# COMMAND OF AERONAUTICS

## AERONAUTICAL ACCIDENT INVESTIGATION AND PREVENTION CENTER

# FINAL REPORT
# A - Nº 019/CENIPA/2013

| | |
|---|---|
| **OCCURRENCE:** | **ACCIDENT** |
| **AIRCRAFT:** | **PR-NOB** |
| **MODEL:** | **L410** |
| **DATE:** | **13 JULY 2011** |

# 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 trigger this occurrence.***

***The document is not focused 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 item 3.1, Annex 13 of the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.***

***Moreover, 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.***

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## SYNOPSIS

This is the Final Report of the 13 July 2011 accident involving the model L410 aircraft, registration PR-NOB. The accident was classified as inflight engine failure.

When the aircraft got airborne during the takeoff, the left engine failed. The crew proceeded on a single engine departure. In the attempt to return for landing, an inflight loss of control occurred, and the aircraft crashed into the ground.

All occupants (fourteen passengers and two crewmembers) perished in the crash.

The aircraft sustained serious damage.

The Czech Republic designated an accredited representative and advisors to take part in the investigation.

## GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

| | |
|---|---|
| ABC | Automatic Bank Control |
| AFM | Aircraft Flight Manual |
| AGL | Above Ground Level |
| AI | Aircraft Industries |
| AMM | Aircraft Maintenance Manual |
| ANAC | (Brazil’s) National Civil Aviation Agency |
| ASDA | Accelerate and Stop Distance Available |
| CCF | Medical Certificate |
| CENIPA | (Brazil’s) Aeronautical Accident Investigation and Prevention Center |
| CFR | Code of Federal Regulations |
| CG | Center of Gravity |
| CHT | Technical Qualification Certificate |
| CMM | Coordinate Measuring Machine |
| CRM | Crew Resource Management |
| CVR | Cockpit Voice Recorder |
| DCTA | (Brazil’s) Aerospace Science and Technology Department |
| EDS | Energy-Dispersive X-ray Spectroscopy |
| FAA | Federal Aviation Administration |
| FAP | Pilot Evaluation Form |
| FCU | Fuel Control Unit |
| FPI | Fluorescent Penetrant Inspection |
| GGT | Gas Generator Turbine |
| IFR | Instrument Flight Rules |
| INFRAERO | Brazilian Enterprise for Airports Infrastructure |
| INSPAC | Civil Aviation Inspector |
| IPEV | (Brazil’s) Institute for Research and Testing in Flight |
| KIAS | Knots-Indicated Airspeed |
| LABDATA | (CENIPA’s) Flight Recorder Data Readout and Analysis Laboratory |
| Lat | Latitude |
| LDA | Landing Distance Available |
| Long | Longitude |
| MEL | Minimum Equipment List |
| METAR | Meteorological Aerodrome Report |
| MGO | General Operations Manual |

| | |
|---|---|
| MLTE | Terrestrial Multi-Engine Aircraft |
| MPR | (ANAC's) Procedure Manual |
| NOAR | *Nordeste Aviação Regional Linhas Aéreas Ltda* |
| NSCA | Command of Aeronautics' System Norm |
| NTSB | National Transportation Safety Board (USA) |
| OEI | One Engine Inoperative |
| PCM | Commercial (Airplane) Pilot License |
| PIC | Pilot-in-Command |
| PLA | Airline Transport Pilot (Airplane category) |
| PLAH | Airline Transport Pilot (Helicopter category) |
| PPR | Private Pilot (Airplane category) |
| PrTop | Operational Training Program |
| QRH | Quick Reference Handbook |
| QTC | GE – Quality Technology Center |
| RA | Radio- Altimeter |
| RESA | Runway End Safety Area |
| RBAC | Brazilian Civil Aviation Regulation |
| RBHA | Brazilian Aeronautical Certification Regulation |
| RSV | Flight Safety Recommendation |
| SBRF | ICAO location designator – *Gilberto Freire (Guararapes)* Airport |
| SBMO | ICAO location designator – Zumbi dos Palmares (Maceió) Airport |
| SBNT | ICAO location designator - *Augusto Severo* Airport |
| SEM | Scanning Electron Microscope |
| SIPAER | (Brazil's) Aeronautical Accidents Investigation and Prevention System |
| S/N | Serial Number |
| SOP | Standard Operating Procedures |
| SSFDR | Solid State Flight Data Recorder |
| TBO | Time Between Overhauls |
| TEAM | *Transportes Especiais Aéreos e Malotes Linhas Aéreas Ltda.* |
| TODA | Take-off Distance Available |
| TORA | Take-off Runway Available |
| TWR-RF | Recife Aerodrome Control Tower |
| UTC | Universal Time Coordinated |
| V1 | Critical engine failure recognition speed |
| V2 | Takeoff safety speed |

| | |
|---|---|
| $V_{EF}$ | Calibrated speed at which the critical engine is assumed to fail at takeoff |
| VMC | Visual Meteorological Conditions |
| $V_{MCA}$ | Minimum Control Speed in the Air |
| VR | Rotate Speed |
| WAT | Weight, Altitude and Temperature |

| | | |
|---|---|---|
| **AIRCRAFT** | **Model:** L410UVP-E20<br>**Registration:** PR-NOB<br>**Manufacturer:** LET Aircraft Industries | **Operator:**<br>*NOAR – Nordeste Aviação Regional Linhas Aéreas Ltda* |
| **OCCURRENCE** | **Date/time:** 13 July 2011 / 0954 UTC<br>**Location:** Visconde de Jequitinhonha Av.<br>**Lat:** - 08°09'08" S – **Long:** - 034°54'34" W<br>**Municipality–State:** Recife –Pernambuco | **Type:**<br>Inflight Engine Failure |

# 1 FACTUAL INFORMATION

## 1.1 History of the flight

At 0650 local time, the aircraft departed from SBRF runway 18, destined for SBNT, carrying fourteen passengers and two crewmembers on a regular public transportation flight.

During the takeoff, after the aircraft passed over the departure end of the runway, the copilot informed that they would return for landing, preferably on runway 36, and requested a clear runway.

The aircraft made a deviation to the left, out of the trajectory, passed over the coastline, and, then, at an altitude of approximately 400ft, started a turn to the right over the sea (Figure 1).

After about 90º of turn, upon getting close to the coast line, the aircraft reverted the turn to the left, going farther away from the coast line.

After a turn of approximately 270º, it leveled the wings and headed for the airport area. The copilot informed, while the aircraft was still over the sea, that they would make an emergency landing on the beach.


Figure 1 - Profile of the flight trajectory according to the flight data recorder.

Witnesses reported that, as the aircraft was crossing over the coast line, the left propeller seemed to be feathered and turning loosely.

At 0654 local time, the aircraft crashed into the ground in an area without buildings, between *Boa Viagem* Avenue and *Visconde de Jequitinhonha* Avenue, at a distance of 1,740 meters from the runway 36 threshold. A raging post-impact fire occurred.

### 1.2 Injuries to persons

| Injuries | Crew | Passengers | Third parties |
|---|---|---|---|
| Fatal | 02 | 14 | - |
| Serious | - | - | - |
| Minor | - | - | - |
| Unhurt | - | - | - |

### 1.3 Damage to the aircraft

The aircraft was completely destroyed.

### 1.4 Other damage

Nil.

### 1.5 Personnel information

### 1.5.1 Information on the crewmembers

| HOURS FLOWN | | |
|---|---|---|
| | PILOT | COPILOT |
| Total | 15,457:45 | 2,404:35 |
| Total in the last 30 days | 68:35 | 76:15 |
| Total in the last 24 hours | 00:00 | 00:00 |
| In this type of aircraft | 957:45 | 404:35 |
| In this type in the last 30 days | 68:35 | 76:15 |
| In this type in the last 24 hours | 00:00 | 00:00 |

NB.: The data relative to the hours flown was provided by the operator.

#### 1.5.1.1 Professional training

The pilot in command (PIC) received his wings at the Brazilian Air Force Academy in 1965.

The copilot did the Private Pilot Course (Airplane category) in the *Aeroclube de Pernambuco* in 1978.

#### 1.5.1.2 Validity and category of licenses and certificates

The PIC had an Airline Transport Pilot (Airplane category) license, and his Technical Qualification Certificates regarding L410 type aircraft, Terrestrial Multi-Engine aircraft (MLTE), and IFR rating were valid.

The copilot had a Commercial Pilot (Airplane category) license, and his Technical Qualification Certificates regarding L410 type aircraft, Terrestrial Multi-Engine aircraft (MLTE), and IFR rating were valid.

**1.5.1.3 Qualification and flight experience**

Both the PIC and the copilot were qualified and had a level of experience appropriate to the flight.

The PIC had an experience of more than 46 years in aviation. He had begun his career in the Brazilian Air Force, where he flew twin-engine aircraft, such as the B-25, B-26, C-45, C-91 (Avro - Hawker Siddeley 748), C-95 (EMB-110) and Learjet 35, in addition to the four-engine B-17 and C-130. Still as a military pilot, he flew UH-1H and CH-33 helicopters. After retiring, he earned an Airline Transport Pilot (Airplane category) license in 1997, as well as an Airline Transport Pilot (Helicopter category) in 1999. In the civil aviation area, he flew Boeing 707 and ATR-300 aircraft.

The copilot flew as pilot-in-command of C-172, C-182, C-206 and PA-34 single-engine aircraft between the years 1993 and 2008. His twin-engine aircraft experience began with the L-410.

**1.5.1.4 Validity of the medical certificate**

The pilots held valid Medical Certificates (CCF).

**1.6 Aircraft information**

The high-wing twin-engine aircraft, model L410UVP-E20, serial number 2722, registered in the Regular Public Transport category, with a capacity of 19 (nineteen) occupants (2 pilots and seventeen passengers), was manufactured by LET Aircraft Industries in 2010, and was purchased as a brand new product.

Under the PR-NOB registration, it was the second L410 aircraft operated by the company. It arrived in Brazil on 10 June 2010 and started commercial operations on 27 July 2010.

The Airworthiness Certificate was valid.

The airframe, engine and propeller logbooks were up-to-date.

The last Check P2 aircraft inspection (300 hours) was performed by the Nordeste Aviação Regional Linhas Aéreas Ltda. Company (NOAR) in Recife, State of Pernambuco, on 10 July 2011, and after the inspection the aircraft flew a total of 21 hours and 18 minutes.

The last Check P3 aircraft inspection (1,200 hours) was conducted by *TEAM Linhas Aéreas* in Rio de Janeiro, State of Rio de Janeiro, on 30 January 2011, and the aircraft flew a total of 895 hours and 18 minutes thereafter.

The aircraft, which had a total of 3,033 FC (flight cycles) and a total of 2,126 hours and 12 minutes, had not yet reached the parameters requiring the first overhaul (Check P4 - 2,400 hours).

At the time of the accident, the aircraft was equipped with two M601E engines manufactured by the GE Aviation Czech, with serial numbers 101001 (number 1/left) and 914025 (number 2/right).

The number 1 engine was manufactured by GE Aviation Czech in January 2010, and had flown a total of 2,126 hours and 12 minutes since then.

Its last inspection (Type 3, according to the Turboprop Engine Maintenance Manual Models M601E and M601E-21 - Revision 3) was conducted by technicians of the GE Aviation Czech from the Czech Republic at the premises of NOAR in Recife on 10 July 2011, during the P2 Check of the aircraft.

This engine flew 21 hours and 18 minutes after that last inspection, and had not yet reached the maintenance program parameters requiring it to be overhauled.

The number 2 engine had a total of 6,154 hours and 23 minutes, being 539 hours and 14 minutes after the last overhaul, and 21 hours and 18 minutes after the last inspection performed during a P2 Check on 10 July 2011.

The engine maintenance program established the execution of overhauls every 3,000 flight hours (TBO - Time between Overhauls), 6,660 cycles, or 5 calendar years, whichever occurred first.

The first aircraft operated by the company, registration PR-NOA, arrived in Brazil on 12 March 2010, and was also purchased as a brand new product directly from the factory. It started operational activities on 06 April 2010.

Upon receipt of the PR-NOB, the operator began to receive support from a LET Aircraft Industries technical representative, who remained in Brazil for a few months.

This technician warned of the need to comply with a service bulletin of non-mandatory nature (M601E/40R-1) to detect possible wear of internal engine parts, especially the combustion chamber.

The service bulletin was issued on 16 January 2009, and was applicable to several models of the M601 engine family with over 1,000 hours accumulated, including the M601E, which equipped the operator’s aircraft.

The bulletin contained manufacturer’s instructions concerning the execution of a boroscopic exam during the inspection of 300 hours, as well as the actions that had to be taken according to the test results (Figure 2), namely:

- Wear less than 50% - repeat boroscopic exam at least in the third subsequent inspection of 300 hours, i.e., a maximum 900 flight hours after the last boroscopic exam;
- Wear greater than or equal to 50% but less than 70% - repeat verification at every inspection of 300 hours, reporting the fact to the engine manufacturer, and
- Wear greater than 70% - replace the combustion chamber support before the next operation of the aircraft, reporting the fact to the engine manufacturer.

Upon compliance with the service bulletin, the maintenance personnel found it necessary to change both PR-NOA engines, with approximately one year of operation, and a TBO below 3,000 hours, on account of internal wear of the combustion chamber support, and also on account of corrosion at high temperatures in the engine hot section.

b. Wear evaluation:

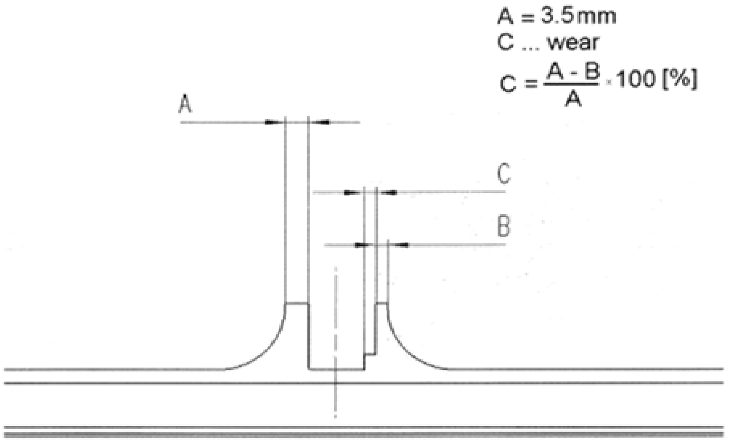



Fig. 4 – EVALUATION OF SLOT SIDE WEAR

b1. Wear of slot sides is less than 50%: Repeat check at least at each third 300 hr inspection (in 900 engine flight hours)

b2. Wear of slot sides is greater or equal to 50% but less than 70%: Repeat check at each 300 hr inspection. Operator must inform on this condition the engine manufacturer GE AVIATION CZECH s.r.o.

b3. Wear of slot sides is greater than 70%: Replace outer combustor liner prior to further operation. Report condition to engine manufacturer GE AVIATION CZECH s.r.o.

Figure 2 - Service Bulletin M601E/40R-1.

Likewise, it was necessary to change the PR-NOB number 2 (right) engine, on account of excessive wear of the combustion chamber components. It was replaced by the serial number 914025 engine.

The number 1 engine of the aircraft showed a level of wear within the tolerance limits, and began to be monitored, as follows:

| Boroscopic inspection | Date | Hours flown | Wear level |
|---|---|---|---|
| 1st | 17/January/2011 | 1,099:04 | 0% |
| 2nd | 23/March/2011 | 1,586:38 | 30% |
| 3rd | 07/May/2011 | 1,759:44 | 35% |
| 4th | 11/June/2011 | 1,985:40 | 40% |
| 5th | 22/June/2011 | 2,052:35 | 50% |

Table 1 - Evolution of corrosion in the engine number 1 combustion chamber.

Due to the evolution in the level of internal wear of the engine number 1 combustion chamber support (Figure 3), it was decided that the item would be replaced during the 10 July 2011 inspection in the Recife NOAR facilities.

In this service, the GE Aviation Czech technicians replaced the following components: combustion chamber support (they removed the PN-239.5 M601, SN 024, and installed the PN-255.7 M601, SN 4282), and the oil cap PN-M601 308.3 (they removed the SN 4981, and installed the SN 3651).

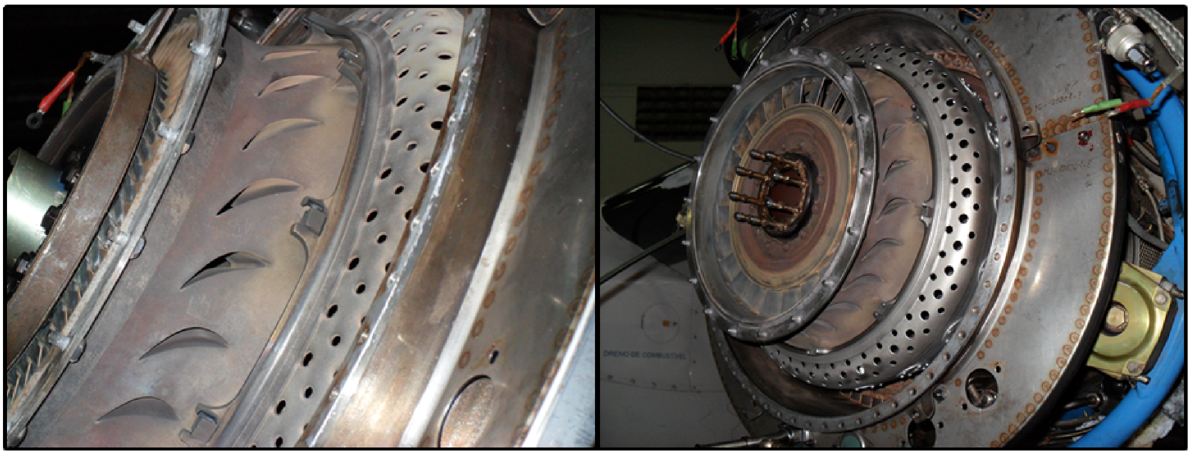


Figure 3 – Removed and installed combustion chambers.

During the execution of this service, the GE Aviation Czech technicians confirmed that the Gas Generator Turbine (GGT) Rotor Assembly of the turbine compressor removed from engine serial number 101-001 exhibited blade corrosion beyond the limits prescribed in the manual (Figure 4), and it was replaced.

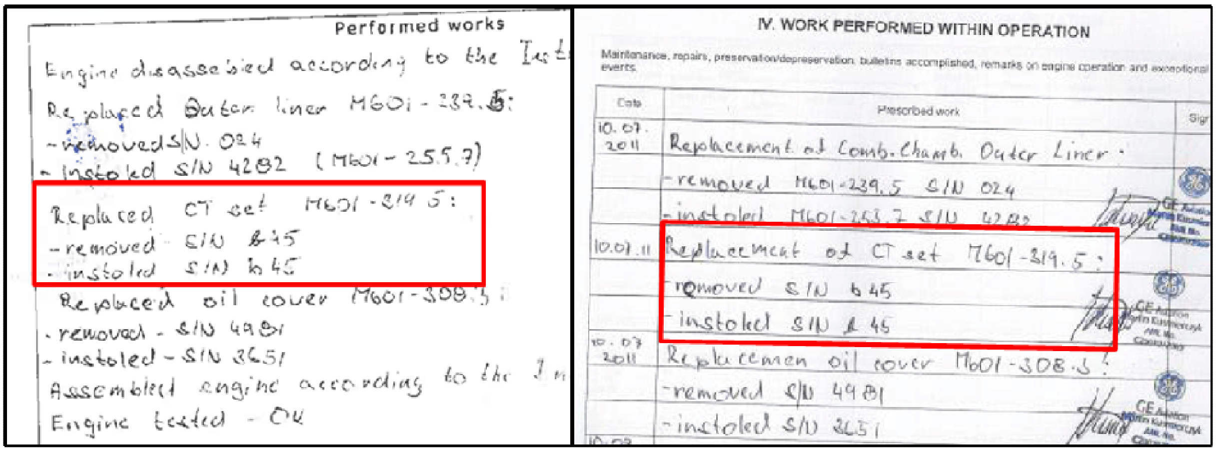
Figure 4 - Compressor turbine disk removed on account of corrosion at high temperatures.

