airline Transport Pilot License (Airplane)

PN	Part Number
POH	Pilot's Operating Handbook
PPR	Private Pilot License (Airplane)
PSI	Pound Force Per Square Inch
PSO-BR	Brazilian Civil Aviation Safety Program (SSP)
RA	Rain
REDEMET	Command of Aeronautics' Meteorology Network
RE	Recent
RH	Right-Hand side
RLD	Required Landing Distance
RMK	Remark
SB	Service Bulletin
SBBH	ICAO location designator – Pampulha Airport, *Belo Horizonte*, State of *Minas Gerais*
SBCF	ICAO location designator - *Tancredo Neves* Aerodrome, *Confins*, State of *Minas Gerais*
SBSP	ICAO location designator – *Congonhas* Airport, *São Paulo*, State of *São Paulo*
SCT	Scattered clouds (3 - 4 Oktas)
SIC	Second in Command
SIGWX	Significant Weather Chart
SIPAER	Aeronautical Accidents Investigation and Prevention System
SOP	Standard Operating Procedures
SSDK	ICAO location designator – Aerodrome of *São Pedro*, *Igaratinga*, MG
TAF	Terminal Aerodrome Forecast
TAWS	Terrain Awareness Warning System
TLA	Thrust Lever Angle
TN	Minimum Temperature (Followed In TAF)
TPP	Private Air Services Registration Category
TSRA	Thunderstorm and Rain
TX	Maximum Temperature (Followed In TAF)
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
V_{REF}	Speed of Reference

1. FACTUAL INFORMATION.

Aircraft	**Model:** EMB-500 **Registration:** PR-LMP **Manufacturer:** EMBRAER	**Operator:** TRACBEL S/A
Occurrence	**Date/time**: 30OUT2020 - 20:50 (UTC) **Location:** *São Pedro* Aerodrome (SSDK). **Lat.** 20°04'33"S **Long.** 044°43'42"W **Municipality – State:** *Igaratinga – Minas Gerais*.	**Type(s):** [RE] Runway excursion

1.1. History of the flight.

At approximately 20:00 UTC, the aircraft took off from SBSP (*Congonhas* Airport, *São Paulo*, State of *São Paulo*), bound for SSDK (*São Pedro* Aerodrome, *Igaratinga*, State of *Minas Gerais*) on a personnel transport flight, with two pilots and two passengers on board.

The takeoff and the en-route phase of the flight were uneventful. The aircraft landed on the runway 29 of SSDK. The aircraft traveled the full length of the runway and exceeded its longitudinal limits.

After exiting the runway, the aircraft collided with an object on the ground, traveled for approximately 130 m, fell from a height of approximately 10 meters, and caught fire.

The aircraft was destroyed.

The crewmembers and passengers suffered minor injuries.

Figure 1 - Aircraft after coming to a complete stop.

1.2. Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	2	2	-
None	-	-	-

1.3. Damage to the aircraft.

The aircraft was destroyed.

1.4. Other damage.

NIL.

1.5. Personnel information.

1.5.1. Crew's flight experience.

Flight Experience		
	PIC	SIC
Total	7,300:00	676:40
Total in the last 30 days	25:00	34:00
Total in the last 24 hours	02:00	02:50
In this type of aircraft	2,350:00	409:20
In this type in the last 30 days	25:00	34:00
In this type in the last 24 hours	02:00	02:50

Obs.: The data on the hours flown was obtained through information provided by the pilots.

1.5.2. Personnel training.

The PIC (Pilot in Command) did his PPR course (Private Pilot – Airplane) in 1999, at *Escola de Aviação CHB* in *Belo Horizonte*, State of *Minas Gerais*.

The SIC (pilot Second in Command) did his PPR course (Private Pilot – Airplane) in 2010, at *Escola de Aviação* Starflight in *Belo Horizonte*, State of *Minas Gerais*.

1.5.3. Category of licenses and validity of certificates.

The PIC held a PLA license (Airline Transport Pilot - Airplane), and had valid EPHN aircraft type (which included the EMB-500 model) and IFRA ratings (IFR Flight - Airplane).

The SIC held a PCM license (Commercial Pilot - Airplane), and valid EPHN type aircraft and IFRA ratings.

1.5.4. Qualification and flight experience.

The PIC had approximately 7,300 flight hours on BE-9T/9L/33, C182/210, CSE5, CAP-4, E50 and PA-28/34 aircraft.

The SIC had around 676 flight hours on BE-58/9L, C-150/152/182/510, E50, PA-34/46 and SR-20/22 aircraft.

The PIC and SIC had completed flight simulator training for the EMB-500 aircraft at the CAE Flight Training in *Guarulhos*, State of *São Paulo*. The referred training finished in November 2019.

Both pilots had qualification and experience for the type of flight.

1.5.5. Validity of medical certificate.

The pilots held valid CMAs (Aeronautical Medical Certificates).

1.6. Aircraft information.

The SN 50000094 Phenom-100 aircraft was a product manufactured by EMBRAER in 2009, and registered in the Private Air Services Registration Category (TPP).

The CVA (Airworthiness Verification Certificate) was valid.

The records in the airframe and engine logbooks were up to date.

The last comprehensive inspection of the aircraft (type "Annual Maintenance Inspection - *IAM*"), was performed by OPD Aviation maintenance organization, in *Belo Horizonte*, *Minas Gerais*, on 18 May 2020. The aircraft flew 87 hours and 15 minutes after that inspection.

The Phenom-100 was a pressurized low-wing aircraft with fully retractable tricycle landing gear, with a single tire on each leg, and designed for operation on paved runways. The aircraft was certified without a reverser system on the engines.

The accident aircraft was not equipped with drag-generating aerodynamic systems, such as *ground spoilers* or *speed brakes*.

The brake system of the PR-LMP consisted of two subsystems: the main brake and the emergency/parking brake. These systems were actuated by the aircraft's hydraulic system.

The function of the main brake was to control the hydraulic pressure in the brakes as a function of the pressure applied to the pedals.

The main brake consisted of an electronic brake system controlled by the PIC or SIC via their brake pedals. The brake pedals actuated pedal transducers that sent brake signals to the Brake Control Unit (BCU), which controlled the LH and RH (left- and right-hand) brakes independently.

Each wheel's brake was controlled by a dedicated Brake Control Valve (BCV). The BCU measured the output of the wheel speed transducer, pedal transducer and pressure transducer; and provided an electrical command corresponding to the associated BCV.

The hydraulic pressure was made available to the brakes by means of a solenoid valve (BCV), electronically controlled by the BCU. This valve provided pressure when one depressed the pedals with the aircraft on the ground.

In addition, the brake system had anti-skid protection, which had the function of preventing skidding, as well as maximizing the efficiency of the brakes in accordance with the condition of the runway surfaces. The antiskid controlled the amount of hydraulic pressure applied to the brakes and, if necessary, reduced that pressure to regain wheel speed and prevent lockups and skidding.

In an aquaplaning condition, the application of the brakes would not result in significant deceleration of the aircraft, since the friction with the ground would be very low. In aircraft equipped with an anti-skid brake system, wheel locking is minimized, as the brake pressure is gradually released until friction with the ground is reestablished.

In case of utilization of the emergency/parking brake system, the hydraulic pressure applied to the brake assembly would be proportional to the displacement of the actuation lever. In this condition, antiskid protection would not be available.

The brake system also had the *Integrated Maintenance* / *Built-in Test* (BIT) function, which provided monitoring and indication of failures in the system.

The Investigation Commission identified that the PN 90005034-7 BCU-7 was installed on the PR-LMP on 18 May 2020.

On 23 April 2021, about six months after the date of the accident in question, the aircraft manufacturer issued the Service Bulletin SB500-32-0019, recommending, in a non-mandatory fashion, the replacement of the BCU-7 models by the BCU-8 PN 90005034-8, within 36 months (or 1,800 flight hours), whichever came first.

According to the SB500-32-0019, the motivation for the issuance of the technical publication would be the existence of pilot reports related to the perception of poor braking performance during landings with aircraft equipped with the BCU-7.

However, the modifications incorporated in the brake system by the BCU-8 did not change the braking distances, that is, the aircraft with the BCU-8 installed should use the same version of the operational planning software (OPERA - *Optimized Performance Analyzer*) used by the aircraft equipped with the BCU-7.

1.7. Meteorological information.

The TAF (Terminal Aerodrome Forecast) of SBBH (located at a distance of 46 NM from SSDK) had the following information:

TAF SBBH 301600Z 3018/3106 06005KT 8000 BKN035 TX28/3018Z TN18/3106Z

TEMPO 3018/3022 TSRA BKN030 FEW040CB BECMG 3023/3101 13007KT RA SCT007 BKN030 RMK PGH

For the time interval surrounding the moment of the accident, the 16:00 UTC TAF of SBBH on 30 October 2020 had a forecast of broken clouds at 3,000 ft., as well as rain and thunderstorm.

The SIGWX (Significant Weather Chart), generated at 09:50 UTC on 30 October 2020, valid until 00:00 UTC of 31 October 2020, showed the presence of rain showers and embedded CBs (cumulonimbus clouds) with base at 2,700 ft and tops above FL 250.