The performed-works' form was filled in by the GE Aviation Czech technician, who wrote that the item M601 PN-319.5, S/N b45 had been removed and replaced by the S/N b45 (*sic*).

The same writing appears in the Engine Log Book managed by the manufacturer and kept at headquarters, as seen in Figure 5.

Although this writing gave the impression that the disc rotor installed was the same one which had suffered wear, during the opening of the engines it was established that the worn disc rotor, with the serial number 012867-2-144 was effectively replaced by another rotor disk b45, serial number 409783-338.

This misunderstanding occurred in the assumption that “S/N” (Set Number – which identified that section of the engine) stood for Serial Number, which identifies the part of the assembly. In this case, b45 is the GGT rotor assembly identification.



Performed works
Engine disassembled according to the Inst...
Replaced Outer liner M601-239.5:
- removed S/N. 024
- instaled S/N 4282 (M601-255.7)
Replaced CT set M601-319.5:
- removed S/N b45
- instoled S/N b45
Replaced oil cover M601-308.5:
- removed - S/N 4981
- instoled - S/N 3651
Assembled engine according to the In...
Engine tested - OK

IV. WORK PERFORMED WITHIN OPERATION
Maintenance, repairs, preservation/depreservation, bulletins accomplished, remarks on engine operation and exceptional events

| Date | Prescribed work | Sig |
|---|---|---|
| 10.07.2011 | Replacement of Comb. Chamb. Outer Liner: | |
| | - removed M601-239.5 S/N 024 | |
| | - instoled M601-255.7 S/N 4282 | |
| 10.07.11 | Replacement of CT set M601-319.5: | |
| | removed S/N b45 | |
| | instoled S/N b45 | |
| 10.07.2011 | Replacemen oil cover M601-308.5: | |
| | - removed S/N 4981 | |
| | - instoled S/N 3651 | |

Figure 5 – Writing in the records (performed works’ form, and page 99 of the log book).

Still in relation to the services provided by GE Aviation Czech on 10 July 2011, some of the operator’s employees had doubts as to the full completion of the engine vibration test after the replacement of the compressor turbine disk.

According to the operator’s technicians who monitored the service, one of the wiring items of the equipment used for the test had broken before the verification had been completed.

Furthermore, there were no records of the implementation of a vibration test in the documentation left by the manufacturer after the completion of the services.

After the completion of the left engine components’ replacement service, the PR-NOB aircraft was submitted to a test flight (monitored by GE Aviation Czech technicians), and subsequently released for passenger transport flights.

When questioned about the effective execution of the vibration test, the GE Aviation Czech provided the Investigation Commission with a report containing the engine test results, which were within normal parameters (Figure 6).

It should be added that, according to the pilots who flew the aircraft after the engine parts were replaced, the performance of the aircraft was good, without any complaints concerning contingent vibration.

The GE Aviation Czech was not able to say why such documentation was not attached to the other documents left in Brazil, relative to the maintenance services performed in the PR-NOB left engine by their technicians.

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AvTrend Bronze 1.09.193                                          Page 1 of 8

================== '101001E' - Vibration Spectrum Survey ==================
Customer: 101001E
Started: 07/10/2011 21:18.13              Finished: Yes
A/C Reg:                                  A/C Total TM: 0.0
Eng S/N:                                  TSO: 0.0
Eng Pos: 12337                            TSN: 0.0
----------------------------------------------------------------------------
2020 Analyzer Information
Owner: GE AVIATION CZECH                  Serial No: 50249
Addr:                                     Versions:
 BERANOV'YCH 65                           Boot ROM: 5.01
 199 02 FRAHA 9                           Application: 5.01
 CZECH REPUBLIC
Phone: 420-222-538-111                    Cal Date: 10/01/2010 15:25.07
----------------------------------------------------------------------------
AvTrend License Information
Owner: GE Aviation CZECH
Serial Number: 2041                       License Number: 2A7B919D
Level: Bronze                             Type: Permanent
----------------------------------------------------------------------------
Setup: M601 ENGINE
Resolution: 400
Average Type: Exp                         Blocks in Average: 4
Min Freq: 0.00                            Max Freq: 50000.00
Frequency Units: RPM

Channel A (GT): 991D-1
  (20.000 mVolts/g's, Normal Polarity, Single-Ended)
  Full-Scale Range: 10.00 mm/sec RMS
Channel B (VT): 991D-1
  (20.000 mVolts/g's, Normal Polarity, Single-Ended)
  Full-Scale Range: 10.00 mm/sec RMS

Condition 1: 60%
Condition 2: 70%
Condition 3: 80%
Condition 4: 90%
Condition 5: 95%
Condition 6: 97%
Condition 7: 99%
Condition 8: 100%

Spectrum Limits: None

Condition 1 (60%): Data Taken
Condition 2 (70%): Data Taken
Condition 3 (80%): Data Taken
Condition 4 (90%): Data Taken
Condition 5 (95%): Data Taken
Condition 6 (97%): Data Taken
Condition 7 (99%): Data Taken
Condition 8 (100%): No data acquisition
```

Figure 6 – Vibration Test Report presented by GE Czech Aviation.

The aircraft was equipped with V510/90A/C Avia Propeller sets, serial numbers 100003 (number 1/left) and 100004 (number 2/right).

The number 1 and number 2 propellers had been in the aircraft since the beginning of operations, and had a total of 2,126 hours and 12 minutes each one, being 21 hours and 18 minutes after the last inspection. These propeller sets had not yet reached the maintenance program parameters requiring them to be overhauled. Inspections of the propeller sets were being held at the intervals specified in the manufacturer's maintenance program.

## 1.7 Meteorological information

The aerodrome of Recife was operating under VMC. At the moment of the occurrence, the wind strength was 5kt, blowing from 240º.

The 0600 and 0700 METARs were as follows:

- 0600 (local time): 23006KT 9999 FEW015 SCT070 22/19 Q1014; and
- 0700 (local time): 22007KT 9999 FEW014 BKN070 23/20 Q1015.

## 1.8 Aids to navigation

Nil.

## 1.9 Communications

The aircraft maintained radio contact only with Recife Tower (TWR-RF), on account of the short time between takeoff and the accident.

According to ATC records, at 06:51:04, when the aircraft was already in the air, the NOAR Flight 4896 crew informed the Tower that the takeoff was being aborted, and that they were proceeding for landing. In this transmission, it was possible to hear the copilot asking the pilot to lower the nose of the aircraft. A few moments later, the NOAR Flight 4896 crew confirmed that they would abort takeoff and return for landing, requesting a free runway. The original intention of the crew was to proceed to runway 36.

At 06:53:56, the aircraft crew reported that they would not be able to reach the runway, and that they would make a landing on the beach. This was the last transmission from the NOAR Flight 4896. It was possible to hear the copilot suggesting a landing in the sand.

At 06:57:02, a helicopter that was in coordination with Recife Tower reported that the firefighters could be summoned because a lot of smoke was coming from the crash site. On the approach to the crash site, the helicopter crew told the Tower that the accident aircraft was being consumed by fire, and that no survivors could be seen.

## 1.10 Aerodrome information

On the date of occurrence, the aerodrome of Recife (SBRF) had a shared-use public and military airport status, under the administration of INFRAERO, with runway thresholds 18 and 36 (headings 184° and 004°, respe ctively), measuring 3,007 meters x 45 meters, paved with asphalt, at an elevation of 33ft.

Runway 18 was used for takeoff (track 184°). This runway had an acclivity in the first 600 meters, while maintaining virtually 0º slope in the last 2,407 meters, having no RESA (Runway End Safety Area). At a distance of approximately 160 meters after the departure end of the runway 18, there was a wall separating the airfield from the urban area.

The declared takeoff distances for runway 18 were the following:

| TORA (m) | ASDA (m) | TODA (m) | LDA (m) |
|---|---|---|---|
| 3,007 | 3,114 | 3,007 | 3,007 |

A NOTAM (SBRF B0919/2011 NOTAMR - SBRF B0353/2011), issued on 02 June 2011 and valid until 02 September 2011, stated that the last 210 meters of the runway 36 stop area were closed due to damage to the pavement. However, this change did not affect the declared distances for takeoff from runway 18.

The approximate distance between the runway 36 threshold and the shoreline, considering the takeoff axis, is 2,360 meters, with buildings along the path (Figure 7).

Figure 7 – Aerial view of the runway 18 takeoff axis.

**1.11 Flight recorders**

The aircraft had a model FA2100 Cockpit Voice Recorder, with memory capacity of up to two hours, and a model FA22XX MADRAS Solid State Flight Data Recorder (SSFDR), with a minimum recording capacity of 25 hours. Both recorders were manufactured by L-3 Communications.

The CVR was successfully read out at the CENIPA's Flight Recorders Readout and Analysis Laboratory in Brasilia, Brazil.

As for the FDR, on account of the damage which resulted from the impact and subsequent fire, the readout was accomplished at the NTSB in Washington DC, USA.

According to the CVR data, during the takeoff briefing, the PIC said that he would consider the possibility of landing on the runway, if a failure occurred after V1 (decision speed), with sufficient runway and the landing gear still not retracted.

He also said that, if a failure occurred after V1 and with the landing gear retracted, he would proceed with the flight, while the copilot would be in charge of monitoring the instruments and complementing the emergency procedures after 400ft AGL. He informed that, in such case, the turns would be made towards the "good engine" side.

During the takeoff, three seconds after the PIC requested retraction of the landing gear, it is possible to identify a significant change in the cockpit background noise.

It can also be observed that, despite the PIC's request to retract the landing gear, his request was only complied with 50 seconds later, after the fourth time he repeated it.

After verifying the engine failure occurrence, the copilot asked the PIC to "abort takeoff" three times, adding that the aircraft had lost power. The PIC proceeded with the departure, saying that there was not enough space to abort takeoff.

The PIC, then, told the copilot to request landing on runway "thirty", repeating this request twice, without taking into account that Recife aerodrome runway has the thresholds 18 and 36. The copilot, however, informed the TWR-RF that the aircraft would proceed for a landing on runway 36.

Shortly after this message, the copilot asked the PIC to "lower the aircraft nose". In his reply, the PIC asked the copilot to take it easy, and the copilot agreed: "I know, we are at 400ft, let's fly!"

Then, there was a significant change in the cockpit background noise, with the PIC telling the copilot to feather the propellers of engine number 1.

The PIC told the copilot to call TWR-RF, and the copilot asked what his message to ATC should be. The PIC instructed him to tell ATC that they were in emergency.

The copilot’s answer to the PIC was: “We are in emergency. We are cleared to land on runway 36, let’s go”.

Then, the alerts “Don’t sink! Don’t sink!” and “Too low, terrain” were heard several times.

At 06:52:45, the PIC asked the copilot to feather the left engine propeller blades, and the copilot answered by saying that the propeller blades had already been feathered.

At 06:52:52, the copilot asked the PIC to turn towards the aerodrome. The PIC answered that he was already doing so.

Shortly after, at 06:53:02, the stall alert went off.

The copilot then said “eighty-one, lower the nose”, and then the alerts “Don’t sink! Don’t sink!” and “Too low, terrain!” were heard.

At 06:53:22, the copilot uttered “one hundred twenty feet” and then a stall alert was heard.

The copilot asked the PIC to ‘hold the power’, and the PIC said that ‘it was in full power’.

Then, the copilot asked the PIC not to hold the nose too much to keep the aircraft from stalling.

He then asked the PIC whether they would land on the beach, and received a firm “no” as an answer.

At 06:53:43, the copilot commented to the PIC that they were at a hundred twenty feet, and that there was not sufficient height to proceed to the runway, suggesting that they should land on a sand strip on the beach.

The PIC replied that he would not land on the beach, and informed that they would land in the “field”, instead.

At 06:53:56, the copilot said to the TWR-RF: “NOAR 4-8-9-6 is... it is going to make an emergency landing on the beach …it is not possible to reach the runway… land here in the sand… land in the sand that does not…”.

Then, the stall alert went off.

The PIC, anew, told the copilot that they would not land in the sand, and the copilot replied that they would fall on top of the buildings.

From this moment on, the stall alert continued being heard for 19 seconds up to the time the stall occurred, occasionally intercalated with the alerts “Don’t sink! Don’t sink!” and “Too low, terrain!”

At 06:54:12, the copilot asked the PIC to “please” land on the beach, to which the PIC rudely answered that he would not do that.

The copilot insisted, saying that they were not able to reach the runway, and the PIC said: “It’s OK! Leave it to me!”

At 06:54:25, the copilot made a comment to the PIC that they were stalling (and repeated the comment).

At 06:54:38 the recording was discontinued.

From the readout of the SSFDR, it was possible to successfully retrieve data relative to 110 parameters of the last 192 hours of operation.

The graphs below show the main parameters for the aircraft performance evaluation.

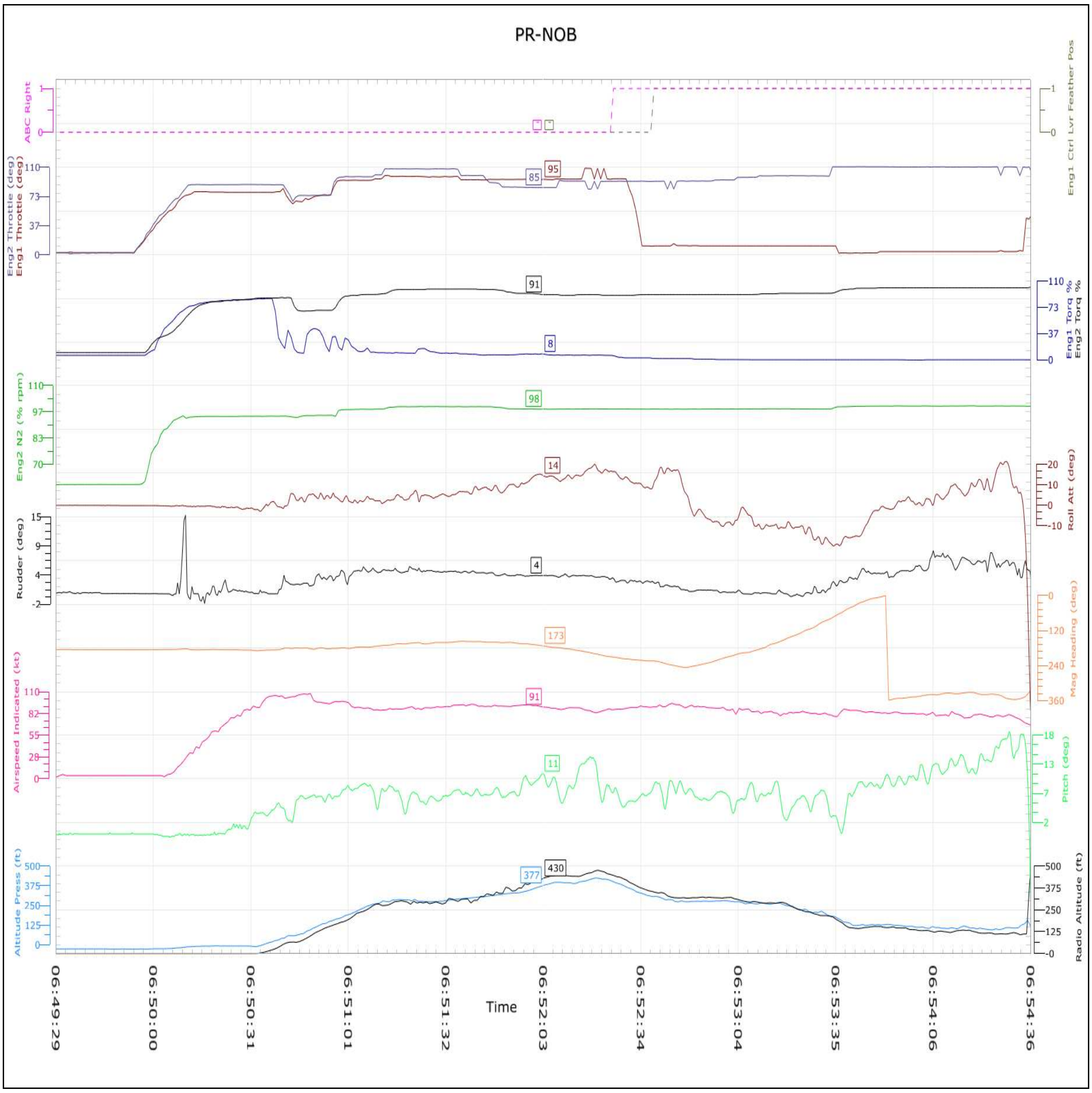



Figure 8 – Flight 4896.

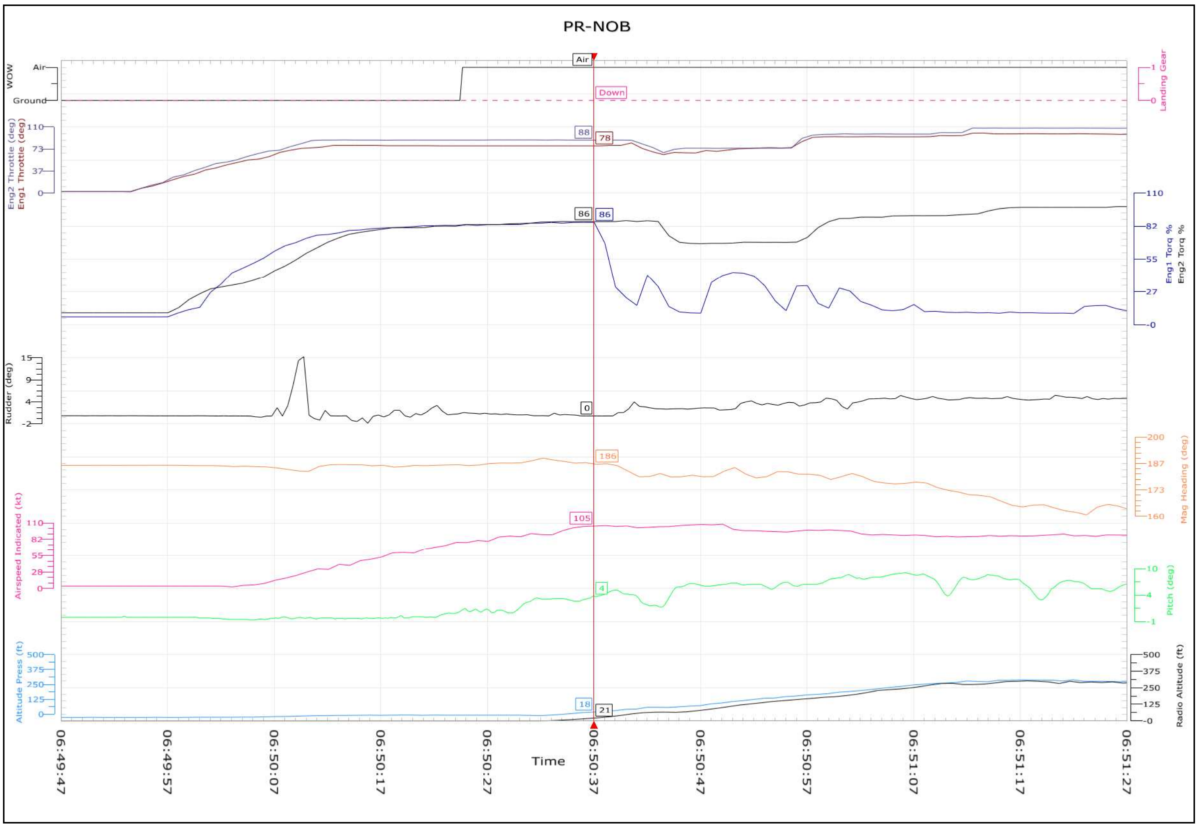



Figure 9 – The moment of the left engine failure.

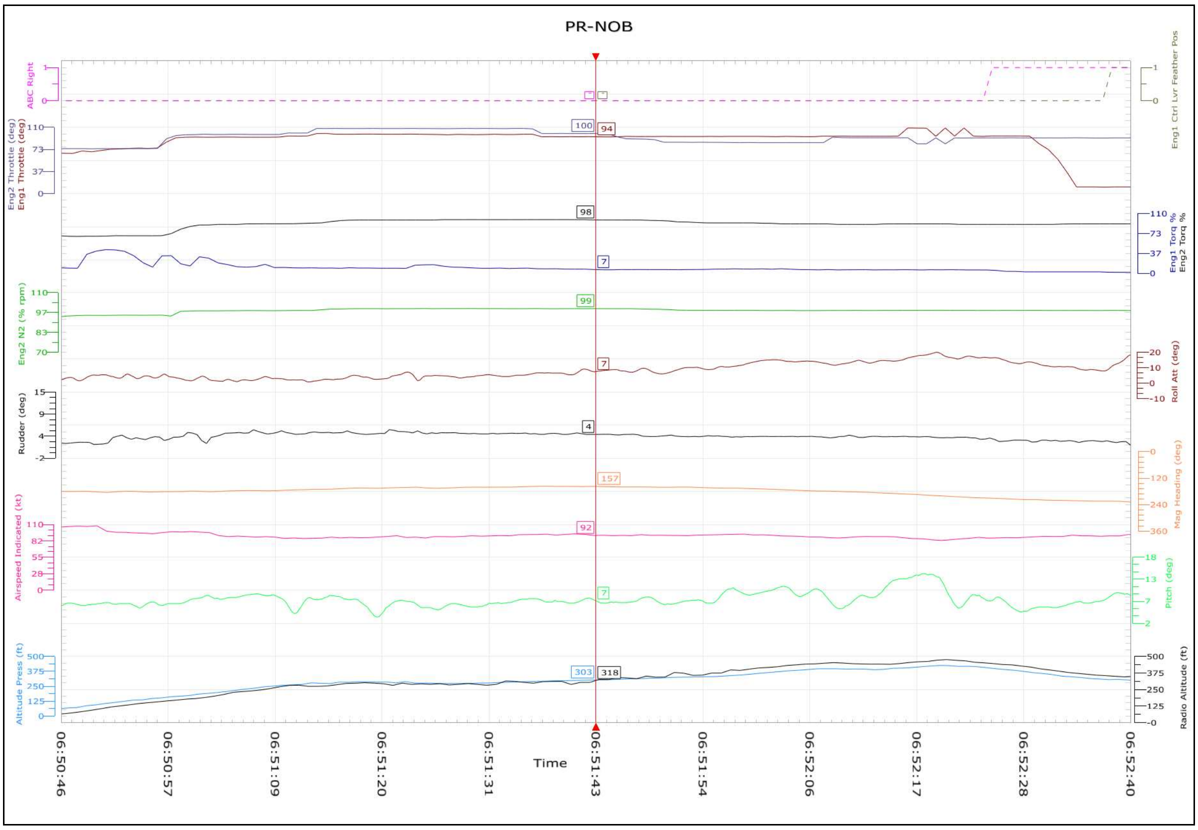



Figure 10 – Beggining of the right turn for returning to the aerodrome.

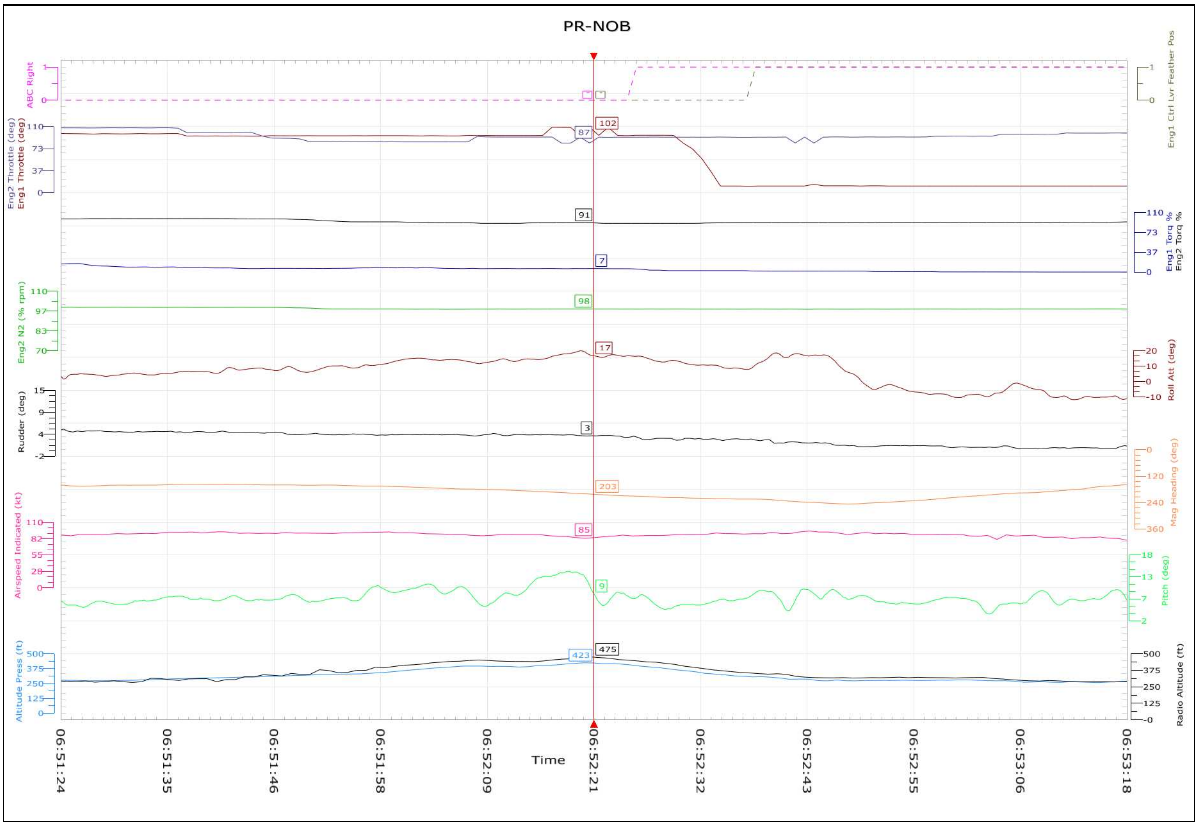



Figure 11 – Beginning of height loss.

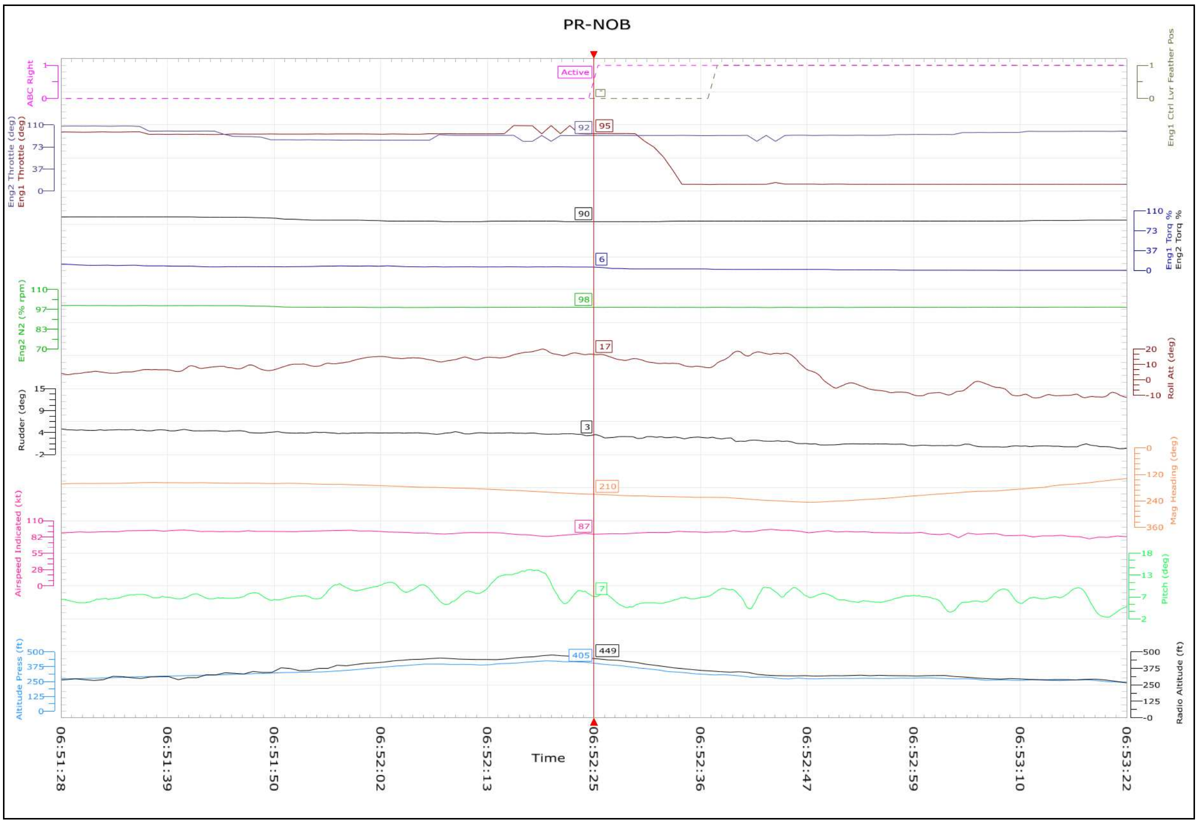



Figure 12 – Opening of the ABC.

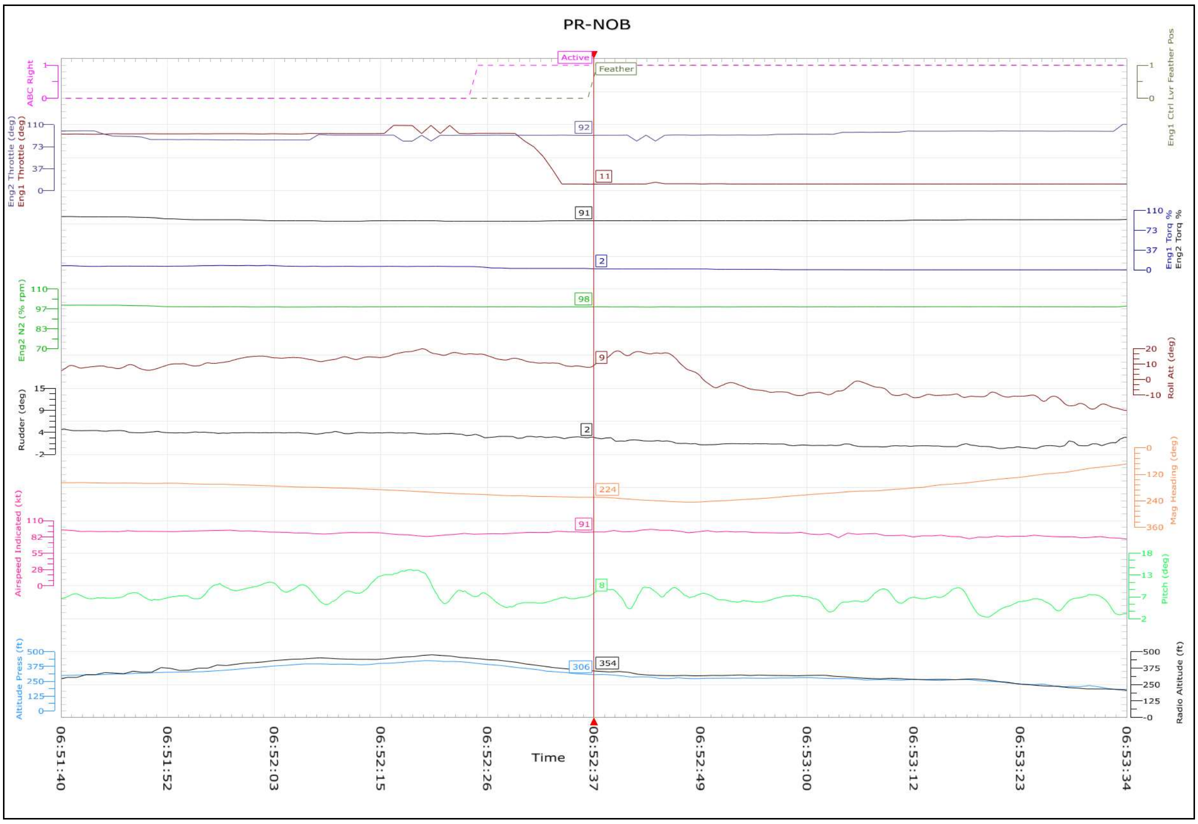



Figure 13 – Manual feathering.

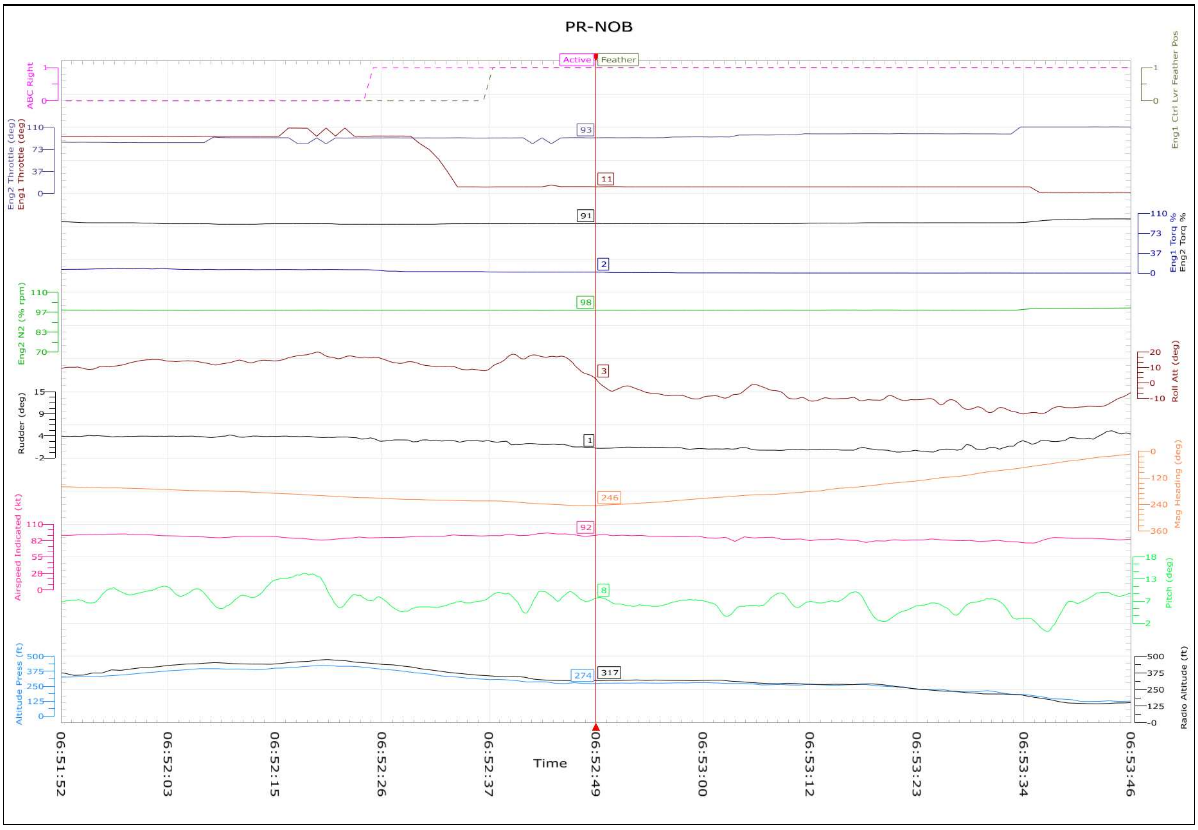



Figure 14 – Reverse turn to the left.

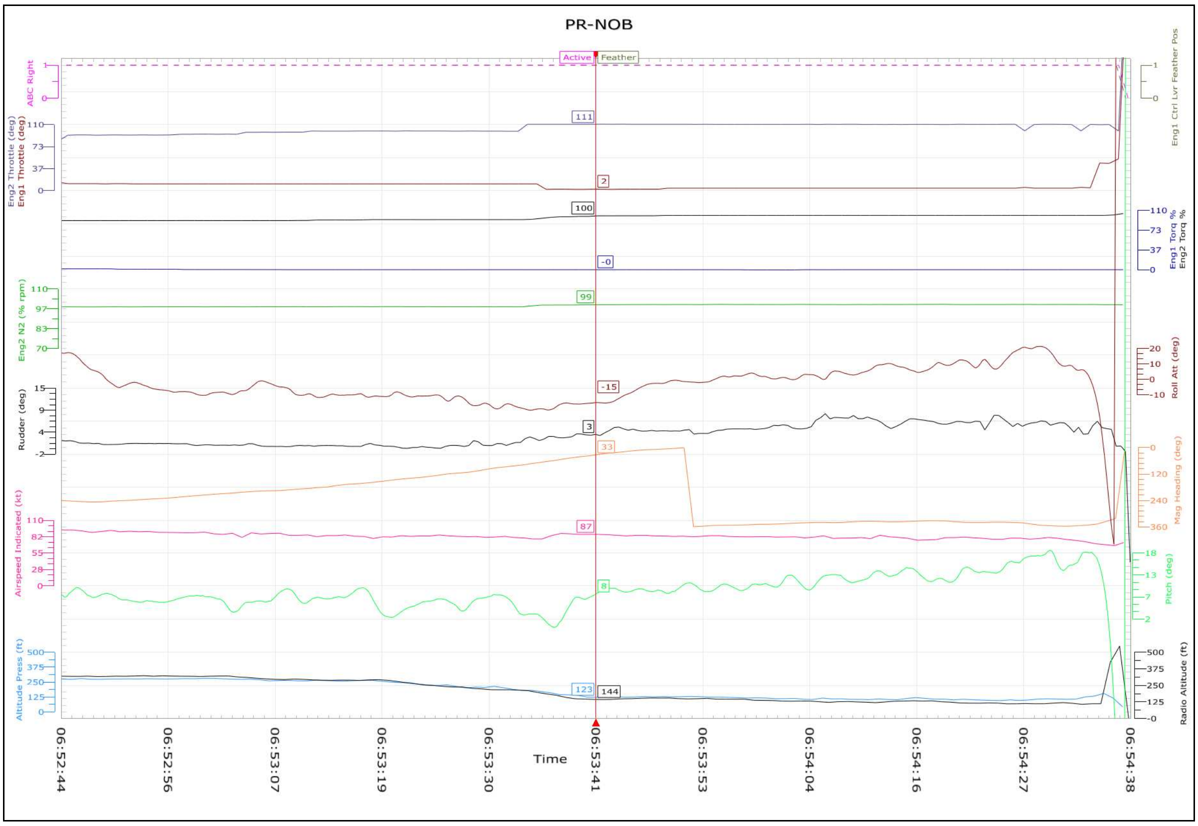



Figure 15 – Right engine torque reaches 100%.

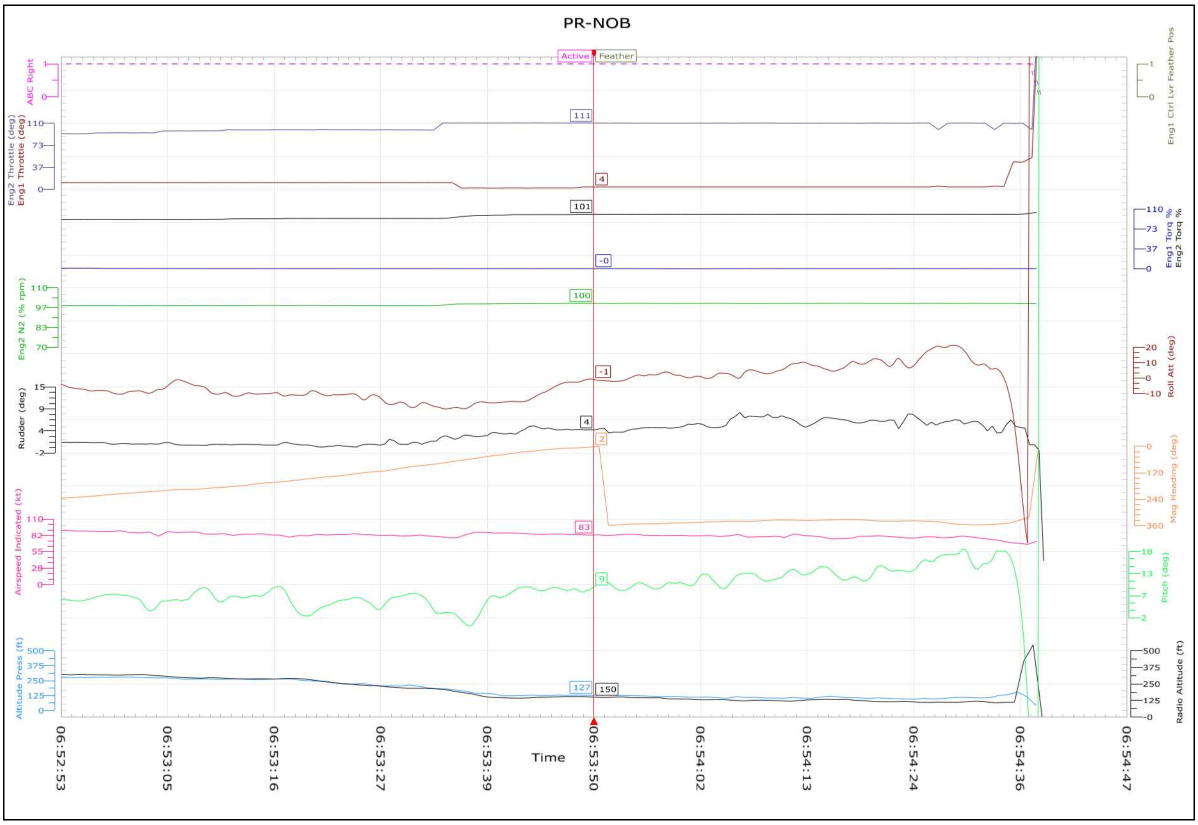



Figure 16 – $V_{MCA}$ limit

0 below shows the estimate drift values, calculated from the FDR data.

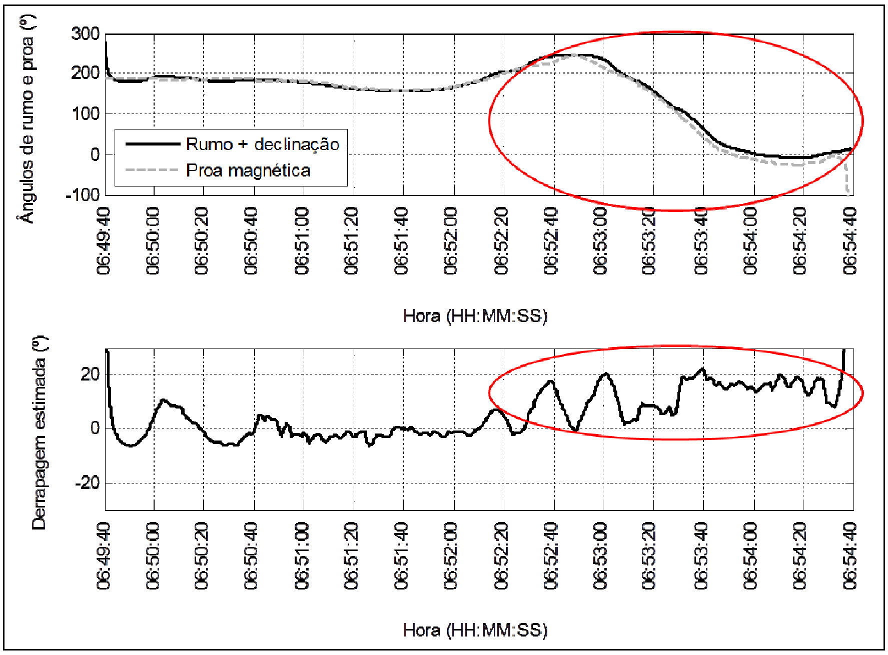



Figure 17 – Calculation of drift based on the FDR data.

Table 2 shows an extract of the flight parameters relative to the main moments considered in the analysis.

| Time | RA Height | Speed | Hdg | Angle of bank | Pitch | Rudder |
|---|---|---|---|---|---|---|
| 6:50:37 | 24 ft | 104 Kt | 186° | 2° (right) | 4° | 0° |
| 6:50:43 | 66 ft | 104 Kt | 180° | 5° (right) | 2° | 2° |
| 6:51:35 | 298 ft | 88 Kt | 159° | 5° (right) | 8° | 4° |
| 6:51:48 | 344 ft | 93 Kt | 160° | 10° (right) | 8° | 4° |
| 6:52:01 | 415 ft | 93 Kt | 169° | 15° (right) | 9° | 4° |
| 6:52:19 | 470 ft | 84 Kt | 199° | 20° (right) | 14° | 3° |
| 6:52:40 | 348 ft | 93 Kt | 228° | 18° (right) | 9° | 2° |
| 6:52:49 | 317 ft | 92 Kt | 246° | 3° (right) | 8° | 1° |
| 6:53:00 | 319 ft | 90 Kt | 214° | 10° (left) | 7° | 0° |
| 6:53:28 | 232 ft | 83 Kt | 112° | 15° (left) | 5° | 0° |
| 6:53:36 | 182 ft | 84 Kt | 061° | 20° (left) | 1° | 3° |
| 6:53:50 | 150 ft | 83 Kt | 002° | 1° (left) | 9° | 4° |
| 6:54:00 | 136 ft | 83 Kt | 348° | 2° (right) | 10° | 5° |
| 6:54:10 | 124 ft | 81 Kt | 335° | 4° (right) | 11° | 7° |
| 6:54:19 | 124ft | 81 Kt | 334° | 9° (right) | 11° | 6° |
| 6:54:30 | 117ft | 80 Kt | 356° | 13° (right) | 16° | 6° |
| 6:54:34 | - | 72 Kt | 349° | 7° (left) | 18° | 6° |

Table 2 – Flight data considered in the analysis.

## 1.12 Wreckage and impact information

The aircraft crashed in an area without buildings, between the avenues of Boa Viagem and Visconde de Jequitinhonha, at the coordinates 08°09'08" S and 034°54'34" W, at a distance of 1,740m from the runway 36 threshold (Figure 18). There was a raging post-impact fire, and the aircraft was completely destroyed.


Figure 18 – Aerial view of the point of impact, and its position in relation to runway 36.

The marks (Figure 19) of the first impact (at a few meters from the point at which the aircraft stopped) were possibly made by the right engine, which caused the right wing to rupture close to the fuselage, moving to the other side and coming to a rest to the left side of the aircraft.

Figure 19 – Marks of the first impact.

The flaps were found in an 18-degree deflected position (Figure 20).

Figure 20 – Left wing flap 18-degree deflection (the same as the one of right wing).

In the central console, it is possible to identify the presence of an advance seal in the power control lever of the right engine, indicating that the resource of extra power was not utilized by the crew (Figure 21).

Figure 21 – Inviolate seal of the right engine power control lever.

## 1.13 Medical and pathological information

### 1.13.1 Medical aspects

A detailed research of the medical condition the of PIC – who was 68 years old, 1.72 m tall, and weighed 78 Kg – was conducted, due to accounts made by some of the company pilots at interviews, suggesting that he would have physical restrictions that limited his performance as a pilot, including night-vision difficulty, as well as lack of strength in his right leg which caused him to limp.

Besides searching in his medical records, the commission contacted persons with whom he had either a personal or professional relationship.

According to data collected from his medical records, the PIC had displayed a condition of difficulty in walking, although without detriment to strength or functionality. Such condition was totally overcome by means of a surgery made around the mid of 2010 (therefore, approximately one year before the accident). The surgery had not caused any functional sequels.