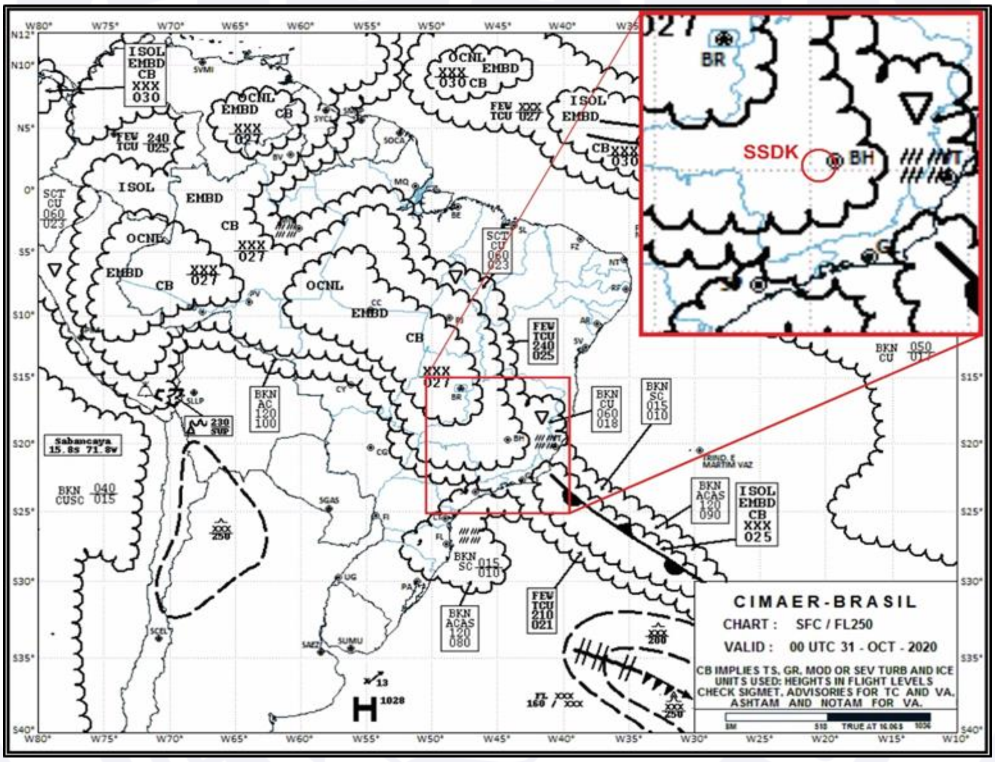


Figure 2 - SIGWX chart generated at 09:50 UTC on 30OCT2020.
Source: Command of Aeronautics' Meteorology Network (REDEMET).

The METARs of SBBH and SBCF, located respectively at 46 NM and 50 NM from the accident site, had the following information:

METAR SBBH 301900Z 09006KT 9999 FEW010 BKN040 BKN100 18/22 Q1013=

METAR SBBH 302000Z 00000KT 9999 BKN040 BKN080 23/19 Q1014=

METAR SBBH 302100Z 10007KT 9999 BKN040 BKN080 23/18 Q1015=

SPECI SBBH 302115Z 10002KT 4000 -RA SCT010 BKN020 OVC090 22/19 Q1015=

METAR SBCF 301900Z 02007KT 9999 TS VCSH FEW017 BKN035 FEW040CB BKN080 23/19 Q1013=

METAR SBCF 302000Z VRB02KT 9999 4000N TS -SHRA FEW010 SCT035 FEW040CB BKN100 22/19 Q1014=

METAR SBCF 302100Z 13003KT 100V180 9999 4000N -RA FEW010 BKN030 BKN070 21/20 Q1015 RETS=

According to the messages generated, the conditions observed around the time of the accident indicated thunderstorms, rain showers and visibility of 4,000 m at both aerodromes (located at a distance of 46 NM and 50 NM from SSDK).

The 20:50 UTC satellite image of 30 October 2020, channel 16, showed low clouds with characteristics indicative of the presence of precipitation west of SSDK.

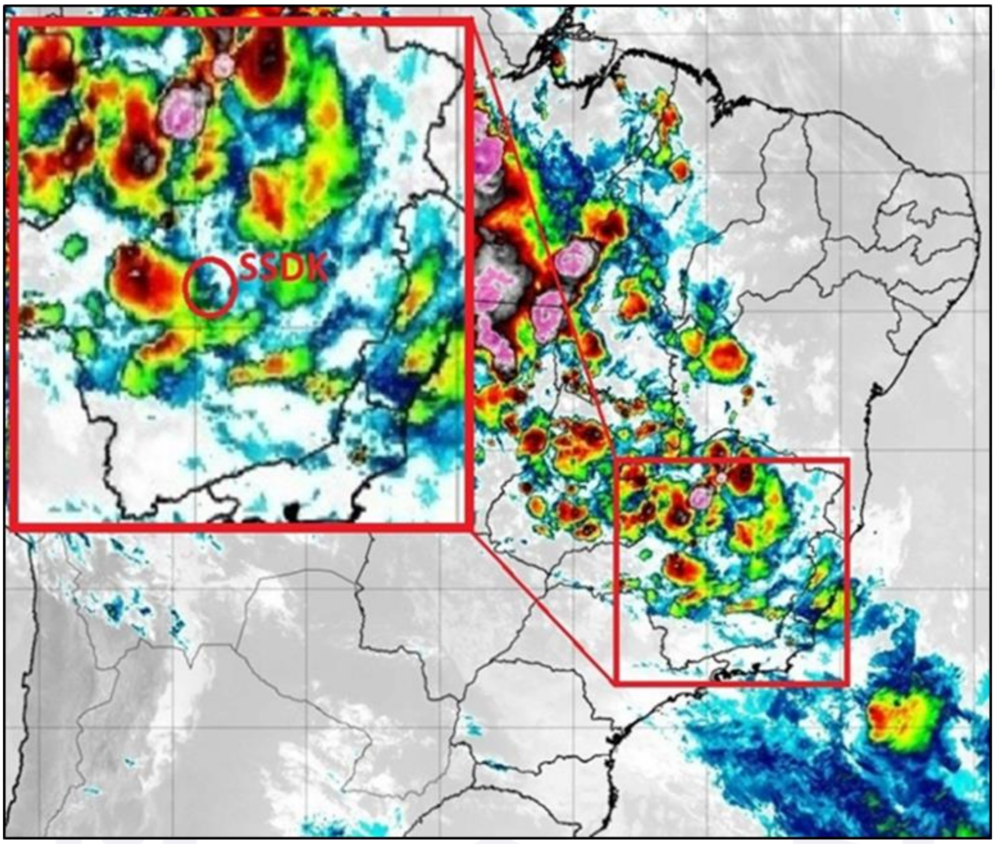


Figure 3 - GOES 16 satellite image channel 16, from 30OCT2020 at 20:50 (UTC).
Source: adapted from the Center for Weather Forecast and Climatic Studies (CPTEC).

According to accounts made by observers, there had been heavy rain before the arrival of the PR-LMP in SSDK.

The pilots involved in the accident stated that they were aware of the weather conditions in SSDK, and that they had been operating under VFR upon arrival at their destination.

1.8. Aids to navigation.

NIL.

1.9. Communications.

According to the audios of communication between the PR-LMP and the ATC units, it was possible to verify that the crew maintained satisfactory radio contact and that there were no technical abnormalities in the communication equipment during the flight.

1.10. Aerodrome information.

The aerodrome was private, under administration of *Predial J. M. Imobiliária e Participações S. A.*, and operated VFR, during day- and night-time.

The runway was paved with asphalt, with thresholds 11/29, measuring 1,300 m x 23 m, at an elevation of 2,728 ft.

The Investigation Commission identified a "facilities' manual" containing information on the operation in SSDK. This manual had the following information concerning approach/landing:

> 1,300-meter long asphalt runway;
>
> In radiotelephony communication phraseology, use the call-sign "*Aeroporto São Pedro*";
>
> Touchdown zone 500' and 1000' on both thresholds;
>
> Runway 29 with +1.51% gradient;
>
> SSDK Airport is included in the Jeppesen and Lufthansa Database; and
>
> Follow marshaller's directions for parking on the apron.

The manual also contained the following information regarding airport weather:

> Weather information can be obtained through the "Weather Wunderground" App. The search for "*Itauna*" will return to SSDK station, *São Pedro* Airport.

Official aeronautical information indicated that a Precision Approach Path Indicator (PAPI) was available for the threshold 11. The approach slope was set to 3.34° at that location.

In Figure 4, depicting a photograph taken during the investigation process, it is possible to observe a mirrored condition of the runway shortly after precipitation of heavy rain.

Figure 4 –Threshold 29 of SSDK: wet and mirrored surface after rainfall.

The mirrored condition observed in Figure 4 was similar to the one observed on the day of the accident, as shown in the image depicted in Figure 5 recorded by a passenger during approach for landing at the aerodrome in question on the day of the occurrence.

Figure 5 - Runway conditions on the day of the accident.

It was not possible to verify whether, besides water, there were other contaminants on the runway, which could reduce the coefficient of friction of the said runway.

One observed that the runway did not have transverse grooving for the drainage of water. The Investigation Commission did not identify a consistent behavior concerning the measurement of either the runway's coefficient of friction or the runway's macrotexture.

Since it was a private aerodrome, there were no requirements related to these aspects established by the ANAC (Brazil's National Civil Aviation Agency).

For this aerodrome, the operation of a Telecommunication and Air Traffic Service Provider Station (EPTA) to inform flight crews on the aerodrome conditions was not required.

1.11. Flight recorders.

The aircraft was equipped with a model FA2100, PN 2100-3083-50 CVDR (Cockpit Voice and Data Recorder) manufactured by *L3 Communication*.

The recorder was sent to the Cenipa's LABDATA (Flight Recorder Data Readout and Analysis Laboratory), where one successfully downloaded the pertinent data, and verified that the recordings were discontinued after the first impact.

1.12. Wreckage and impact information.

According to reports from the pilots, when they realized that it would not be possible to stop the aircraft within the runway limits, they commanded a turn to the right-hand side in search of a better escape area.

In the course of the initial investigation, the investigators identified continuous marks on the runway that ended at the point where the PR-LMP exited the runway.

The marks resulted from the "cleaning" action generated by the rubber of the aircraft tires in contact with the pavement (Figure 6).

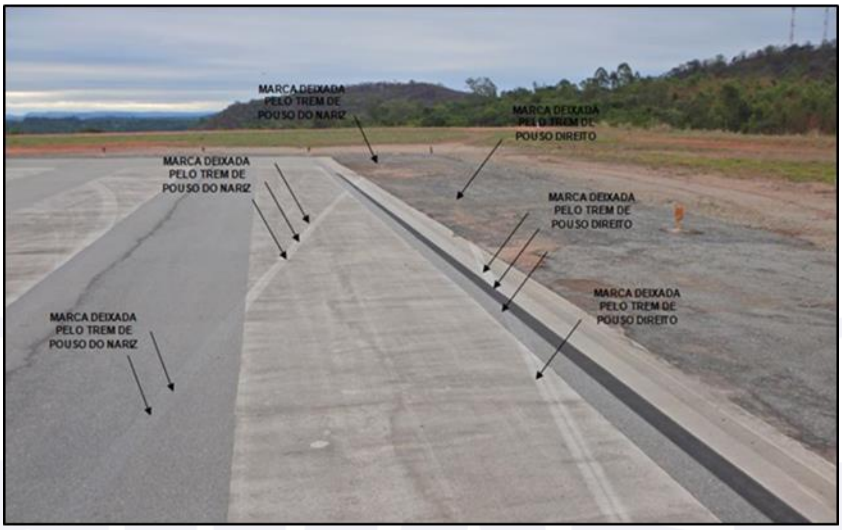


Figure 6 - Marks with an exit profile to the right-hand side of the threshold of runway 11 in SSDK.

From the physical evidence found at the site, it was possible to observe that the aircraft collided with an object on the ground that was outside the runway limits. The first impact on the aircraft occurred close to the tip of the right-hand wing and caused the loss of control.

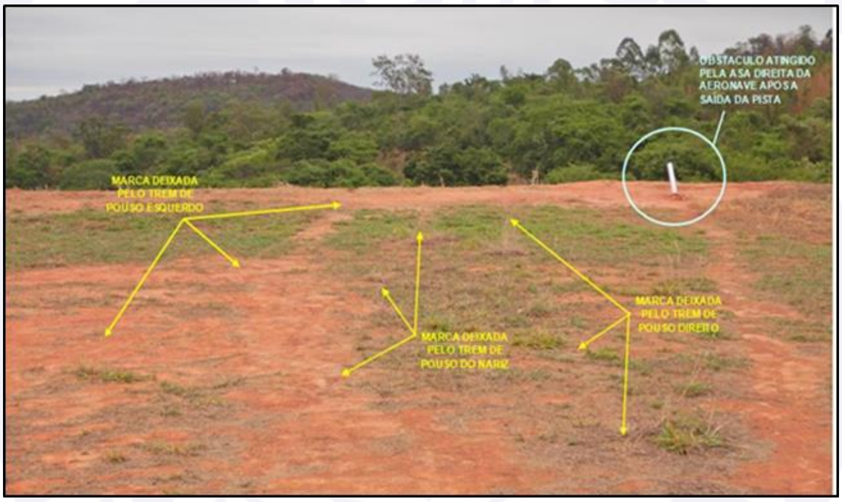


Figure 7 - Location of the first impact showing marks made by the aircraft's landing gear.

Figure 8 – Right-hand wing of the aircraft showing damage resulting from the impact with the obstacle after exiting the runway.

The relief in the area was predominantly irregular and contained trees in its surroundings.

A difference of approximately 10 meters in height was observed between the threshold of the SSDK runway 11 and the spot where the aircraft came to a rest.

Figure 9 - Location of the wreckage with a view of the ravine near the threshold of runway 11 in SSDK.

According to reports from the pilots, the engines continued running at high speed even after the complete stop, and the aircraft caught fire.

As a result, the cockpit, the passenger cabin, and other internal components of the aircraft were consumed by the fire.

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 crew's performance.

1.13.2. Ergonomic information.

NIL.

1.13.3. Psychological aspects.

The PIC was hired to work as an aircraft captain, and his activities in the company started in 2010.

As found by the Investigation Commission, the PIC would normally receive early information on the scheduled flights by means of email messages sent by the company's management, according to the owner's control notebook.

With respect to the accident flight, the mission consisted of transporting the Vice President of the company and a passenger between *São Paulo* and *Minas Gerais*.

According to the planning, although the PIC had already operated at the destination aerodrome (SSDK), he contacted another pilot who was based and operating at that location, in order to get up-to-date information.

From data gathered in interviews, it had rained before the aircraft landed, and the runway was wet. Despite being experienced on the route, the PIC had not conducted other flights under similar conditions in the locality.

Moments before landing, and after contacting the local radio operator, the PIC decided to make the approach to runway 29. He was aware of the runway conditions and, according to him, he sought to apply landing techniques that would allow the aircraft to stop within the shortest possible distance.

As reported in an interview, the positive slope (uphill) found when landing on runway 29, combined with the wind considered calm, were factors that influenced his decisions concerning the operation at that time, since it was close to the limits of the flight envelope of the aircraft and the runway was wet.

After touching down, the PIC had the perception that the aircraft was not decelerating as expected and, as a result, he decided to attempt a go-around. At that moment, he was alerted by the SIC that he had neither the speed nor enough runway length to successfully perform the procedure, and he gave up trying the go-around maneuver.

Given that scenario, it was not possible to maintain the aircraft within the runway limits, and the PIC decided to veer the aircraft trajectory to the right-hand side, where there was an escape area with fewer obstacles.

According to records verified by the Investigation Commission, the pilots would perform, on average, 1 to 2 flights per week, accumulating 14 to 25 flight hours per month. There was no evidence of excessive workload or fatigue in the crew.

Despite the presence of the company's Vice President on board, there was no external pressure, especially on the part of the aircraft operator, for the flight to be conducted under the conditions presented.

Based on the data collected by the investigators, the PIC possessed autonomy to abort the flight upon considering that something could put the operation at risk. In fact, he had already aborted flight legs before for not having favorable conditions for the flights.

As for his personal and professional life, the PIC declared that he was experiencing a balanced phase, without major adversities. The night before, he had had a good night's sleep. There were no reports of psychological issues that could interfere with or impact the operation.

The PIC and SIC knew each other before working together at the company, and had a friendly relationship.

1.14. Fire.

The pilots reported that, when performing the emergency evacuation procedures, they observed that it was not possible to shut down the engines using the ENG START/STOP knobs or the SHUTOFF 1 & 2 buttons.

The engines continued running during the procedures for evacuation of the passengers and crew. According to reports from the ones involved, a large amount of fuel was leaking from the wings, which provided the combustion material that gave rise to the fire.

The source of ignition possibly originated from the engines that remained at high speed after the aircraft stopped and could not be turned off after the impacts.

The aerodrome in SSDK did not have firefighting services. The local Fire Brigade was called to extinguish the fire, which was finally controlled about four hours after the accident.

Fig. 10 - Rear left-hand side view of the PR-LMP aircraft wreckage.

1.15. Survival aspects.

The people waiting for the arrival of the PR-LMP in SSDK were the first ones to attempt rescuing the victims of the accident.

As reported by observers, moments after the accident happened, smoke was coming from the place where the aircraft crashed. While approaching the crash site, the observers saw the aircraft on fire and the engines running noisily at high rpm.

At that time, the two crewmembers and the two passengers had already escaped from the accident site by their own means.

1.16. Tests and research.

The data retrieved from the CVDR allowed identifying the events related to the landing, with their respective distances in relation to the threshold of runway 11, as detailed in Figure 11.