As for his night-vision limitation, the ophthalmology specialist physician considered that his sight condition was non-indicative of incapacitation in accordance with the Brazilian Civil Aviation Regulation (RBAC) 67.

### 1.13.2 Ergonomic information

Nil.

### 1.13.3 Psychological aspects

#### 1.13.3.1 Individual information

According to data collected, the PIC was strongly involved with the company, and was always in search of information capable of improving the operation. The company had the intention of letting him work exclusively in the administrative area.

The PIC had already worked as Director of Operations in the company, and was working as Advisor of Institutional Affairs, since he had many acquaintances in the outside environment.

According to accounts of the interviewees, the PIC was considered a strong, incisive, assertive, demanding, and anxious person. His style, sometimes, intimidated a few people. He showed difficulty accepting criticism and suggestions. Such feature was noticed during the inflight failure, with the PIC being resistant to the copilot’s suggestions.

There was an episode involving the PIC which resulted in his leaving the Operations Directorship and in his being evaluated in operational terms. Nonetheless, he was considered qualified for flight by his evaluators and by the ANAC inspector. He was even considered qualified for the delivery of training.

The copilot, in turn, had joined the company to work in the infrastructure sector, and only later was he included in the board of pilots. His previous experience in the air activity had been gained in the flying school. He flew for pleasure, since he made a living from his own road transport enterprise.

He was considered by some of the interviewees as a more difficult person to deal with, being silent, reserved, although always willing to help. He would collaborate a lot with the company’s administrative area.

In professional terms, he was described as a pilot who still had little knowledge of the aircraft, but that was concerned with flight safety and that would not put operations to risk. They also said that he showed difficulty in making decisions.

As for the occurrence, the CVR data indicate that the PIC maintained his decision to proceed towards the runway, although the aircraft stall alert kept sounding. The copilot, in turn, did not react immediately to the PIC’s commands to retract the landing gear, and only did it after several requests.

### 1.13.3.2 Psychosocial information

Some of the interviewees reported that the PIC used to attribute great emphasis to the briefings, mainly the ones related to takeoff, and would distribute functions in flight.

There were a few accounts of the existence of a difficult relationship between the PIC and the copilot, due to problems that occurred in some flights, such as the one of the taxiway excursion in Maceió (see item 1.19.1), as well as due to CRM problems, which gave rise to some divergences between them, making the people responsible for the flight schedule aware of not putting them together in the same flight for some time. However, there is evidence that this crisis would have been mitigated in the weeks prior to the accident.

The interviews also showed that some of the company crewmembers had reservations about flying with the PIC due to his incisive attitude. Another reason was that they thought he no longer had the best physiological condition to fly an aircraft.

As for the copilot, the majority of the interviewees said that he showed difficulty dealing with leadership issues, when having to submit to a senior worker, since he had some experience in single-pilot aircraft and confused his role as *pilot flying* with the position of *pilot in command*. The accounts indicated that some of the captains did not like to fly with him due to his reluctant behavior in accepting the role of copilot and the authority of the aircraft captain.

There was a friendly relationship between the copilot and the Director-President of the company, and everybody considered the latter to be an open and accessible person.

Among the directors of the company, the relationship was good, according to information collected. Nonetheless, it was possible to identify that the PIC, in his period as Director of Operations, used to be stricter with some of the other professionals of the company.

There was not an appropriate and friendly communication channel established between the Operations Directorship and the Technical (Maintenance) Directorship for the exchange of information about aircraft problems and the making of necessary provisions.

Although there were not any dissensions in the work environment, it could be observed that there was an informally instituted separation of professionals, who would then belong to one of two groups: the “military” one and the “non-military” one. This separation, however, did not prevent the emergence of conflicts between professionals of the same group.

In relation to the accident flight, the CVR data indicate that, during the inflight emergency, the PIC and the copilot had a divergence on what had to be done.

### 1.13.3.3 Organizational information

The NOAR Company is part of a business group focused on entrepreneurship and development, also working in the field of education and communications. The company began at a time when there was not a regional airline working in the northeast of Brazil, a lack that had been felt by the founders 12 years before.

After examining several aircraft models, a consultant of the group learned of the airplanes manufactured by Aircraft Industries, and operated in Brazil by the TEAM and NHT companies, and the conclusion was that it would be possible to begin a regional company utilizing that model of aircraft.

Thus, a consultancy was set with the manufacturer and the TEAM Company. This latter, in turn, subsidized the business plan presented to the manufacturer.

According to reports, the operation of the company started at a time when the pilots and mechanics had little knowledge, not only in relation to the commercial routines but also in relation to the aircraft model.

The aircraft was considered dependable and with an appropriate operational cost, characteristics which led to the purchase of two units that would start the company.

The company structure consisted of the Presidency, Executive Directorship (subordinated to the Director-President) and the Operations, Commercial, Technical, Administrative, Finance, and Operational Safety Directorships (subordinated to the Executive Directorship).

The company presidency was responsible for the paper work, while the directorships (composed of staff that had come from the aviation environment) dealt with the operation itself.

In the interviews, it became apparent that the presidency had faith in the company's project.

At the time the company began its activities, the directorships were manned by professionals appointed by a TEAM company professional, who worked as a consultant for the implementation of the NOAR company.

When the Executive Director was substituted, there were changes in the other positions of the directorships.

The Executive Director held monthly or fortnightly meetings, as needed, to discuss the company's issues.

When the company started the passenger transport operations, it had five captains and two copilots (another captain and another copilot were being trained), with a net that consisted of 70 sorties per week, making up a flight volume of 36 hours per week (without considering the time necessary for the boarding and deplaning preparatory procedures).

At the time of the accident, the company had six captains and five copilots, with a programmed net of 78 sorties per week, making up a volume of 48 hours of flight per week (without considering the time necessary for the boarding and deplaning preparatory procedures).

Although bigger, the net operated by the company at the time of the accident had a better distribution throughout the week, besides being shared by a larger number of pilots.

According to information provided by the operator, all professionals working for the company had been submitted to a process of recruitment and selection, with interviews and specific tests, for which psychologists had been hired. The decision, either in selecting or dismissing the employees, would be made by the company directors.

According to representatives of the operator, the relationship between the operator and the aircraft manufacturer was based on mutual confidence. However, according to information collected, the fact that the manufacturer's main office was in the Czech Republic made the solving of logistic issues more difficult.

The operator had a perspective of growth, and intended to purchase two more aircraft before long, with the objective of reaching a total of six units.

The first group of pilots and mechanics in the NOAR company did their initial training at the TEAM company in the late 2009. The training was completed approximately six months before the beginning of the passenger transport operations. The training of the other pilots was done at the NOAR company in 2010, and evidence was gathered that there was a lack of training standardization, as well as a lack of cockpit doctrine regarding some procedures, especially in relation to emergencies, such as, for example, engine failure during takeoff.

As there was not an ANAC-certified simulator training prescribed for the E20-L410UVP, the manufacturer recommended that the proper training should be done in flight.

The theoretical training (*ground school*) of the third group of students was given by the NOAR copilots, and information was gathered that classes were taught by some of the very students. Due to a lack of instructors, other classes were given by copilots with little experience in the equipment. There was participation of an ANAC inspector in this training, and some non-conformity issues were observed that made it necessary to extend the duration of the course from a forecast one-month to almost three months before it could be completed.

There was a training program (PrTop) with inflight training criteria, but it was not always faithfully complied with. The program dealt with training standardization, although the company professionals did not master the subject, as learned from interviews.

It is worth highlighting that the Quick Reference Handbook (QRH) that was found in the NOAR airplane (written in Portuguese) had contents that were identical to the TEAM aircraft checklists, even in relation to some speeds, thus differing from the Checklist supplied by the manufacturer.

On many occasions, the adaptation of the students to the aircraft was made without participation of an instructor, since there were not enough instructors in the company. The trainings of engine failure situations were not given in full.

The training of the mechanics (which was given by the TEAM company) consisted of familiarization with the equipment during two weeks and, according to information collected, the mechanics themselves considered the training deficient, since, exceptionally, they did services of a higher level than the one that had been trained (P2 inspections, for example).

In this respect, it is important to point out that, according to the company operating specifications, the level of maintenance it was authorized to perform was the P1 inspection. However, on account of a request made by the company, the ANAC exceptionally authorized NOAR to make some P2 inspections. Such authorization was granted based on the premise that the NOAR company's maintenance sector was in the final stage of certification, something that led the ANAC to conclude that the NOAR mechanics were prepared for even more complex inspections.

Besides, the airplane operated by the TEAM company was an older model, different from the one purchased by the NOAR company.

The course for maintenance assistants was taught by the NOAR maintenance inspectors. Although they were certified instructors, the investigation found out that they were not confident they had the knowledge required for the instruction.

The company had an Operational Council composed of the directors, and the Executive Director was the one responsible for communicating the council's decisions to the Director-President.

The first CRM training delivered in the company was outsourced, and later, during the refresher training, a meeting was held only with the pilots, who did group work and discussed the topic of “decision-making” with a psychologist belonging to the other company owned by the Director-President.

The start of maintenance activities in the NOAR company was monitored by two professionals of the TEAM company. The NOAR maintenance technicians used to contact the NHT company maintenance in search of help to do the services. According to information collected, effective knowledge in the maintenance area was gradually obtained by means of the services carried out at the NOAR company.

According to accounts, the professional capacity of the maintenance technicians was considered to be high level by the company, since many of them had a military aviation background. The investigation learned that contingent decisions made by the maintenance team to discontinue the operation of an aircraft would not be questioned, and that the operational limits were respected. However, such information is not compatible with the praxis associated with the use of the Auxiliary Book, also known as “Blue Book”.

According to information collected, the Auxiliary Book concept was to report discrepancies of non-operational nature relative to the aircraft, such as, for example, an unsewn seat or a ripped carpet. As the time passed by, they began to report technical problems which affected the operational condition of the aircraft, without putting this kind of information in the Logbook.

In the Auxiliary Book of the other airplane of the company (PR-NOA), more than eighty reports of technical problems were listed. Only two of them had been duly transcribed by the captains in the Logbook (part II, technical condition of the aircraft). The PR-NOB’s Auxiliary Book was not found, as it was possibly destroyed by the post-impact fire.

In the audit report (nº 10089/2011 R) issued by the ANAC, it was possible to see that the technical maintenance problems of the PR-NOA airplane, besides not being entered in the Logbook, were not tracked on a daily basis. One can verify that the airplane was kept in the flight routine, independently of the problems informed by means of the Auxiliary Book, without any technical opinion being given by the maintenance team.

Therefore, according to the report, there was not an appropriate supervision of the technical maintenance problems affecting the aircraft, in order to identify the existing dysfunctions and take the necessary actions.

**1.14 Fire**

The aircraft caught fire immediately after impact (Figure 22), which occurred at 0654 local time. There were approximately 980Kg of fuel in the aircraft tanks.

Figure 22 – The aircraft on fire, and after the fire was extinguished.

At 0707, a fire fighting vehicle of the State of Pernambuco Military Fire Brigade arrived in the crash site. An INFRAERO vehicle, in charge of providing support to the airport air operations, arrived at 0732.

At 0835, the fire was extinguished, according to a report by the Recife's Military Fire Brigade. The fire consumed more than 75% of the airplane (Figure 22).

With the purpose of verifying whether all the passengers were sitting and with their seat belts buckled in, the investigation commission attempted to locate the 19 safety seat buckles in the aircraft.

Supposedly, there would be sixteen locked buckles and three open ones.

However, only three buckles were found, and one of them had been partially consumed by the fire.

**1.15 Survival aspects**

There were no survivors. All aircraft occupants perished in the impact.

**1.16 Tests and research**

The aircraft engines were taken to the Science and Aerospace Technology Department (DCTA) in São José dos Campos, State of São Paulo, for analysis.

The exam of the external part of the right engine revealed that it had been seriously damaged by the post-impact fire.

The propeller blades had been partially melted on account of the long period of exposure to the fire.

Figure 23 shows the extra latch of the fuel control unit (FCU) broken. Since the wire seal of the power control lever was intact, it is not possible to determine when or how the FCU extra latch was broken.

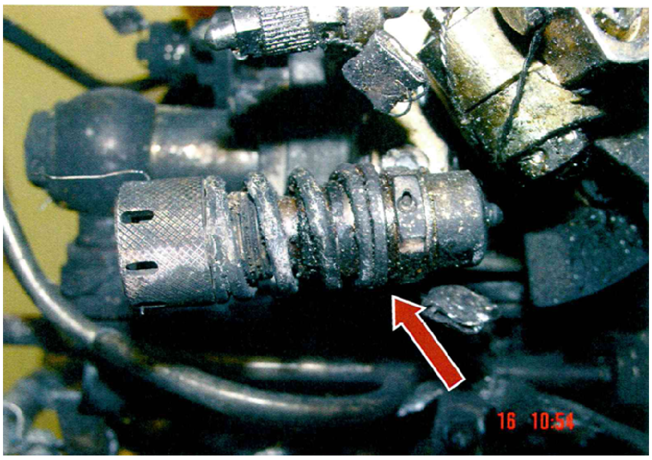


Figure 23 – FCU extra power latch with the seal ruptured.

Data from the SSFDR are not compatible with an increase in power of the engine number 2, on account of the use of this extra latch.

The traces observed in all the opening stages indicate that the right engine was functioning normally and developing power up to the moment of impact.

The marks of heavy rubs which were found in the hot section (in the compressor turbine rotor, in the fixation nut of bearing number 2, in the cap of bearing number 2, and in the diaphragm), the damage to the stator blade of the power turbine, and the 45º torsion observed in the exhaust area are a signature characterizing the normal functioning and power development of this engine.

Thus, there is no doubt regarding the operability and development of power by this engine up to the moment of impact.

The left engine also sustained severe damage from the long period it was exposed to the fire. All the evidence that was found indicates that the left engine was not functioning at the moment of impact.

Externally, the propeller blades were in the feathered position, and the 45º torsion in the engine exhaust area was not found. Internally, all the signatures confirmed that the left engine was not functioning at the impact.

The marks of impact found in the diaphragm and the fractures in some of the power turbine blades (Figure 24) also indicate that the left engine was not functioning at the moment of impact.

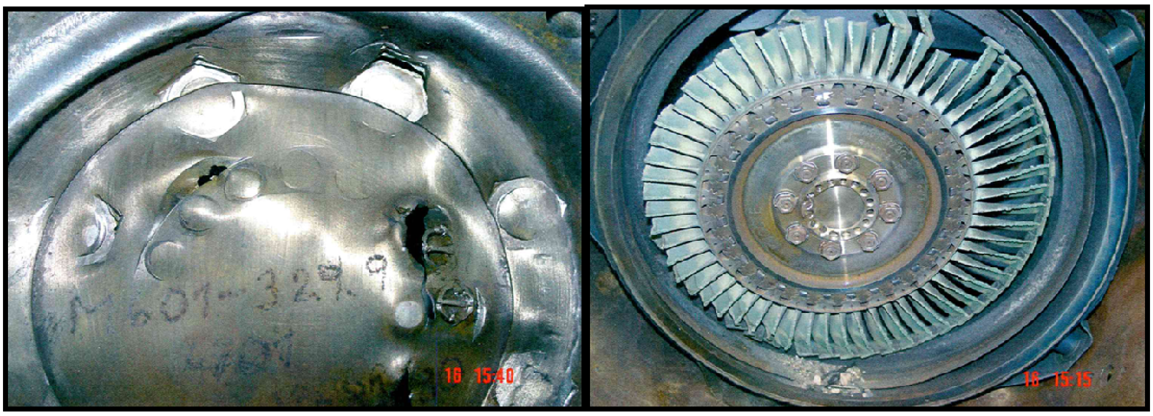


Figure 24 – Internal marks on the left engine.

In this engine, it is possible to observe the separated GGT blade S/N T52A175 which had occupied the position 27 in the GGT disk, as can be seen in Figure 25.

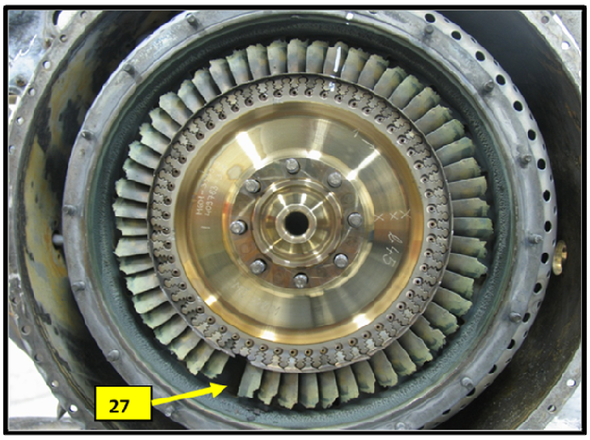



Figure 25 – Left engine GGT disk with the position 27 blade fractured.

The left engine GGT disk had the same diameter measure as the original one of manufacture, indicating that it had not suffered any significant growth or plastic deformation on account of overspeed, after the breakage of the blade.

The blade of the position 27 broke in the shank area, resulting in secondary damage to the remainder set of blades.

In Figure 26, the white arrow (on the left) shows the region where the fracture of the S/N T52A175 blade began, whereas the yellow arrow (on the right) shows the corresponding region of an undamaged blade.

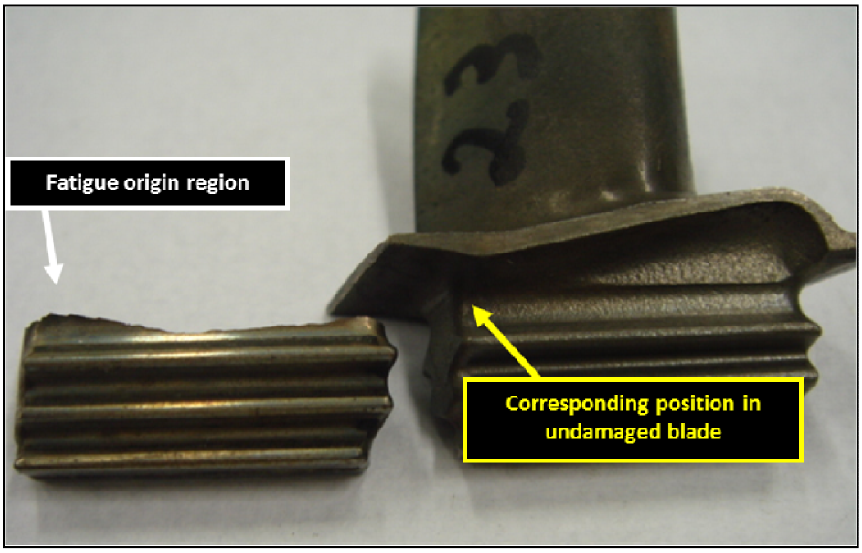



Figure 26 – Beginning of fatigue in the S/N T52A175 blade, and analogous image of an undamaged blade.

In Figure 27, it is possible to see the distinction between the area in which the fatigue spread and the area of final tensile overload.

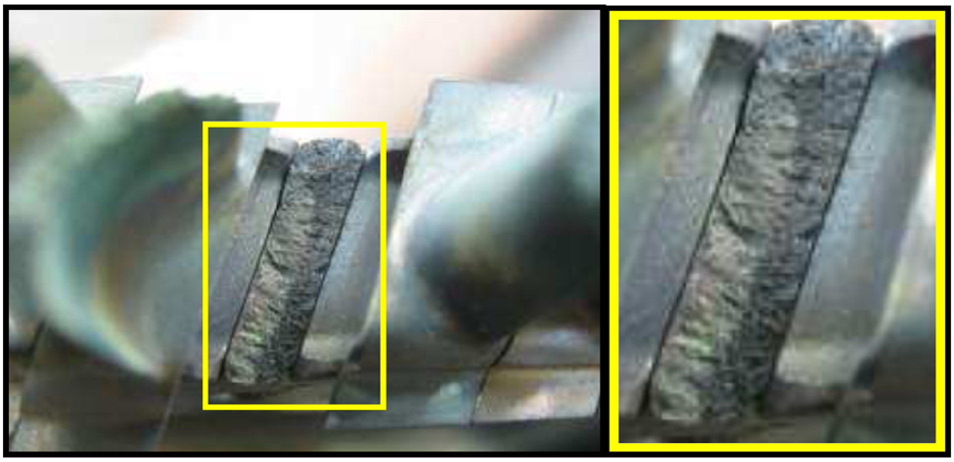


Figure 27 – View of the fractured area in the S/N T52A175 blade.

Approximately 50% of the surface of the remaining blades was damaged. There was heavy secondary damage to all the remaining blades submitted to a high rotating speed and load factor. The fracture of the blade in the position 27 was easily observed after the engine rotor GGT was disassembled.

Examinations of the compressor turbine disk and its blades were carried out, aiming at identifying the possible cause of the rupture of the S/N T52A175 blade. For convenience, the analyses were carried out at the GE laboratories in the USA, under supervision by the Investigation Commission and monitoring by both the manufacturer and the operator.

According to information provided by GE Aviation Czech, the fractured blade (S/N T52A175) was manufactured on 14 June 2000, and was installed in the engine PN M601E – SN 873-026. By means of leasing, this engine was being operated in an L-410 of the Kapo Aviakompania in Russia.

When this engine (of the Kapo Aviakompania L-410 aircraft) was overhauled, the compressor turbine disk blades were removed and inspected by means of a liquid fluorescent penetrant inspection (FPI) process on 5 February 2011. Two of these blades were discarded due to leading edge damage, while two other ones were submitted to a destructive metallographic test, as prescribed in the engine overhaul manual. In the end, a total of 51 blades were considered to be in condition of reutilization. 31 of these blades had come from the T52A heat lot (to which the one that fractured – S/N T52A175 – belonged), and 20 were from the T50H heat lot.

A new disk set was then assembled with reutilization of the 51 approved blades, and four new blades from the 74F heat lot were added. This new assembly was later installed in the left engine of the PR-NOB airplane (on 10 July 2011). In this aircraft, it operated for 21 hours and 18 minutes, reaching a total of 1,996 hours and 18 minutes by the time the failure occurred.

| Position in the disk | Heat lot and S/N | Position in the disk | Heat lot and S/N | Position in the disk | Heat lot and S/N | Position in the disk | Heat lot and S/N | Position in the disk | Heat lot and S/N | Position in the disk | Heat lot and S/N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | T52A 221 | 11 | T52A 194 | 21 | T52A 203 | 31 | T50H 53 | 41 | T50H 72 | 51 | T52A 157 |
| 2 | T50H 51 | 12 | T50H 110 | 22 | T50H 80 | 32 | T50H 8 | 42 | T50H 131 | 52 | T50H 54 |
| 3 | T52A 181 | 13 | T50H 21 | 23 | 74F 73N | 33 | T50H 18 | 43 | T52A 158 | 53 | T52A 172 |
| 4 | T52A 224 | 14 | T50H 147 | 24 | T52A 179 | 34 | T50H 108 | 44 | T52A 190 | 54 | T52A 200 |
| 5 | T50H 73 | 15 | T50H 75 | 25 | T52A 174 | 35 | T50H 149 | 45 | T50H 109 | 55 | T52A 214 |
| 6 | 74F 23H | 16 | T52A 212 | 26 | 74F 23N | 36 | T50H 185 | 46 | T52A 204 | | |
| 7 | T52A 209 | 17 | T50H 34 | **27** | **T52A 175** | 37 | T52A 228 | 47 | T52A 155 | | |
| 8 | T52A 213 | 18 | T52A 173 | 28 | T50H 101 | 38 | T52A 223 | 48 | T50H 103 | | |
| 9 | T52A 189 | 19 | T52A 210 | 29 | T52A 188 | 39 | T52A 182 | 49 | T52A 197 | | |
| 10 | 74F 123N | 20 | T52A 217 | 30 | T52A 229 | 40 | T52A 211 | 50 | T52A 171 | | |

Table 3 - Compressor turbine disk blades production heat lots of the accident engine.

Therefore, in the compressor turbine disk of the accident engine, the blades had come from three distinct heat lots (T52A, T50H and 74F), as seen in Table 3. So, for the purpose of a comprehensive evaluation by this investigation team, blades from the three heat lots were selected (including the fractured blade, S/N T52A175) to be submitted to visual, fractographic, and metallographic exams, hardness measurement, FPI inspection, as well as dimensional inspection, this latter also carried out in the respective disk slots.

The fracture of the S/N T52A175 blade occurred in the region of the blade shank, originating from an incipient, faceted subsurface fatigue, located close to the trailing edge of the blade, on its convex side. The propagation of the crack reached approximately 50% of the blade shank cross-section before it separated due to tensile overload mechanisms (Figure 28).

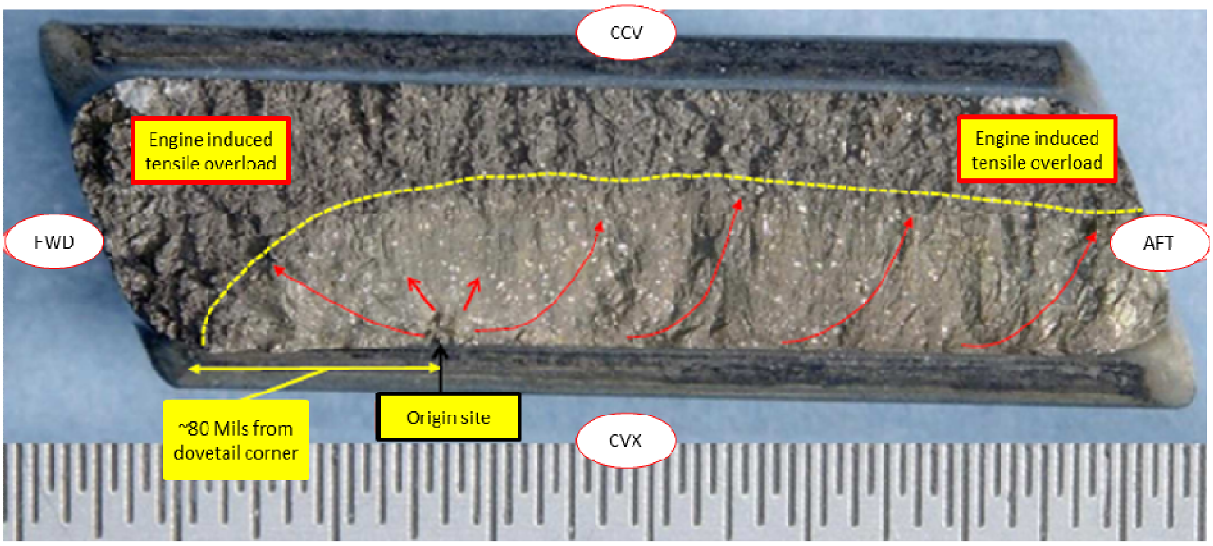



Figure 28 – View of the fatigue propagation in the S/N T52A175 blade.

Detailed stereoscopic examinations did not reveal any evidence of other cracks in the shank area of the other blades of the left disk, or irregular marks, or unusual marks on the faces of the blades.

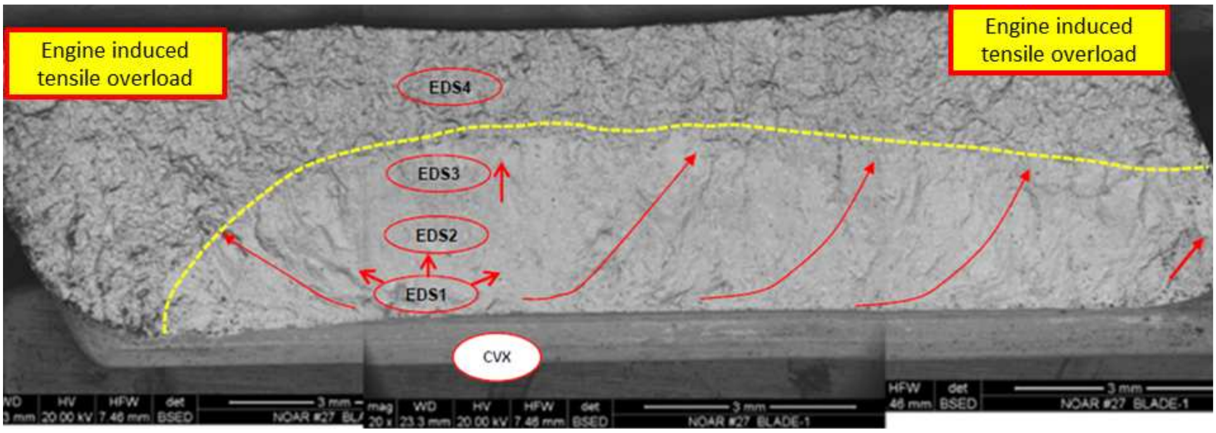



Figure 29 – Fractorgraphic exams.

By means of fractographic examinations, the fracture surface of the S/N T52A175 blade was evaluated in the Scanning Electron Microscope (SEM) in the unclean condition, in order to assess which types of remains were present on the surface in various places, as shown in Figure 29. The Energy-Dispersive X-ray Spectroscopy (EDS) obtained spectrums of the fatigue regions (locations EDS1, EDS2 AND EDS3) and of the region induced by engine tensile overload (EDS4).

Evidence of chlorides (Cl), silicon (Si), iron (Fe) and copper (Cu) were detected in both the fatigue region and the tensile overload region, indicating that the odd remains had been deposited after the separation of the blade. No signs of phosphorus (P) were detected in the fatigue region, as a potential residue of the penetrant liquid used in the FPI.

The fractographic examination exhibited a faceted, subsurface fatigue process (crystallographic) and a subsequent “smooth” aspect (low rugosity), transgranular propagation, without secondary cracks, consistent with lower alternating stress (high cycle fatigue) mechanisms in larger-grained structures typical of cast materials.

A metallographic section was prepared through the fracture surface of the S/N T52A175 blade for a subsequent gradual step polishing in the region of the faceted subsurface origin. The exam of the region of the fatigue crack origin after each stage of polishing did not reveal evidence of any significant anomaly in the material. The general microstructure consisted of a cast equiaxed grain structure that met design requirements.

The hardness obtained in the shank region of the blade met the design requirements and was consistent with the appropriately processed material.

The FPI of the remainder of the blades of the left engine GGT disk did not reveal evidence of additional cracks.

Dimensional exams of 14 blades (and respective slots) of the left engine GGT disk were carried out, utilizing the Coordinate Measuring Machine (CMM), an extremely precise piece of measuring equipment available at the GE Aviation Quality Technology Center. The way the selection of the blades was made allowed a significant sampling in terms of position of each blade in the disk, besides containing the three heat lots.

The GE dimensional inspection report concluded that:

*"No evidence of any gross out of tolerance dimensions were observed, although several GGT Blade and GGT Disk slot dimensions were found to be slightly out of drawing tolerance, typically on the low side. The slightly out of tolerance dimensions were considered typical of engine run hardware and not expected to have any significant vibrational affects to the GGT region of the engine."*