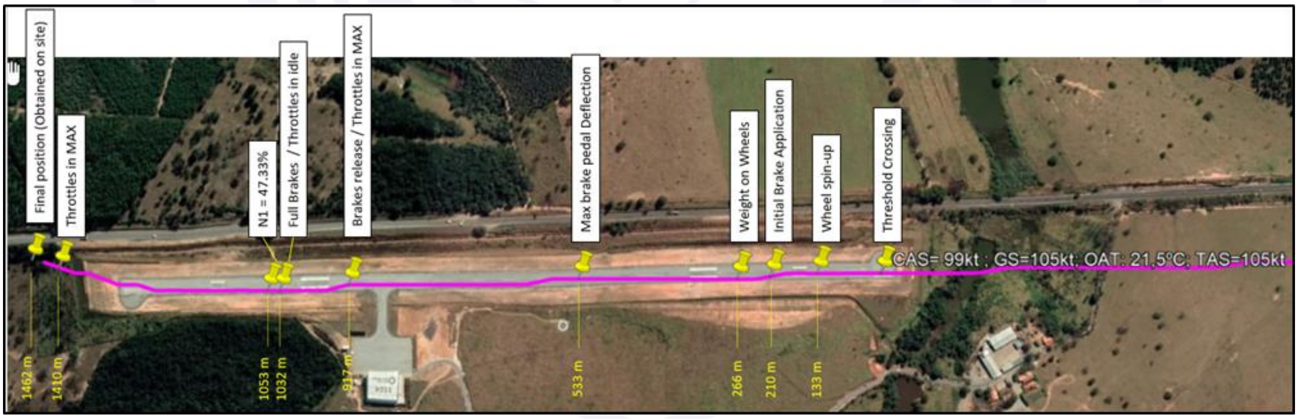


Figure 11 - Sequence of events during the landing with their respective distances in relation to the threshold of runway 11. Source: adapted from Google Earth.

Additionally, one also obtained the data shown in Figures 12, 13 and 14.

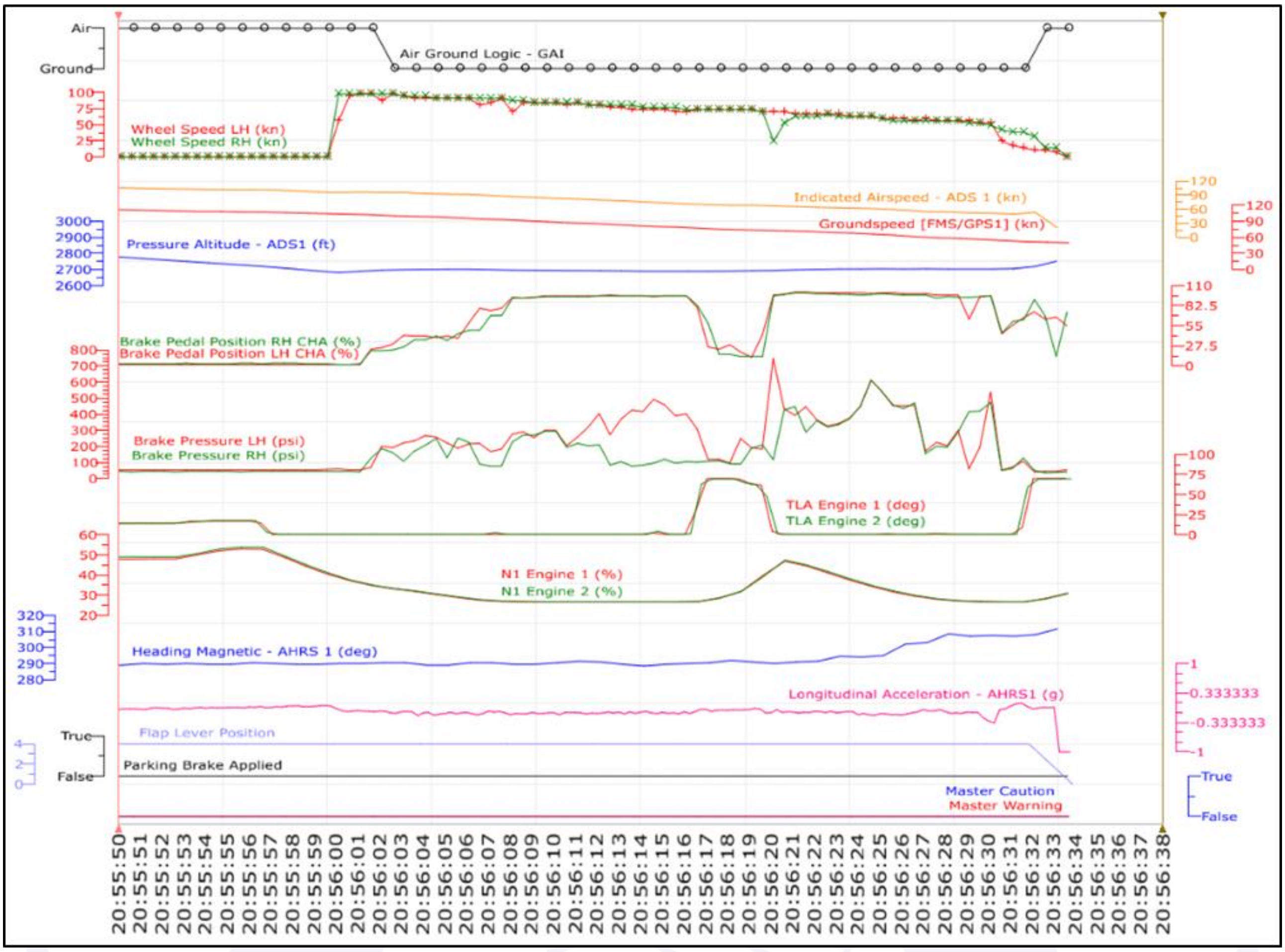


Figure 12 – Approach and landing data obtained through the CVDR Readout.

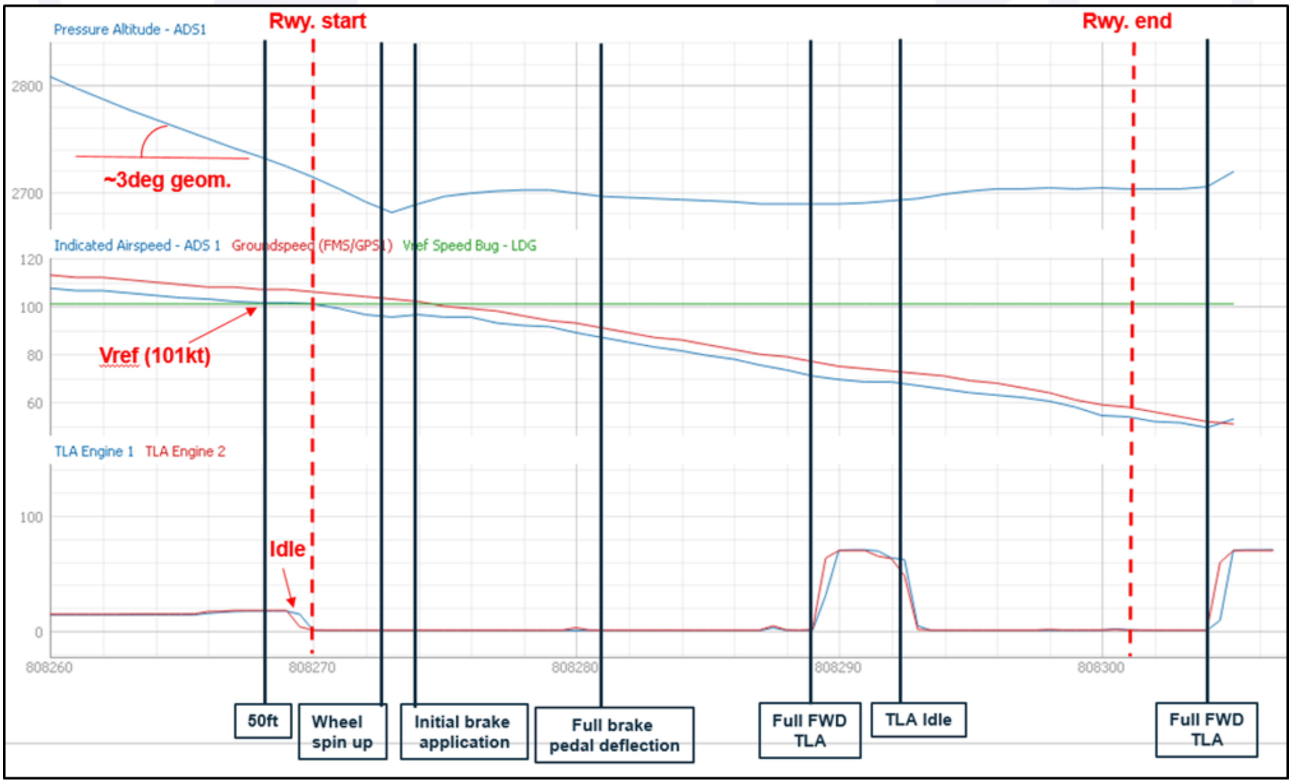


Figure 13 - Pressure altitude data, indicated speed, ground speed, and TLA (Thrust Lever Angle).