Upon request from the investigation team, a clarification regarding the meaning of the expressions "tolerance", “slightly out” and “gross out”, used in that report was provided by GE:

*"Dimensional tolerances are the specified permissible deviations from a known nominal dimension. It can also be considered as the permissible variation in the size of a part or a part feature. On new parts, dimensional tolerances are listed on the applicable drawings and drawing features. Every part feature will have a minimum and maximum value. The tolerance is that average with a not to exceed values for the min and max values. As an example, diameter “A” can be as small as 1.00 inches or as large as 1.50 inches. Its dimensional tolerance will be 1.25 inches +/- 0.25 inches.”*

Remarking that, due to the proprietary nature of the GGT disk and GGT blade dimensional data, GE attempted to provide a non-value assessment on the tolerance measured during the examination, and recalling that the measured GGT blades and disk were involved in an aircraft accident in which these parts experienced loads and stresses that could not be measured, the investigation team was informed that:

*“SLIGHTLY OUT means that the measured event hardware was just outside new part drawing dimensional tolerances, but according to Engineering the dimensions are OK. GROSS OUT of tolerance is totally out of new part drawing dimensional tolerances. Dimensional data was primarily performed to check for any* ‘grossly out of tolerance’ *dimensions on the event blades and/or event disk posts which could have provided a 1/rev stimulus or other excitation which was not found."*

The results of the analyses determined that the crack initiation and propagation of GGT blade S/N T52A175, located in position 27 of the left engine GGT disk, was caused by a high cycle (lower stress level) fatigue mechanism. No defects, corrosion or microstructural alterations were observed that could have favored the start of a fatigue process. The onset of the crack occurred in an internal region of the material just below the surface (≈ 200 μm).

### 1.17 Organizational and management information

Refer to item 1.13.3.3.

### 1.18 Operational aspects

#### 1.18.1 Pilot training

The NOAR company started its operational activities with the training of its first five pilots in the L410 aircraft. The PIC belonged to this group.

This training was given by TEAM Linhas Aéreas in Rio de Janeiro in the months of November and December 2009, and included both theoretical and practical activities, with the initial local flight and en route flight instruction being given in an aircraft owned by TEAM Linhas Aéreas.

From the PIC's Pilot Evaluation Forms (FAP) relative to the practical flight training he received at the TEAM company, one can see that:

- The FAP form did not have a specific field for evaluation of the takeoff engine failure training;
- In the FAP's "VI – Maneuvers" item, the following issues were listed: turns, stalls, feathering, single-engine flight, airstart, emergency lever and spoiler. In the PIC's FAP, one can read that during his training in the L410, that he received a satisfactory mention in the "VI Maneuvers" item;
- In "XII – Additional items", the FAP form had two lines left blank for the inclusion of some exercise not described before. In the item XII of the PIC's FAP, there was not any record of a takeoff engine failure training; and
- In the field "Comments" of the PIC's FAP, nothing is said about the execution of a contingent takeoff engine failure exercise.

In the interviews conducted during the investigation, at least on one occasion it was verified the omission of the practical training of takeoff engine failure among the pilots who graduated in the first group (at the TEAM facilities), and the crew just simulated the takeoff engine failure, followed by a single-engine approach, without any correlation with the takeoff engine failure training.

Figure 30 shows the takeoff engine failure training method prescribed in item 5 of the manufacturer's training program (*L410 Aircraft Pilot Type Training Program*, item 5) approved before an L410 primary certification authority, in its 20 October 2009 version.

After the arrival of the first airplane at NOAR (this happened only on 12 March 2010), the pilots who had been trained at the TEAM company were submitted to a training of the differences between the newly arrived airplane and the TEAM airplane in which they had had their initial training.

In one of the FAPs (dated from 9 April 2010) received by the PIC in this training, the following comment can be seen:

> *"Training done, with practice of all the phases of takeoff engine failure below V1 and aboveV1."*

5. Practice training of one engine simulated failure during take off up to the speed $V_1$ and above the speed $V_1$ and instrument approach and landing with one engine inoperative.

Aim:

To familiarize the student with the uniqueness of aircraft behavior during engine failure at take off and during instrument approach with one engine inoperative.

Method:

Practice training of engine simulated failure during take off run - the instructor reduces power setting at takeoff run phase up to speed $V_1$ and student pilot executes the aborted take off in compliance with AFM procedures bringing the aircraft to a safe stop.

The practice training of engine failure above $V_1$ cannot be carried out at take off level because of safety aspects and therefore it takes place in a simulated take off at an attitude not lower than 2000 ft AGL and covered up cockpit. The instructor may decide for a further training of engine failure during take off, which will take place during the real take off after the undercarriage has been retracted.

Figure 30 – L410 manufacturer's pilot training program.

The investigation commission verified that there was an engine failure simulation at the takeoff from SBRF and, just after the aircraft passed 400ft AGL, it made a turn to join the downwind leg at 1,000ft. On this occasion, without passengers and cargo, the takeoff weight was 5,450 Kg or less, allowing a rate of climb of up to 492 ft/min (2.5 m/sec) with one engine inoperative.

The second group of NOAR pilots, to which the copilot involved in this accident belonged, began the L410 airplane theoretical and practical training in July 2012 at the NOAR facilities. The instruction was taught by the pilots who had graduated in the first group (trained at the TEAM company).

The paragraph 2.1 of the NOAR's Operational Training Program (PrTop) approved by the ANAC disposed about the complete initial training for newly-hired crewmembers. In item 2.1.4.2, among the activities prescribed in the syllabus of the ground curriculum segment, the following is highlighted:

- Routine and emergency procedures, operation limitations; and
- PIC's and copilot's *checklists* – preparation for the flight.

In item 2.1.5, the activities prescribed in the syllabus of the flight curriculum segment are listed, and especially:

- Ground training for takeoff engine failure (up to V1 and above V1), during climbs and approaches with one engine inoperative (without reference to the amount of training and the time load); and

- Takeoff engine failure practice (up to V1 and above V1) during climbs and approaches with one engine inoperative (with two training sessions and a total of one-hour duration).

Although the documentation protocolled by the operator at ANAC attests the completion of comprehensive training, no other record was found showing that the activities highlighted above (among those specified in items 2.1.4.2 and 2.1.5 of PrTop) were actually performed.

After the accident, the commission verified, by means of interviews, that the student-pilot himself had to adapt his training schedule to the availability of the instructors, something that was not always feasible. As a result, on one occasion, there was the case of a pilot under training that was reprimanded by the instructor on his first flight, due to a lack of knowledge that had to have been transmitted in these instructions before the flight.

In the practical flight training FAPs of the copilot involved in the accident, no records were found concerning the takeoff engine failure emergency training.

In interviews with various pilots, it was verified that many of them did not do the *Engine Failure during Takeoff – Above V1* emergency training.

The third group of NOAR pilots began their theoretical and practical training of the L410 airplane in November 2010, also at the NOAR facilities. Of the five instructors that taught the theoretical training, four were graduates from the first group.

Part of the classes delivered to this group was monitored by a Civil Aviation Inspector (INSPAC) in the period from 3 to 7 November 2010.

The nº 8708/2010 Operational Safety Vigilance Report (NOAR Linhas Aéreas Regionais – 0905 99 3000 102) opinion issued by the ANAC after evaluating the course was the following:

*During the period of observation of the Complete Initial Training Course (Basic Indoctrination, General Emergencies, Hazard Materials, and L410-UVP-E Ground Curriculum), it was possible to notice inaccuracies in the text of the LET 410 UVP E20 Ground School Manual (which was the main Instruction Material provided), as well as deficiencies in some of the instructors regarding their classroom skills, parts of the syllabus contained in the PTmOp which were not presented, and incompliance of the time load prescribed in the PTmOp. In summary, those were the points of deficiency observed during the time of observation of the training.*

*It is worth highlighting that the period of observation coincided with the normal ANAC working hours on week days. Since the instructional sessions would sometimes prolong to 12:45 in the morning period, and to 18:45 in the afternoon period, and, occasionally, even on weekends, it was not possible to observe all the instructions that were delivered in the course.*

*Taking into consideration the points of deficiency noticed during the period of observation of this training course, this INSPAC is favorable to the requesting of provisions to be made by the NOAR Linhas Aéreas to correct the mentioned deficiencies, and complement both the program contents and the time load covered by the instructions delivered and which were observed in this mission.*

*After the company presents the corrections for the mentioned deficiencies, and complements both the program contents and the time load covered by the instructions delivered, it can proceed with the training notification nº 015/CND/2010.*

Completion of the training course by the third group was delayed for a few weeks, so that all the non-conformities pointed out by the ANAC could be solved. Upon completion of the training of this group, the NOAR Company had a total of nine captains and six copilots.

**1.18.2 Training - regulation**

The Brazilian Aeronautical Certification Regulation (RBHA) 135.347 in force at the time the first class of pilots completed their training disposed:

*"(a) The initial, the transition, and the level-upgrading trainings, as well as the training of the differences, shall include flying and practicing every procedure and maneuver contained in the approved training program curriculum.*

*(b) The maneuvers and procedures required by paragraph (a) of this section shall be performed in flight, except for the maneuvers and procedures that can be performed in an aircraft simulator or in another appropriate training device, as authorized by this subpart."*

The updating of that regulation (RBAC 135) did not change the contents of the paragraph 135.347.

In item 3.2.1, the IAC 135-1002, dated from 20 September 2005, establishes groups of aircraft, and the L410 belongs to the Group I. For the aircraft in this group, the item 4.1.c establishes the need to utilize the flight simulator (five training sessions and a session for evaluation) for the complete initial training flight curriculum.

By the date of the accident, there was not an L410 simulator approved by the Brazilian Civil Aviation Authority. For cases like this, the 119-001/SSO ANAC Procedures Manual (MPR), dated from 22 April 2009, in its item 3.1.16, allows the approval of air operators' training proposals that do not prescribe the utilization of simulators, if the manufacturer has approved, before the primary certification authority, the minimum training with the flight curriculum to be complied with only in the aircraft.

As a requirement for the approval, the item 3.1.27 of the MPR establishes that the INSPAC must observe the minimum training program approved by the primary certification authority.

According to the pilot training program approved for the manufacturer, the takeoff engine failure above V1 emergency inflight training cannot be done at takeoff height due to safety reasons. Thus, it had to be given with the instructor simulating a takeoff with the aircraft at 2,000ft AGL, and with covered up cockpit (Figure 30).