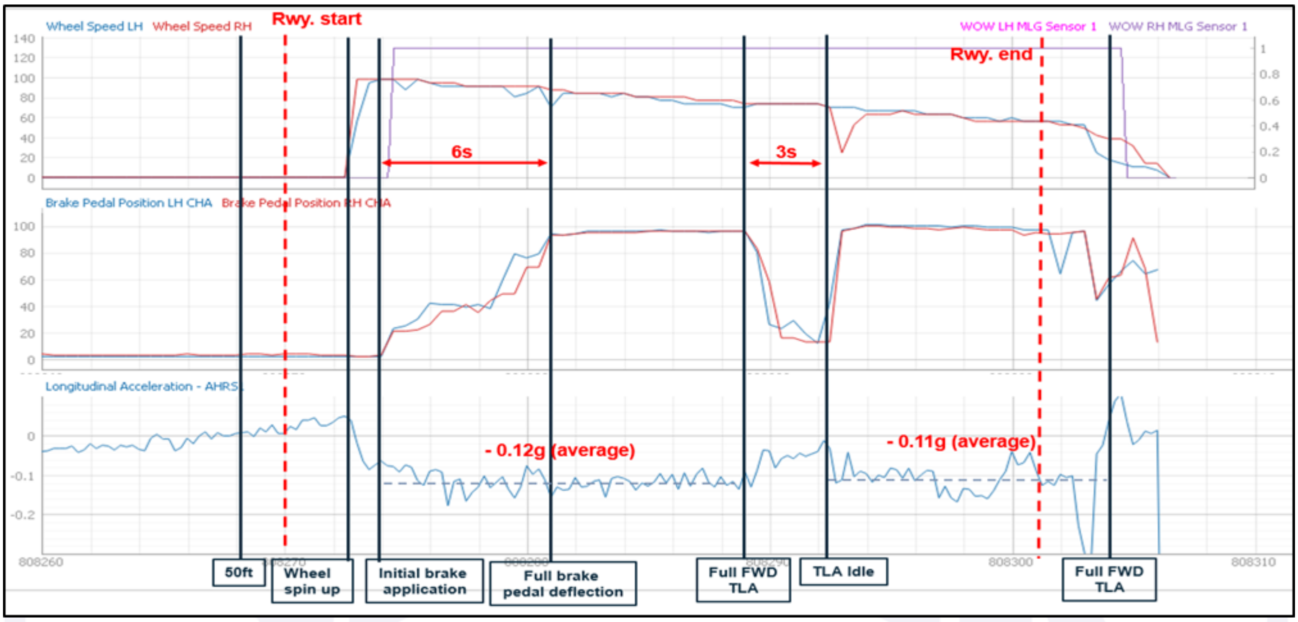


Figure 14 – Data on the speed of the wheels, position of the brake pedals, and longitudinal acceleration.

According to the manufacturer, the calculated values of actual landing distance (ALD) took into account an approach where the aircraft passed through 50 ft above the threshold at the reference speed, on a stabilized 3º-slope, and maximum application of the brakes immediately after touching down, as shown in Figure 15.

The required landing distance (RLD) was published by the aircraft manufacturer in the Aircraft Flight Manual (AFM), and considered the application of additional safety margin factors on top of the ALD.

The definitions of ALD and RLD, according to the ANAC, were as follows[1]:

> ALD: Actual Landing Distance. Distance required to land and brake the aircraft to a complete stop after crossing over the runway threshold at 50 feet. It does not include any additional safety margin factors, and represents the aircraft's best performance for the respective landing conditions.
>
> RLD: Required Landing Distance. Distance required to land and brake the aircraft to a complete stop. Obtained by applying additional safety margin factors to the ALD.

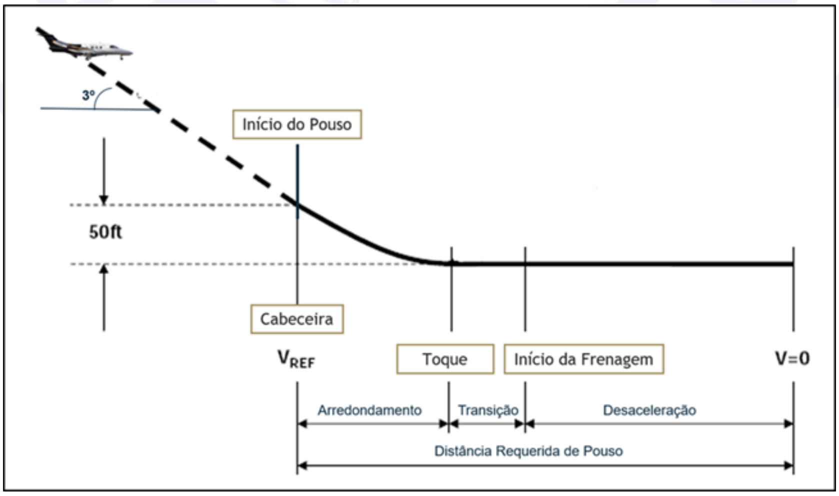


Figure 15 - Conditions considered for calculation of the required landing distance.

[1] Source: https://www.anac.gov.br/assuntos/legislacao/legislacao-1/boletim-de-pessoal/2020/48/anexo-iv-is-91-009a.pdf).

The analysis of the data recorded in the CVDR and the data of the diagrams revealed that:

- the reference speed for landing was 100 kt;

- the average ramp-angle utilized along the descent was approximately 3.9º;

- upon joining the final leg for landing, the aircraft was at a distance of 1.4 NM short of the runway, at a height of 578 ft., maintaining a speed of 126 kt, with a pitch-down angle of -7º, and at a rate of descent of approximately 1,500 ft/min. The average ramp-angle utilized from this point until passing the height of 50 ft was 3.8º;

- the aircraft passed through 50 ft AGL at a distance of approximately 130 meters short of the runway threshold;

- the speed at 50 ft was 101 kt., 1 kt above the Reference Speed (V_{REF}) calculated for the landing;

- the thrust levers were placed at *idle*, shortly after the aircraft passed through 28 ft AGL;

- the brakes started being applied 2 seconds after the main-gear wheels began to spin;

- the maximum deflection of the brake pedals was reached 6 seconds after the start of their application;

- when close to 370 m short of the departure end of the runway, the PIC commanded the thrust levers all forward and released the application of the brakes;

- 3 seconds later, the thrust levers were reduced to idle and the brake pedals were fully applied; and

- the aircraft exited the runway at a ground speed of approximately 58 kt.

Additionally, it was possible to collect information on the brake system through the data recorded in the CVDR. One found that the BRK FAIL or ANTISKID FAIL CAS messages were not activated during the event. The BRK FAIL message was displayed on the Multifunction Display (MFD) when there was a failure in the normal braking system, and the ANTISKID FAIL message was displayed when there was a failure in the anti-skid protection system.

In the diagram of Figure 16, it is possible to observe a consistent correlation between the electric current of the brake valve and the pressure of the brakes. The released pressure was in line with what was expected for the level of the current, which indicated that the valve was operating properly.

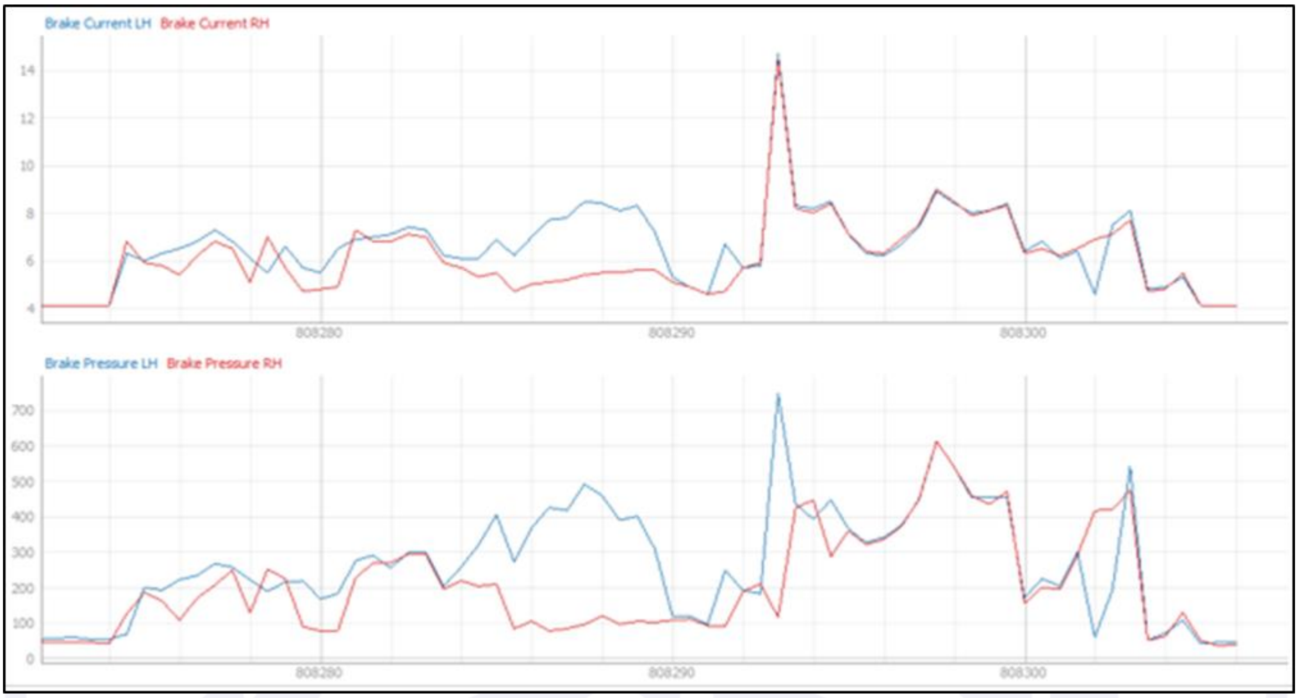


Figure 16 - Data on the brake valve and brake pressure currents.

When observing the speed of the wheels and the speed of the aircraft on the ground, with the exception of the moment when the brakes are released, one verified a positive braking action (Figure 17).

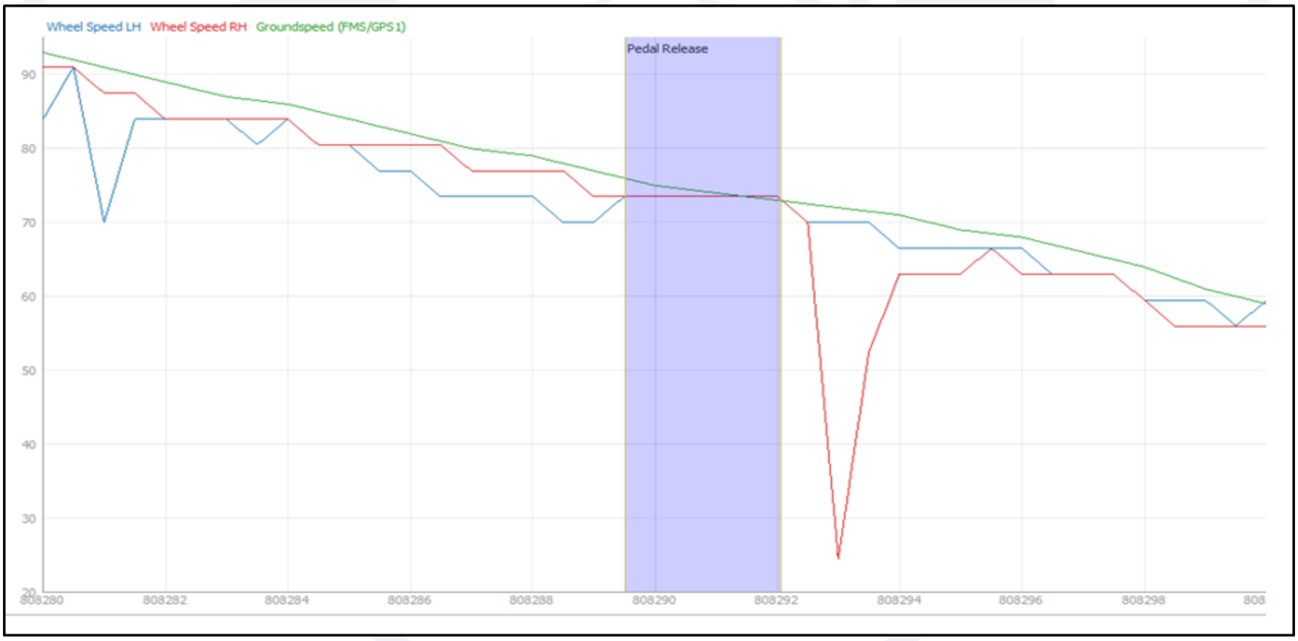


Figure 17 - Data on the speed of the wheels and on the aircraft ground-speed.

The analysis of the event involving the PR-LMP led to the conclusion that the brake pedals were activated in a gradual fashion until reaching their maximum amplitude.

Since no failure of system components was registered, the observed pressure indicated that the antiskid system actuation limited the pressure applied by the brakes to 747 PSI, as shown in Figure 18. The limitation of the pressure value is consistent with the normal operation of the brake system, and is associated with the condition of the runway.

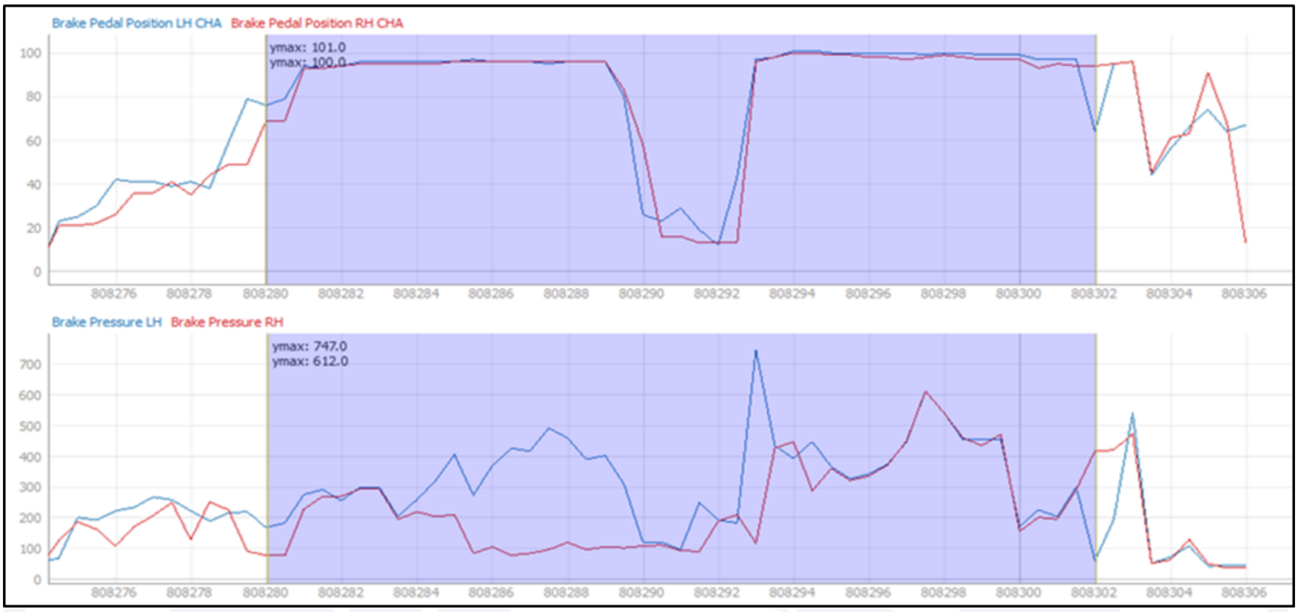


Figure 18 - Graphic representation of the performance of the braking system during the landing run of the PR-LMP.

Thus, the Investigation Commission did not identify any evidence in the recorded data that might indicate an anomaly or failure in the functioning of the systems/components of the PR-LMP capable of having compromised its operation.

1.17. Organizational and management information.

The pilots used to conduct private flights for the company's owners in accordance with the schedule of appointments defined by the very operator.

In addition to holding the position of aircraft captain, the PIC was also responsible for managing the logistical issues of the PR-LMP, in order to keep it available whenever necessary.

1.18. Operational information.

The flight plan details included taking off from the aircraft's base of operations in SBBH, on a flight bound for SBSP in order to pick up two passengers, followed by another leg to SSDK to disembark the passengers and, finally, a flight back to the home base in SBBH.

The aircraft took off from SBSP at 20:04 UTC to accomplish the second leg of the schedule.

The flight had been planned to be performed under Instrument Flight Rules (IFR) at the aerodrome of departure, and under VFR rules at the aerodrome of arrival.

According to reports from the pilots involved, all the planning was elaborated on the previous day with the help of the *Runway Analysis* function of the *Foreflight* application and, on that occasion, they considered that the operation of the PR-LMP in SSDK was feasible, even with a wet runway condition.

All documentation onboard the PR-LMP, including the cargo manifest, was destroyed when the aircraft caught fire. As a result, it was not possible to determine accurately the values considered for the planning of that operation.

The flight was uneventful until the arrival in SSDK. According to information given by the PIC, who had already operated in that location, the approach would be made to threshold of runway 11, which had a PAPI system available.

However, after considering the fact that the operation was being conducted during daytime, in addition to the fact that the average gradient of the threshold 29 was positive (1.51% uphill), and the received information of *wind calm*, the pilots decided to switch the threshold that they had initially planned for the landing, since the approach to the threshold 29 would possibly represent a better landing performance for the aircraft than the approach to the threshold 11.

As noted by the Investigation Commission, although the weather conditions were favorable for the operation under VFR, it had rained in the moments prior to the arrival of the aircraft in SSDK, causing the runway to be wet during the landing of the PR-LMP.

Considering the minimum runway distance necessary for the operation in SSDK under the conditions experienced on the day of the accident, the Investigation Commission sought information in the manuals made available by the manufacturer, in order to identify the parameters for a safe operation in that context.

The Aircraft Flight Manual (AFM) contained the unfactored landing distances in its Section 5. Distances were calculated based on the landing weight of the aircraft, the wind, flap position, and the altitude of the aerodrome.