In a contradictory fashion, however, this same item bestows the instructor with the prerogative of deciding to give additional training during a real takeoff, after retraction of the landing gear.

The document does not provide information on the power setting to be maintained during the training, in order to simulate the condition of a feathered propeller in terms of drag.

The manufacturer’s program also prescribed that the takeoff engine failure (up to V1 and above V1) exercises, during climbs and approaches with one engine inoperative had to be performed in two flights, with a total allotment of one hour for this purpose.

The manufacturer’s training program was updated on 22 March 2010, but no change was made in the takeoff engine failure above V1 emergency training.

The NOAR’s PrTop approved by the ANAC presents the takeoff engine failure emergency above V1 training method in its item 2.1.5.2, nº 5, and it is just a literal translation of the manufacturer’s program contents.

Figure 31 shows the flight profile prescribed for takeoff engine failure, according to both the manufacturer and the operator training programs.

The first takeoff segment begins when the aircraft initiates the takeoff run, and ends when retraction of the landing gear is completed. In the profile, it is possible to identify a V1 (decision speed) that is lower than VR (rotate speed), and the point of landing gear retraction (gear up).

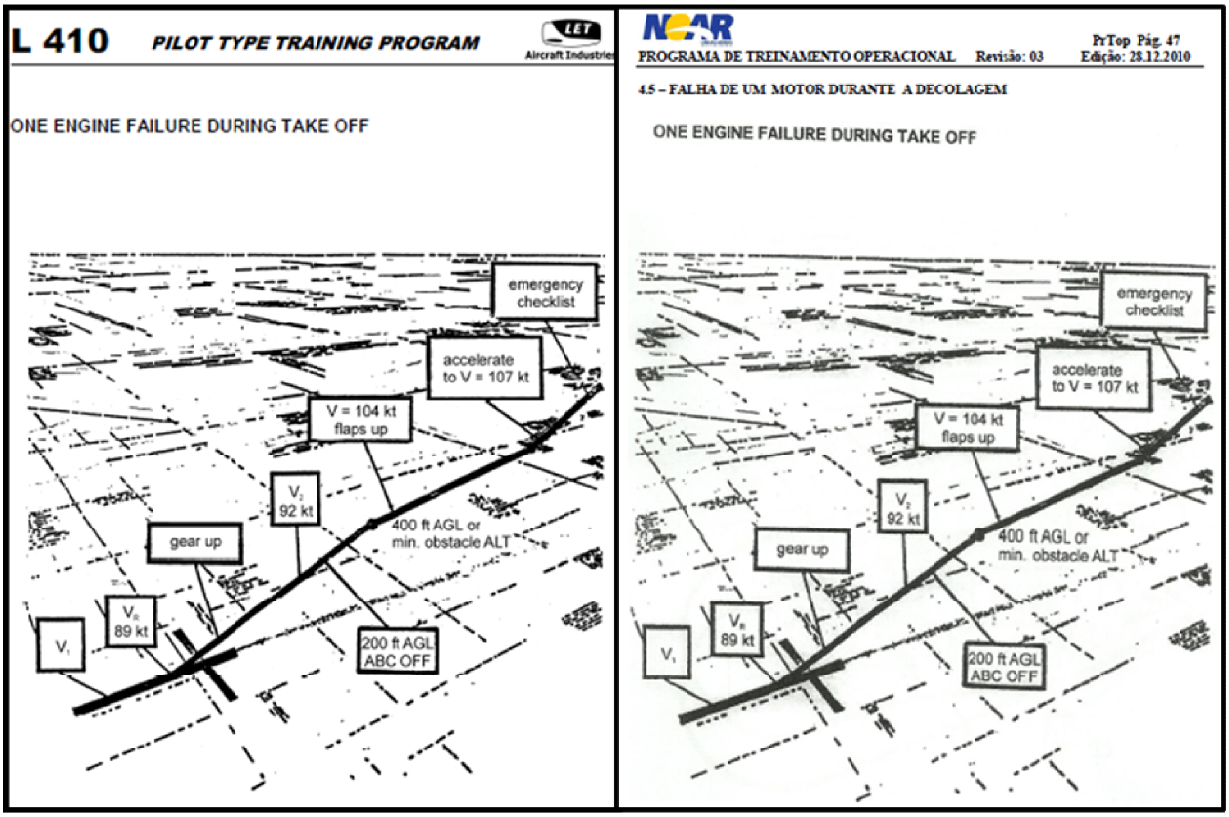



Figure 31 – Flight profile for takeoff with one engine inoperative.

The second segment of the takeoff begins with the full retraction of the landing gear, and ends with the aircraft at 400ft AGL. In this segment, one observes the indication to maintain V2 (safe speed with one engine inoperative) and the indication for the automatic bank control (ABC) to be switched off at 200ft.

The third segment begins at 400ft, with the profile indicating the need to accelerate from 92kt (V2) to 104kt and retract the flaps. Then, one must accelerate from 104kt to 107kt, continuing the climb at this speed. The emergency checklist reading has to be done during this climb at 107Kt (and above 400ft).

### 1.18.3 Manuals and publications

#### 1.18.3.1 Third segment flight profile of the takeoff engine failure

The Section 5 – Performance of the Aircraft Flight Manual (AFM) contains the following information relative to the flight profile of the third segment of takeoff with one engine inoperative:

LET Letecké závody a.s. Czech Republic

**L 410 UVP-E20**
FLIGHT MANUAL

SECTION 5
PERFORMANCE

Third segment

This segment has been divided into two parts:

- segment 3a: acceleration of the aircraft in horizontal flight at the height of 122 m (400 ft) above the runway elevation from speed $V_2$ =170 km/hr (92 kt) IAS to 193 km/hr (104 kt) IAS, wing flaps selected up at this speed with subsequent acceleration to 199 km/hr (107 kt) IAS.
- segment 3b: Climbing from 122 m (400 ft) to 457 m (1,500 ft) above runway elevation. Wing flaps fully retracted and airspeed 199 km/hr (107 kt) IAS. The maximum angle of bank is 5 degree and particial triming of the rudder.

Note: Full triming of the rudder is from altitude 457m (1,500 ft) above runway at speed 210 km/hr IAS (114 kt) IAS.

Figure 32 – AFM Section 5 – 3rd segment.

#### 1.18.3.2 Quick Reference Handbook prepared by the operator

A QRH was found by the investigation commission in the other airplane of the operator (PR-NOA) on the same day of the accident.

The speed parameters found in this QRH were not compatible with the model of the operator’s L410 aircraft, but coincided with those of the TEAM Company, where the first crew members and mechanics had received training.

In the manufacturer’s checklist, the emergencies of inflight engine failure and takeoff engine failure are presented in a distinct manner. In the QRH, the inflight engine failure emergency was appropriately found in the chapter of abnormal procedures. However, in the chapter referring to the section 3 & 3A of the AFM, the emergency relative to takeoff engine failure, when translated into Portuguese, was inappropriately named “inflight engine failure”.

The introductory text of this chapter of the QRH suggests that the handbook is more of a study-support tool than a guide to be used during flight. Within this text, there is a recommendation for the use of the checklist to solve problems during the flight.

Besides containing these inconsistencies, the QRH was difficult to handle. In a test given to an instructor of the company, with the aircraft on the ground and not moving, the investigator asked him to open the QRH in the takeoff engine failure emergency, and, even after a two-minute period, the page had not been found.

One of the interviewees said that there was a time in which the checklist utilized was different from the one provided by the manufacturer and did not deal with some emergencies.

These incorrections had already been observed, and a checklist (in English), whose contents were similar to the manufacturer's, had been made and was allegedly being implemented.

It was not possible to determine which checklist was onboard the accident aircraft, since all the material was destroyed by the post-impact fire.

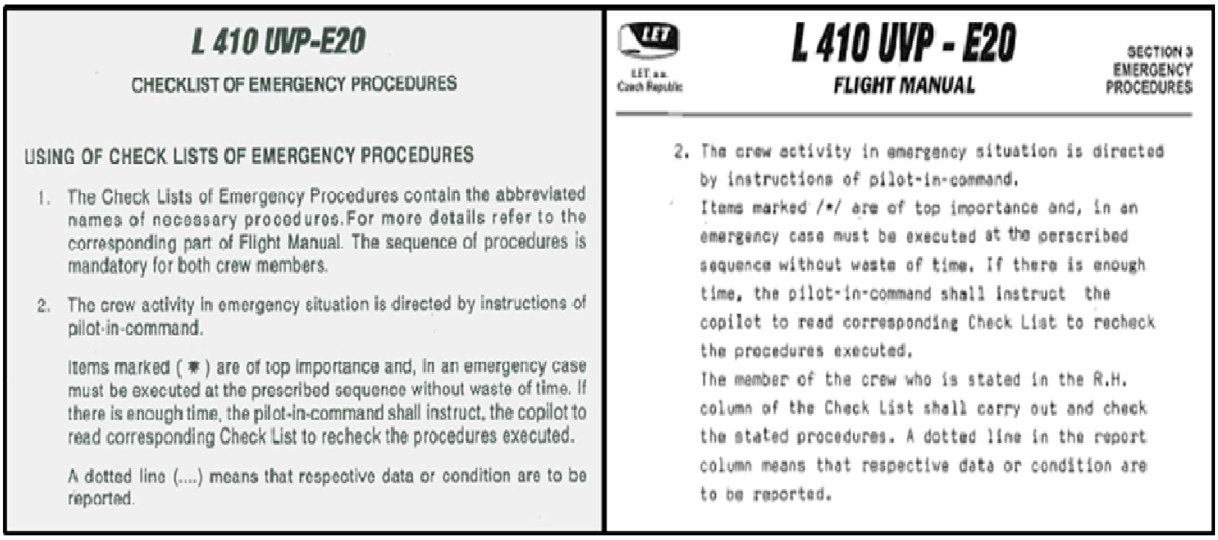
According to the ANAC, the checklist that was submitted by the NOAR company for approval in the process of certification of the company was the very checklist of the manufacturer (in English), dated from 15 May 2003.

The evidence provided by the CVR indicates that the flight 4896 crew utilized 92kt as V2 parameter, in conformity with the manufacturer's checklist, and that there is no indication of the use of either the QRH or the checklist during the emergency.

**1.18.3.3 Discrepancies between the AFM and the manufacturer's Emergency Checklist**

The following discrepancies between the AFM and the Aircraft Industries' Emergency Checklist concerning the *takeoff engine failure – above V1* emergency procedures were observed:

a) both the checklist (page E-1) and the AFM (page 19) bring the remark that the items marked with an asterisk are considered vital and require urgent actions (Figure 33);


L 410 UVP-E20

CHECKLIST OF EMERGENCY PROCEDURES

USING OF CHECK LISTS OF EMERGENCY PROCEDURES

1. The Check Lists of Emergency Procedures contain the abbreviated names of necessary procedures. For more details refer to the corresponding part of Flight Manual. The sequence of procedures is mandatory for both crew members.

2. The crew activity in emergency situation is directed by instructions of pilot-in-command.

Items marked ( * ) are of top importance and, in an emergency case must be executed at the prescribed sequence without waste of time. If there is enough time, the pilot-in-command shall instruct, the copilot to read corresponding Check List to recheck the procedures executed.

A dotted line (....) means that respective data or condition are to be reported.

LET a.s. Czech Republic

L 410 UVP - E20

FLIGHT MANUAL

SECTION 3 EMERGENCY PROCEDURES

2. The crew activity in emergency situation is directed by instructions of pilot-in-command.

Items marked /*/ are of top importance and, in an emergency case must be executed at the perscribed sequence without waste of time. If there is enough time, the pilot-in-command shall instruct the copilot to read corresponding Check List to recheck the procedures executed.

The member of the crew who is stated in the R.H. column of the Check List shall carry out and check the stated procedures. A dotted line in the report column means that respective data or condition are to be reported.

Figure 33 – Remark contained in the checklist (page E-1) and in the AFM (page 19).

b) The checklist, on pages E-4 and E-5, shows three items marked with asterisks (Figure 34);

**L 410 UVP-E20**

CHECKLIST OF EMERGENCY PROCEDURES

**ENGINE FAILURE DURING TAKE-OFF**

**Below V$_1$ speed:**

Abort the take-off.

**Above V$_1$ speed:**

| | |
|---|---|
| * 1) TCL of both engines | check Take-off rating |
| * 2) Landing gear after take-off | UP |
| * 3) Feathering propeller of inoperative engine | CHECK |
| (a) If the automatic feathering cycle has not been accomplished: | |
| MANUAL FEATHER of inoperative engine | DEPRESS |
| - IELU circuit breakers | OFF |
| (b) If the automatic feathering cycle has not been feathered even after above measures had taken then: | |
| PCL of the inoperative engine | FEATHER |
| 4. Airspeed | for 18° flaps V$_2$ = 92 KIAS (170 km/hr IAS) for 0° flaps V$_2$ = 104 KIAS (193 km/hr IAS) |
| At height of 200 ft (61 m) above runway: | |
| 5. AUTO BANK CONTROL switch | OFF |
| 6. Airspeed at height of 400 ft (122 m) for 18° flaps for 0° flaps | 104 KIAS (193 km/hr IAS) 107 KIAS (199 km/hr IAS) |
| 7. Flaps (if extended) | RETRACT |
| 8. Airspeed | 107 KIAS (199 km/hr IAS) |
| 9. Inoperative engine | FIND OUT PARAMETERS.......... |

(cont.)

E-4 (2) May 15/03

**L 410 UVP-E20**

CHECKLIST OF EMERGENCY PROCEDURES

a) If the engine is fully stoped:

(The following items are valid for inoperative engine)

| | |
|---|---|
| - TCL | IDLE |
| - PCL | FEATHER |
| - Fuel stop cock / Emergency throttle lever | SHUT |
| - Fuel fire cock | SHUT |
| - DC GENERATOR and AC GENERATOR circuit breakers switches | OFF |
| - Remaining circuit breaker switches of the engine | OFF |

b) If the engine operate at idle and other parameters correspond to idle power then:

- If the IELU INTERVENT signal does not light then carry out the procedure Use of emergency fuel control circuit (AFM section 3A.3.1.)
- If the IELU INTERVENT signal lights then carry out the procedure Spontaneous IELU interventions (paragraph b) (AFM section 3A.1.5.)

**ENGINE FAILURE DURING MISSED APPROACH**

| | |
|---|---|
| • 1. TCL of both engines | Maximum Take-off rating |
| • 2. Airspeed | >92 kt (170 km/hr) IAS |
| • 3. Flaps | 18° |
| • 4. Landing gear | UP |

(cont.)

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Figure 34 – Checklist containing three items marked with asterisks.

c) The AFM Section 3, pages 14 through 16, shows seven items marked with asterisks, therefore four more items than the checklist (Figure 35);

3.11. ENGINE FAILURE DURING TAKE -OFF

In case of engine failure at speed lower or equal to V$_1$

In case of engine failure at speed higher than V$_1$ :

∗ (1) Power control levers of both engines

Immediately eliminate the sideslip by rudde recommended angle of bank after lift -off is force on the rudder pedal does not exceed (81 kt) IAS.

∗ (2) At the height of 3 – 5 m (10 – 16 ft)

∗ (3) Check the propeller feathering (by means of the propeller RPM in

(a) If the automatic feathering cycl

- MANUAL FEATHER, push of the inoperative engine
- IELU (LH + RH) circuit brea on the overhead panel

(b) :If the inoperative engine propeller ha measures has been taken then :

- PROPeller control lever of the inoperative engine

∗ (4) Maintain take-off safety speed for 18° flaps

for 0° flaps

WARNING NEVER PERMIT THE AIRSPEED TO FOR 18° FLAPS AND 193 km/h IAS (

∗ (5) At height of 61 m (200 ft) above runway: AUT. BANK CONTROL switch on the central control panel

CAUTION: If during the climb to the height 122 m operation or pumping occurs on the fa the procedure as per section 3A.1.4. ,

∗ (6) For 18° flaps: At height of 122 m (400 ft) increase the s Retract the wing flaps into cruise position the aircraft to 199 km/hr IAS (107 KIAS). Maintain this speed up to 457 m (1,500 f

For 0° flaps: Accelerate the aircraft to 199 km/hr IAS Maintain this speed up to 457 m (1,500 f

CAUTION: Maximum permissible duration of Tak only.

∗ (7) Check the parameters of the inoperative engine.

(a) If the engine is fully stopped

The following items are valid for inoperative engine:

| | |
|---|---|
| – POWER control lever | idle |
| – PROPeller control lever | feather |
| – Fuel stop cock/Emergency throttle lever | SHUT |
| – Fuel fire cock | SHUT |
| – DC GENERATOR, AC GENERATOR circuit breakers | off |
| – remaining circuit breakers | off |
| – decide about the place of landing and report to ATC | |

If you decide to continue the flight to destination or alternate airport then at height of 450 m (1,500 ft) above runway accelerate the airplane to airspeed 200 km/hr IAS (108 KIAS) and maintain this speed up to the cruise level.

(b) If the engine operates at idle and other parameters correspond to idle power then:

- If the IELU INTERVENT signal does not light then carry out the procedure according to Section 3A.3.1. Use of emergency fuel control circuit.
- If the IELU INTERVENT signal lights then carry out the procedure according to Section 3A.1.5. Spontaneous IELU interventions (para. b).

ENGINE FAILURE DURING MISSED APPROACH

∗ (1). Power control levers of both engines: Maximum Take-off rating setting

Figure 35 – AFM with seven items marked with asterisks.

d) On page E-4, the checklist shows the item 5 (“AUTO BANK CONTROL switch OFF”) to be implemented at 200ft above the runway, without marking it with an asterisk (therefore, not treating it as vital/urgent). The manufacturer’s Training Program, in turn, when presenting the single-engine takeoff flight profile (Figure 36), establishes the reading and compliance with the checklist only after the speed of 107 kt is reached, with the aircraft above 400ft AGL; and

**L 410 UVP-E20**

CHECKLIST OF EMERGENCY PROCEDURES