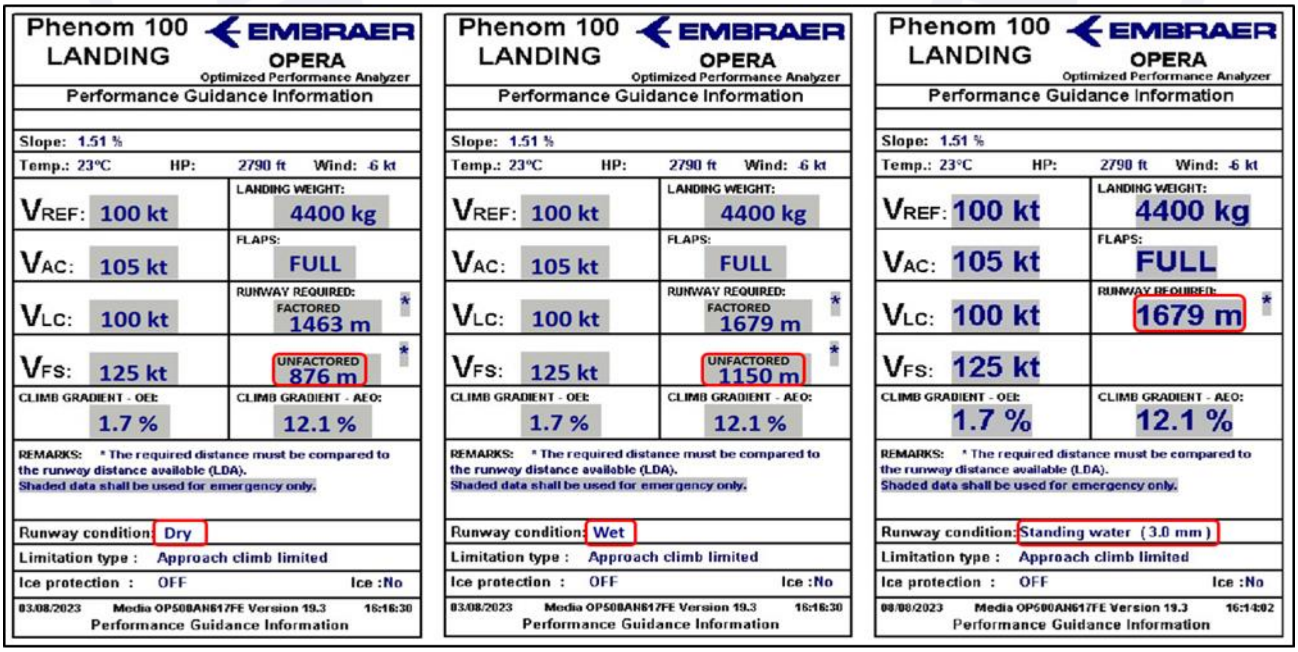
In SBSP, the aircraft was refueled to its maximum fuel capacity, in order to fly the SBSP-SSDK-SBBH segments without the need of refueling.

Considering the amount of fuel, as well as the weight of the passengers and luggage (as reported by the pilots), the landing weight in SSDK was estimated at approximately 4,400 kg.

According to reports from the pilots (confirmed by cabin communications recordings), the wind for landing at SSDK was considered calm.

According to the data obtained from the CVDR, as the PR-LMP passed through 50 ft AGL for landing, the ground speed of the aircraft was 6 kt. higher than the indicated airspeed, representing a 6-kt. tailwind, which was not expected by the crew.

After applying the conditions found at the time of landing in the EMBRAER's OPERA program, utilized for calculating the speeds on the approach and the distance necessary for landing, the results obtained showed that the minimum required distances (unfactored) would be 876 m for a dry-runway condition, 1,150 m for a wet-runway condition, and 1,679 m for a runway contaminated with 3 mm of water (Figure 19).



Phenom 100 LANDING — EMBRAER OPERA Optimized Performance Analyzer
Performance Guidance Information
Slope: 1.51 %
Temp.: 23°C HP: 2790 ft Wind: -6 kt
VREF: 100 kt | LANDING WEIGHT: 4400 kg
VAC: 105 kt | FLAPS: FULL
VLC: 100 kt | RUNWAY REQUIRED: FACTORED 1463 m *
VFS: 125 kt | UNFACTORED 876 m *
CLIMB GRADIENT - OEI: 1.7 % | CLIMB GRADIENT - AEO: 12.1 %
REMARKS: * The required distance must be compared to the runway distance available (LDA). Shaded data shall be used for emergency only.
Runway condition: Dry
Limitation type: Approach climb limited
Ice protection: OFF Ice: No
03/08/2023 Media OP508AN617FE Version 19.3 16:16:30
Performance Guidance Information

Phenom 100 LANDING — EMBRAER OPERA Optimized Performance Analyzer
Performance Guidance Information
Slope: 1.51 %
Temp.: 23°C HP: 2790 ft Wind: -6 kt
VREF: 100 kt | LANDING WEIGHT: 4400 kg
VAC: 105 kt | FLAPS: FULL
VLC: 100 kt | RUNWAY REQUIRED: FACTORED 1679 m *
VFS: 125 kt | UNFACTORED 1150 m *
CLIMB GRADIENT - OEI: 1.7 % | CLIMB GRADIENT - AEO: 12.1 %
REMARKS: * The required distance must be compared to the runway distance available (LDA). Shaded data shall be used for emergency only.
Runway condition: Wet
Limitation type: Approach climb limited
Ice protection: OFF Ice: No
03/08/2023 Media OP508AN617FE Version 19.3 16:16:30
Performance Guidance Information

Phenom 100 LANDING — EMBRAER OPERA Optimized Performance Analyzer
Performance Guidance Information
Slope: 1.51 %
Temp.: 23°C HP: 2790 ft Wind: -6 kt
VREF: 100 kt | LANDING WEIGHT: 4400 kg
VAC: 105 kt | FLAPS: FULL
VLC: 100 kt | RUNWAY REQUIRED: 1679 m *
VFS: 125 kt
CLIMB GRADIENT - OEI: 1.7 % | CLIMB GRADIENT - AEO: 12.1 %
REMARKS: * The required distance must be compared to the runway distance available (LDA). Shaded data shall be used for emergency only.
Runway condition: Standing water (3.0 mm)
Limitation type: Approach climb limited
Ice protection: OFF Ice: No
08/08/2023 Media OP500AN617FE Version 19.3 16:14:02
Performance Guidance Information

Figure 19 - Calculation of the necessary landing distances.

The definition of a contaminated runway, as per the ANAC, was as follows:

> A runway on which more than 25% of the length being used is covered with a sheet of standing water or other type of contaminant (e.g., ice, slush, or snow) with a thickness greater than 3 mm. One also considers contaminated a runway in which the contaminant covers less than 25%, but is covering an area relevant to the operation, such as, for example, the area of rotation and liftoff or the segment of the runway where the plane is at high speed at takeoff where the drag effect is most relevant. (Source: https://www2.anac.gov.br/anacpedia/por-por/tr3616.htm).

In order to support the analysis of the sequence of events that preceded the aircraft's runway excursion, the Investigation Commission highlighted the latest pilot-to-pilot interactions, which might help in understanding the dynamic of the accident (recorded in UTC time):

- At 20:54:43, the SIC informs the PIC "*Gear down and locked*".
- At 20:54:55, the SIC sends the message to a radio operator on the ground, stating that the aircraft is turning "**de base para final da pista 29**" ("*From base leg to final of runway 29*").
- At 20:55:06, the SIC informs the PIC "*Flaps two!*" Shortly afterwards, the PIC makes a "*Flap full*" request, which was carried out accordingly by the SIC.
- At 20:55:20, the radio operator on the ground calls the PR-LMP aircraft with the message "**na escuta, prossiga**" ("*Listening, go ahead*"). At that moment, the SIC reports "**final da 29**" ("*On the final to runway 29*") and the radio operator answers "**beleza, bom pouso**" ("*Great, good landing!*").

The above communication took place in parallel with the "*five hundred*" callout issued by the TAWS (Terrain Awareness Warning System) of the aircraft. At that moment, the aircraft had a speed of 126 kt, a pitch attitude of -6º (nose down), and a rate of descent of approximately 1,300 ft/min. At that moment, the thrust levers were at *idle*.

The Section 4 of the manufacturer's SOP (Standard Operating Procedures) specified that the aircraft should be stabilized at a height of 500 ft under visual conditions, otherwise a go-around must be initiated. In accordance with the manufacturer, the stabilized approach criteria were[2]:

> – the aircraft is on the correct trajectory;
>
> – only small variations in heading and pitch are needed to maintain the trajectory;
>
> – the aircraft speed is neither greater than Vref + 20 kt, nor less than the Vref;
>
> – the aircraft is correctly configured for landing;
>
> – the rate of descent does not exceed 1000 ft/min. If the approach requires a rate of descent greater than 1000 ft/min, a special briefing must be given;
>
> – the power of the engines is appropriate for the configuration of the aircraft;
>
> – all briefings and checklists were accomplished;
>
> – ILS approaches must be flown within a dot range of the glideslope and localizer.

- At 20:55:33, the SIC informs the PIC of the conditions detected by the sensors onboard the aircraft: "**vento calmo, 3 kt de cauda**" ("*Wind calm, 3-kt. tailwind*").
- At 20:56:02, moments after the aircraft touched down on the runway, in the internal communication between the pilots, the PIC declares "**aí não tem capricho, sacou?**" ("*There's no way to do it top level, got it*?"). Immediately, the SIC says "**não tem**." ("*No, there isn't*.")

At interviews, the pilots reported having performed a landing without postponing contact with the runway, in accordance with the techniques normally used for that runway condition.

[2] Source: Embraer Phenom 100/300 Standard Operating Procedures Manual, Section 4-00, Page 41.

- At 20:56:13, the PIC says "**para não,"** ("*It never stops, dude!*"), and the SIC replies "**é... não para**" ("*Yeah... it never stops!"*).

At that moment, according to the pilots, the perception of an abnormal deceleration of the aircraft was verbalized.

- At 20:56:17, the PIC released the brakes and pulled the power levers fully forward, which, according to him, was an attempt to go since the aircraft was not decelerating as expected. The indicated speed was 79 kt and there were just 370 m left to the end of the runway.
- At 20:56:20, the SIC issues the following alert: "**não dá pra arremeter, não!**" ("*No chance to go around!*"). Immediately, the PIC reduced the thrust levers and applied the brakes again at their maximum amplitude in an attempt to stop the aircraft. The indicated speed was 69 kt and there were 260 m left to the end of the runway.
- At 20:56:28, the CVDR recorded sounds compatible with departure of the aircraft from the runway. At that time, the indicated speed was 54 kt.
- At 20:56:34, the recordings were interrupted on account of the impact.

The pilots reported that on the accident flight there was a low perception of the PR-LMP braking in SSDK.

In accordance with the data extracted from the CVDR, there was no failure recorded in the brake system.

According to the pilots and to the CVDR data, the emergency brake system was not utilized.

1.19. Additional information.

NIL.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

The Phenom-100 aircraft, with registration marks PR-LMP, was registered in the TPP category, and was operated by TRACBEL S/A.

The aircraft was engaged on a flight for the transport of passengers from SBSP to SSDK. The flight was planned to be performed IFR at the departure aerodrome, and VFR at the aerodrome of arrival.

Based on the communication records analyzed and on reports of the crew involved, one found that there were no technical abnormalities in the communication equipment during the flight.

According to maintenance records, the airframe and engine logbooks were up-to-date.

The Investigation Commission did not identify any evidence in the recorded data that might indicate any anomaly or failure in the functioning of the systems/components of the PR-LMP that could have compromised the operation of the aircraft.

Meteorological information available indicated the presence of precipitation and visibility restrictions at aerodromes close to SSDK. In addition, observers reported the occurrence of heavy rain before the arrival of the accident aircraft.

The pilots involved in the accident stated that they were aware of weather conditions at SSDK, and that they were operating VFR upon arrival at their destination.

At the time of the accident, a PAPI system was available for the threshold of runway 11 in SSDK. However, despite the existence of the aforementioned landing aid, the positive slope (uphill) of the opposite runway, combined with the calm wind information interpreted by the crew, led them to choose to land on runway 29 instead.

Considering the approach and landing profile adopted, one observed operational deviations during the approach. The aircraft passed 500 ft AGL at a speed of 126kt (26 kt above Vref), at a descent rate of approximately 1,300 ft/min, with a pitch attitude of -6º, maintaining an approach ramp angle of 3.9º. The manufacturer's SOP required the approach to be stabilized when the aircraft reached 500 ft AGL on a visual approach, otherwise a go-around should be initiated.

Although operational deviations were observed and a go-around maneuver was not performed, the Investigation Commission concluded that such deviations did not influence the aircraft's braking performance significantly.

With regard to the wind condition, it should be noted that, in accordance with the data extracted from the CVDR, when the PR-LMP passed through 50 ft AGL on the approach for landing, one verified that the ground speed of the aircraft was 6 kt higher than its indicated airspeed, representing a 6-kt tailwind not expected by the crew.

The fire subsequent to the accident consumed all the documentation onboard the PR-LMP, including the cargo manifest. As a result, it was not possible to accurately determine the values considered for the planning of that flight. However, according to reports from the pilots, the aircraft was within the weight and balance limits specified by the manufacturer.

Considering the amount of fuel, as well as the weight of passengers and luggage (as reported by the pilots), the landing weight in SSDK was estimated at approximately 4,400 kg.

With the aid of the *Runway Analysis function* of the *Foreflight application*, the pilots considered that the operation of the PR-LMP in SSDK was feasible, even with the wet-runway condition.

In the context of the landing in question, there was a 6-kt tailwind component recorded by the data recorders. For this reason, the landing distance for a dry-runway condition would be 876 m; for a wet runway, the distance would be 1,150 m, whereas for a contaminated runway such distance would be 1, 679 m.

When comparing the aircraft performance data to the runway length in SSDK, it is possible to observe that the operation in a contaminated runway condition would not be possible, since the minimum length required would be greater than the 1,300 m of runway available.

Despite no abnormalities were evidenced relatively to the aircraft's systems, the pilots reported having had the perception that the aircraft was not decelerating as expected at the time of the landing roll at SSDK.

With regard to performance, the data recorded in the CVDR suggest that the delay in applying a maximum deflection of the brake pedals, as well as the momentary movement of the thrust levers forward, associated with the release of the brakes, had a nonessential effect on the event, in view of the slippery condition of the runway.

Despite the crewmembers' report, the research aimed to verify the correct functioning of the normal brake system, including the antiskid actuation, led to the conclusion that the low deceleration of the aircraft and the limitation of the hydraulic pressure provided by the system were compatible with a slippery runway scenario.

The investigators observed that the runway did not have transverse grooving for water drainage. The Investigation Commission did not identify a routine of measurement of the coefficient of friction or measurement of the macrotexture of the runway by the aerodrome operator. As it was a private aerodrome, there were no requirements concerning these aspects established by the ANAC.

The investigation verified that, after the occurrence of heavy rain, the SSDK runway was susceptible to the formation of pools of water and showed, notably, a mirrored characteristic, consistent with the reflection of light in accumulated water. The accumulation of water may have favored the phenomenon of aquaplaning in the occurrence in question.

Under the conditions observed on the day of the accident, the aerodrome in SSDK was suitable for the operation of the PR-LMP with either a dry or wet runway, however, it did not meet the length parameters for contaminated-runway situations.

Thus, since no failures were identified in the aircraft's brake system, the hypothesis considered was that the runway was contaminated, which would have reduced braking performance, making it impossible for the aircraft to stop within the runway limits.

3. CONCLUSIONS.

3.1. Findings.

a) the pilots held valid CMAs (Aeronautical Medical Certificates);

b) the pilots held valid ratings regarding EPHN type aircraft (which included the EMB-500 model) and IFRA (IFR Flight – Airplane);

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

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

e) the records of airframe and engine logbooks were up to date;

f) there was no evidence of failures or malfunctioning of systems and/or components that could have affected the performance or control of the aircraft;

g) meteorological information indicated the presence of precipitation and visibility restrictions at aerodromes close to SSDK;

h) during the investigation process, one observed the mirrored condition of the runway shortly after the occurrence of heavy rainfall;

i) the aircraft landed on the runway 29 of SSDK;

j) the aircraft traveled the full length of the runway, and exceeded the runway limits;

k) after exiting the runway, the aircraft collided with an object on the ground, traveled approximately 130 m, fell from a height of approximately 10 meters and caught fire;

l) the cockpit, the passenger cabin, as well as other internal components of the aircraft were consumed by fire;

m) the crew and passengers suffered minor injuries; and

n) the aircraft was destroyed.

3.2. Contributing factors.

Airport infrastructure – undetermined.

Studies and research showed that the low deceleration of the aircraft and the limitation of the hydraulic pressure provided by the brake system were compatible with a slippery-runway scenario.

Thus, one inferred that the runway was contaminated, a condition that would reduce its coefficient of friction and impair the aircraft's braking performance, making it impossible to stop within the runway limits.

Decision-making process – undetermined.

On account of the mirroring condition of the runway in SSDK, it is possible that the crew had some difficulty perceiving, analyzing, choosing alternatives, and acting appropriately, given a possible inadequate judgment of the aircraft's landing performance on contaminated runways.

4. SAFETY RECOMMENDATIONS

None.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

In November 2022, the CENIPA published the Final Reports of the 10 September 2016 accident involving the PT-MMP aircraft, and the 31 October 2017 serious incident with the PT-IVI aircraft. The occurrences above received the typification of runway excursion, with involvement of EMB-500 aircraft.

In March 2023, the Final Report of a serious incident with the PR-CSW was published, again with a runway excursion involving an EMB-500 aircraft.

In the Final Report of the occurrence which affected the PR-CSW, a Safety Recommendation was forwarded to ANAC, recommending that the lessons learned in the investigations were forwarded to the CTACs (Civil Aviation Training Centers) authorized to deliver theoretical and practice instructions in EMB-500 aircraft, with the aim of promoting good practices and recommendations for landing procedures, as well as encouraging consultation of documents published by the aircraft manufacturer.

On, November 22th, 2023.