**ENGINE FAILURE DURING TAKE-OFF**

**Below $V_1$ speed:**

Abort the take-off.

**Above $V_1$ speed:**

- * 1. TCL of both engines — check Take-off rating
- * 2. Landing gear after take-off — UP
- * 3. Feathering propeller of inoperative engine — CHECK
  - (a) If the automatic feathering cycle has not been accomplished:
    - MANUAL FEATHER of inoperative engine — DEPRESS
    - IELU circuit breakers — OFF
  - (b) If the automatic feathering cycle has not been feathered even after above measures had taken then:
    - PCL of the inoperative engine — FEATHER
- 4. Airspeed — for 18° flaps $V_2$ = 92 KIAS (170 km/hr IAS); for 0° flaps $V_2$ = 104 KIAS (193 km/hr IAS)

At height of 200 ft (61 m) above runway:

- 5. AUTO BANK CONTROL switch — OFF
- 6. Airspeed at height of 400 ft (122 m) — for 18° flaps 104 KIAS (193 km/hr IAS); for 0° flaps 107 KIAS (199 km/hr IAS)
- 7. Flaps (if extended) — RETRACT
- 8. Airspeed — 107 KIAS (199 km/hr IAS)
- 9. Inoperative engine — FIND OUT PARAMETERS..........

(cont.)

E-4 (2) May 15/03

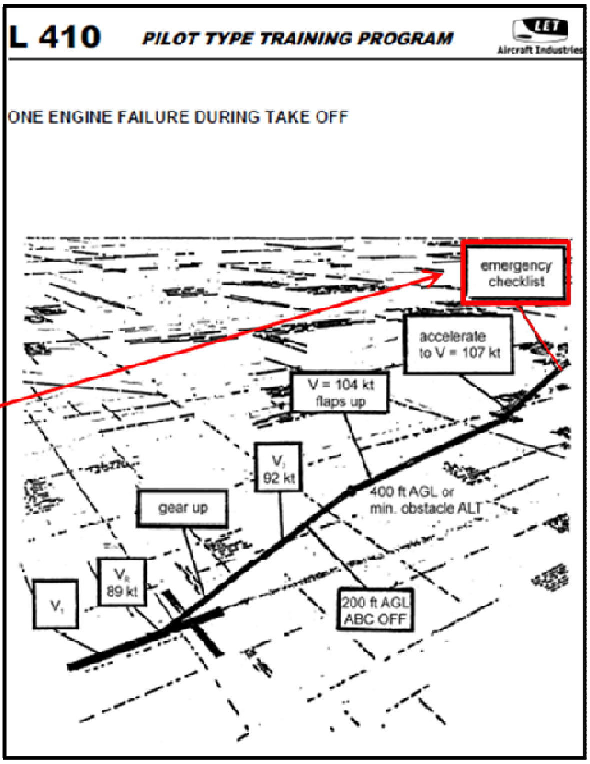



Figure 36 – Conflict between the checklist and the Training Program.

e) On page 15, the AFM indicates a climb up to 1,500ft, maintaining 107 KIAS, while on page E-4 of the checklist there is not any reference to 1,500ft (Figure 37).

**L 410 UVP-E20**

FLIGHT MANUAL — SECTION 3 EMERGENCY PROCEDURES

...

* (6). For 18° flaps:
At height of 122 m (400 ft) increase the speed to 193 km/h IAS (104 KIAS).
Retract the wing flaps into cruise position and without loosing height accelerate the aircraft to 199 km/hr IAS (107 KIAS).
Maintain this speed up to 457 m (1,500 ft).

For 0° flaps:
Accelerate the aircraft to 199 km/hr IAS (107 KIAS).
Maintain this speed up to 457 m (1,500 ft)

CAUTION: Maximum permissible duration of Take-off engine power setting is 5 minutes only.

**L 410 UVP-E20**

CHECKLIST OF EMERGENCY PROCEDURES

**ENGINE FAILURE DURING TAKE-OFF**

...

- 5. AUTO BANK CONTROL switch — OFF
- 6. Airspeed at height of 400 ft (122 m) — for 18° flaps 104 KIAS (193 km/hr IAS); for 0° flaps 107 KIAS (199 km/hr IAS)
- 7. Flaps (if extended) — RETRACT
- 8. Airspeed — 107 KIAS (199 km/hr IAS)
- 9. Inoperative engine — FIND OUT PARAMETERS..........

Figure 37 – Altitude of 1,500ft is not indicated for the speed of 107kt.

### 1.18.3.4 NOAR’s Manual of Standard Operating Procedures (SOP)

The Standard Operating Procedures Manual showed an example of a takeoff briefing, in which two distinct takeoff-abort possibilities due to engine failure are planned.

In Figure 38, such possibilities are underlined in green (up to VR), and in red (above VR) in the text translated from the original in Portuguese.

**Example of before take-off Briefing**
**(Done by the PF)**

"Take-off will be **NORMAL,** from **runway …** threshold**. After lining up,** we will do the **BEFORE TAKE-OFF** and the **CLEAR FOR TAKE-OFF** checklists**, verifying PEDAL STEERING light on.** With brakes applied, **check compass, heading, taking the power up to 60%,** starting the chronometer **and verifying all the parameters.** Releasing the brakes, **the PF increases power to TAKE-OFF POWER, until the PM touches his hand,** adjusting the take-off power within parameters, **and informs:** IAS INDICATOR **speed alive, Cross Check at 50kt, V1(81kt), VR(89kt). In case of failure until VR, we will remain on the ground**, reducing power to IDLE right away, applying **reverser, spoilers and brakes** to stop within the limits of the runway. **Above VR,** with runway available, **I'll return to runway and apply brakes, spoilers and reverser, as needed.** If landing is not possible**, the PF flies the plane; the PM, under command of the PF, retracts the landing gear with positive rate,** identifies and informs the nature of the failure**.** Corrective actions will **only be taken at 400ft,** after careful analysis **and decision by both the PF and PM. If the take-off is not being made by the aircraft captain, and the emergency occurs, the captain has to take over piloting and the other crewmember resumes the copilot duties.**

Figure 38 – Example of a take-off briefing in the operator's SOP.

According to the 14 CFR Part 23, fully adopted in Brazil by means of the RBAC 23, the decision speed V1 is the calibrated ground speed in which, as a result from engine failure or other reasons, it is assumed that the pilot has to decide whether to continue or discontinue takeoff.

Conceptually, it may be said that V1 means the maximum takeoff speed at which the pilot has to take the first action (for example, apply the brakes, reduce power, open aerodynamic brakes) with the purpose of stopping the plane within the acceleration and stop distance. It means, also, the least takeoff speed, following a critical engine failure at $V_{EF}$ (calibrated speed at which a critical engine failure is presumed) where the pilot is able to continue the takeoff and reach the required altitude above the takeoff surface within the takeoff distance.

For the case of aborted takeoff above V1, there are neither graphs nor analyses to guarantee that the aircraft decelerates and stops safely.

According to the SOP, the operator adopted the speed of 81 kt as V1, 89 kt as VR, and 92kt as V2, in conformity with AFM Section 5.

Another point worth to be highlighted is the observation that the corrective actions only have to be made at 400 ft (underlined in blue).

### 1.18.4 Calculation of the Maximum Takeoff Weight

The page 11 of the AFM, Section 5, presents a flow chart for the calculation of the maximum takeoff weight, in which one considers the takeoff limitations according to weight, altitude and temperature (takeoff WAT), as well as the limitations related to the runway length, with attention to the fact that, in the case of an aerodrome free of obstacles, the least value among the ones obtained shall be considered.

Below, one can see the calculations of the maximum takeoff weight, considering that the engine water injection system was not utilized, and using the value of 10m as the SBRF pressure altitude, as well as the temperature of 23ºC at the time of takeoff.

The calculation made from the graph of the figure 5-6a, page 12 of the AFM, Section 5 (Figure 39), indicated a maximum takeoff weight of 6,430 Kg for the second segment.

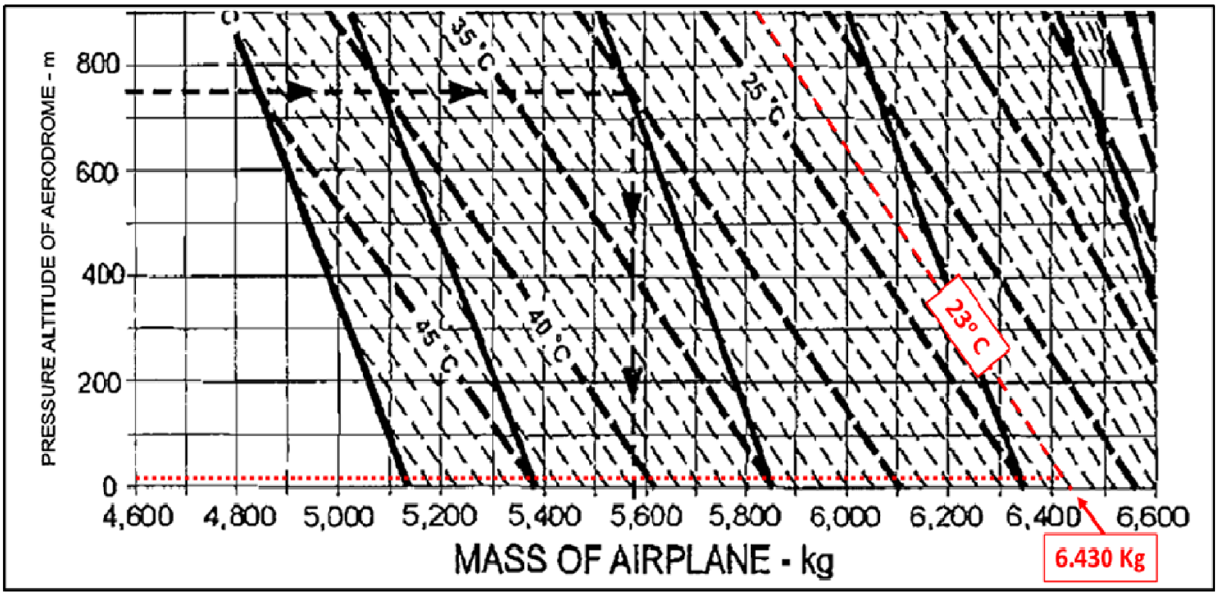



Figure 39 – Maximum takeoff weight according to the AFM graph, page 12a, figure 5-6a.

The calculation made from the graph of the figure 5-6c (page 13 of the Section 5) (Figure 40) indicated a maximum takeoff weight of 6,600Kg for the third segment.

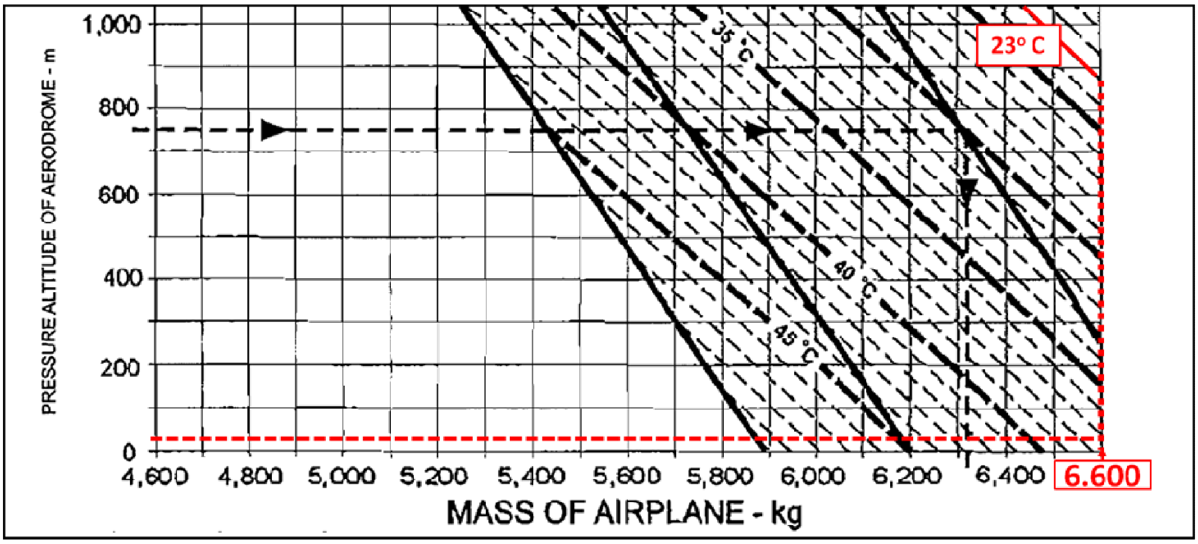



Figure 40 – Maximum takeoff weight according to the AFM graph, page 13, figure 5-6c.

The calculation made from the graph of the figure 5-6d on page 15 of the AFM Section 5 (Figure 41) indicated a maximum takeoff weight of 6,600 Kg for a maximum absorption of energy by the wheel brakes.

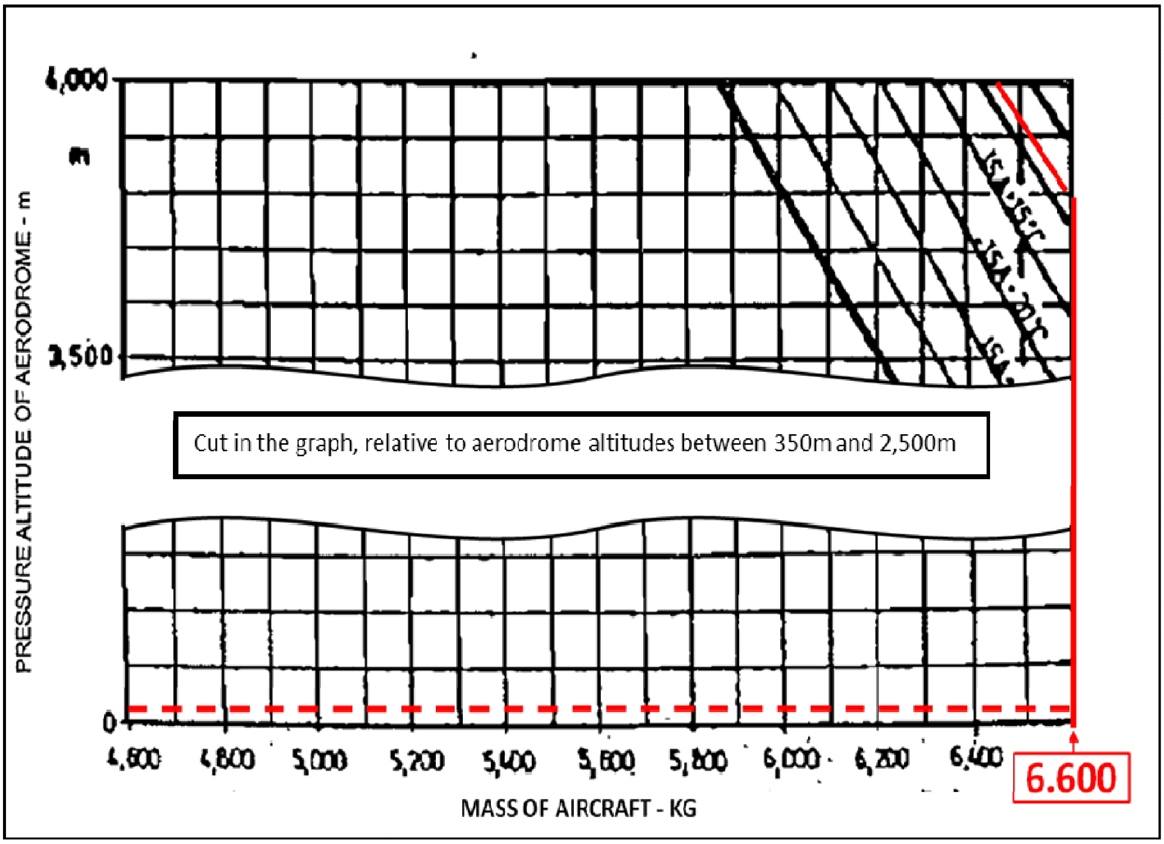



Figure 41 – Maximum takeoff weight by means of the AFM graph, page 15, figure 5-6d.

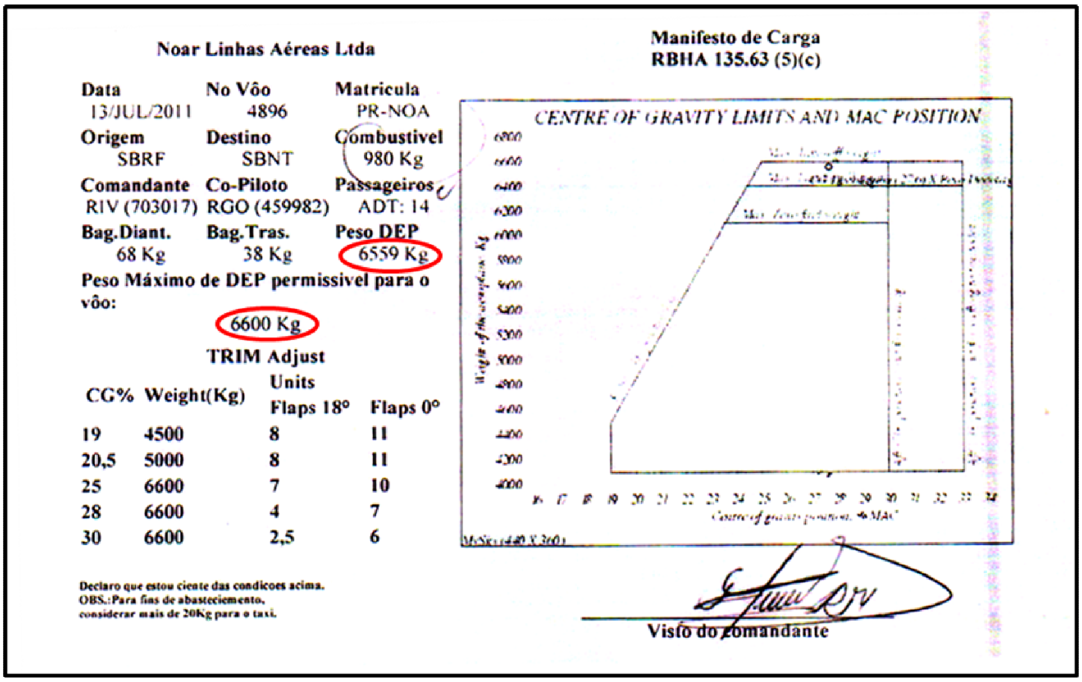
The calculation of the maximum takeoff weight, considering the runway length limiting factors, was made by means of the graphs on pages 25/26 and 27/28 of the AFM Section 5, with adoption of the following parameters: non-utilization of the engine water injection system; aerodrome at sea level; temperature, 23°C; TORA: 3,007 m; ASDA: 3,114m; and TODA: 3,007 m.

The result obtained was a maximum takeoff weight of 6,600 Kg, considering the runway length limitations.

Thus, after obtaining the maximum takeoff weight values relative to the limitations of weight, altitude, temperature and runway length, and considering that SBRF is an aerodrome free of obstacles, one should choose the least takeoff weight obtained.

Therefore, in the environment conditions observed at the takeoff time, the maximum takeoff weight for Flight 4896 was 6,430Kg.

According to the aircraft cargo manifest dispatch (Figure 42), the maximum takeoff weight allowable to the flight was presented as 6,600Kg, therefore 170Kg above the one calculated by means of the AFM tables. The takeoff weight written in the cargo manifest was 6,559Kg.



Noar Linhas Aéreas Ltda

Manifesto de Carga
RBHA 135.63 (5)(c)

| Data | No Vôo | Matricula |
|---|---|---|
| 13/JUL/2011 | 4896 | PR-NOA |
| **Origem** | **Destino** | **Combustivel** |
| SBRF | SBNT | 980 Kg |
| **Comandante** | **Co-Piloto** | **Passageiros** |
| RIV (703017) | RGO (459982) | ADT: 14 |
| **Bag.Diant.** | **Bag.Tras.** | **Peso DEP** |
| 68 Kg | 38 Kg | 6559 Kg |

**Peso Máximo de DEP permissivel para o vôo:**

6600 Kg

**TRIM Adjust**

| CG% | Weight(Kg) | Units Flaps 18° | Flaps 0° |
|---|---|---|---|
| 19 | 4500 | 8 | 11 |
| 20,5 | 5000 | 8 | 11 |
| 25 | 6600 | 7 | 10 |
| 28 | 6600 | 4 | 7 |
| 30 | 6600 | 2,5 | 6 |

Declaro que estou ciente das condicoes acima.
OBS.:Para fins de abastecimento, considerar mais de 20Kg para o taxi.



Visto do comandante

Figure 42 – Cargo Manifest of the NOAR Flight 4896, 13 July 2011.

Although the registration PR-NOA had been written in the cargo manifest, it was in fact used for the dispatch of the PR-NOB, since there had been a change of aircraft in relation to the initial programming.

In all the observed cargo manifests, relative to the period from May to July 2011, it is possible to verify the existence of incorrection in the calculation of the maximum allowable weight for the flight (6,600 Kg). For a takeoff from Recife, Maceió or Natal, with temperatures between 26º and 23º, the maximum allowable weight, according to the AFM, varies from 6,300 to 6,430 Kg.

According to the NOAR's General Operating Manual (MGO), Section VIII, page 3 (revision 01, dated 20 April 2011), approved by the ANAC, for the calculation of the maximum takeoff weight, one had to consider the following weights:

- 2 crewmembers + navigation material and documents: 185 Kg;
- adult passenger: 75 Kg;
- catering service standard weight: 10 Kg; and
- taxi-fuel weight: 20 Kg.

Thus, after adding the weights of the two crewmembers, navigation material and documents (185 Kg), fourteen adult passengers (1,050 Kg), catering service standard weight (10 Kg), luggage (106 Kg, according to the cargo manifest) and fuel (980 Kg), after discounting the amount consumed during the taxi, one obtains a total value of 2,331 Kg. When one adds the weight of the empty aircraft (4,230 Kg) to this figure, one obtains the takeoff weight of 6,561 Kg, i.e., there would be an excess of 131 Kg in relation to the maximum takeoff weight (6,430 Kg).

According to the operator, since catering services were not provided, the weight of 10kg could be deduced, as well as the weight of the anti-ice system (not installed), which corresponds to a decrease of 48.1Kg. Even so, the weight of the aircraft would be 6,502.9Kg, corresponding to an excess of 72.9Kg. These deductions, however, are not mentioned in the MGO.

### 1.18.5 Flight performance with one engine inoperative

#### 1.18.5.1 Factors to be considered on an asymmetrical-power flight

According to the AFM (Section 2, Limitations), the L410 UVP-E20 was certified in accordance with the 14 CFR Part 23 requisites. Therefore, the performance of the aircraft during a takeoff with one engine inoperative and with maximum takeoff weight was demonstrated to the primary certification authority.

A failure of the left engine is considered more critical in terms of control and performance, according to the item 5.1.1 of the AFM Section 5. In this Manual, the calculation of the performance for the takeoff with one engine inoperative takes into consideration the left engine failure.

With the right engine functioning and the left engine inoperative, the force of rolling and yaw is greater than when the left engine is operating and the right engine is not. In other words, the directional control is more difficult when the left engine (the “critical” one) fails (Figure 43).

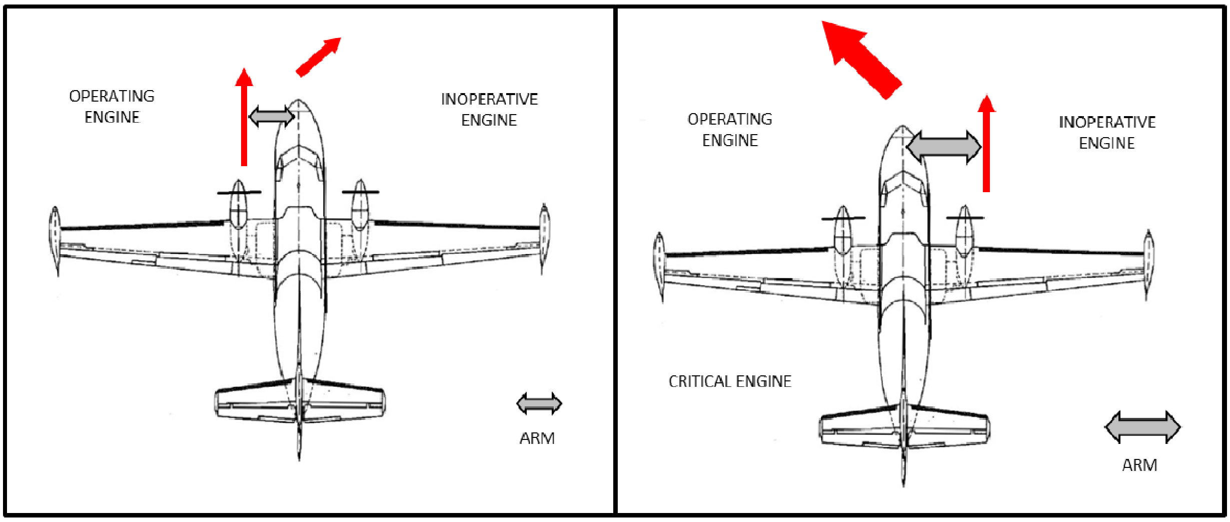



Figure 43 – Momentum generated in flight with power asymmetry in twin-engine aircraft.

As shown in Figure 44, in the case of propeller aircraft, the rotation of the blades introduces a rotational component in the flowoff, in a way that creates a lateral force in the flowoff that strikes the vertical stabilizer.

The direction of this lateral component of the wind is related to the direction of the propeller rotation. Depending on which engine fails, this lateral force may either assist or hinder the directional control of the aircraft.

In the case of aircraft in which the propellers rotate clockwise (when seen from the back of the aircraft) the aircraft control will be more hampered by the failure of the left engine (critical engine) on account of the torque effect.

The torque effect is the reaction that tends to move the aircraft in a direction opposite to the one of the propeller rotation, making the aircraft roll, which, in turn, may induce a left yaw momentum. This effect increases the tendency to yaw when there is a left engine failure.

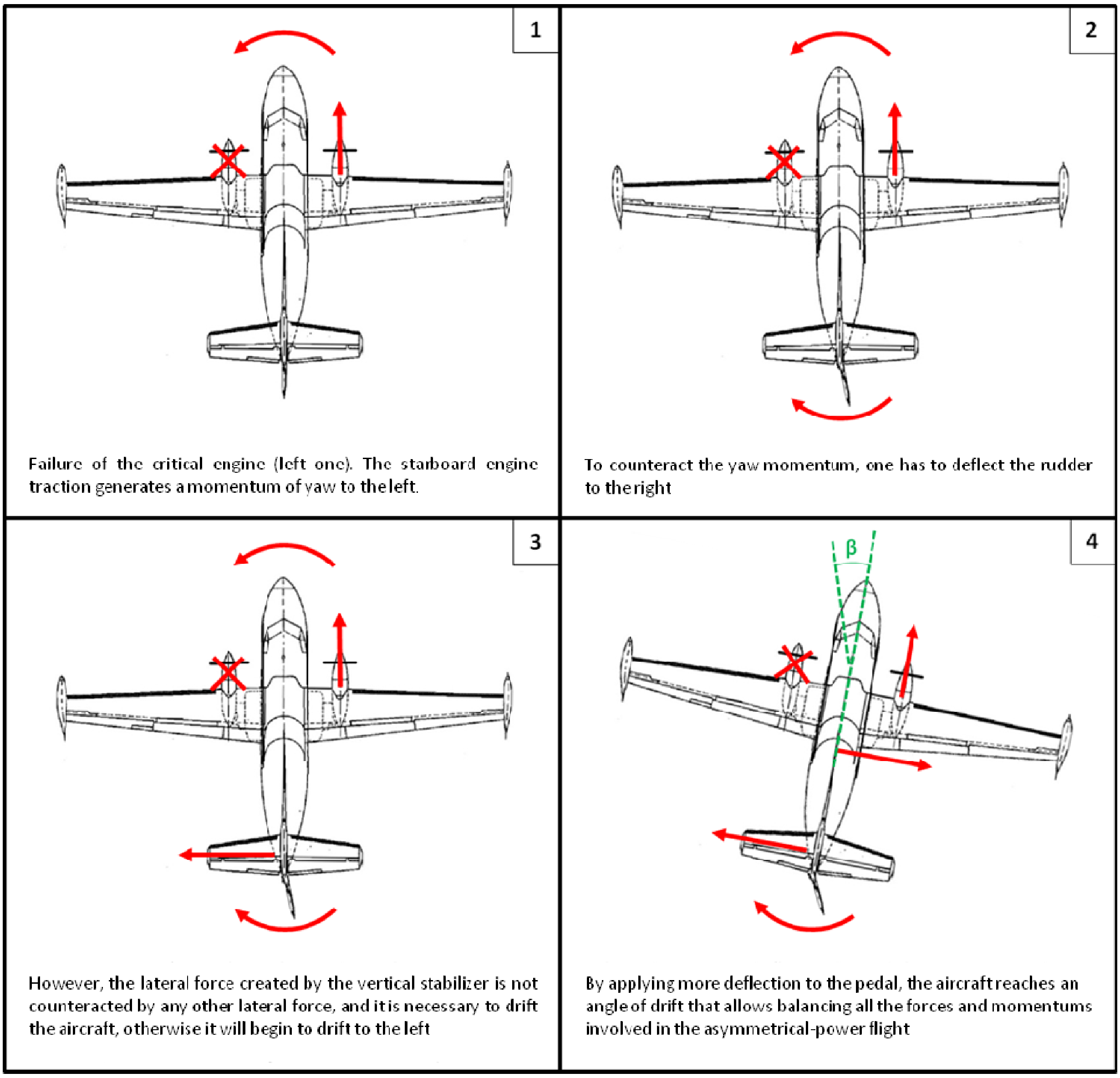



Figure 44 – Power asymmetry flight in twin-engine aircraft.

When the right engine is the one that fails, the effect is the opposite. Therefore, this fact also contributes to the left engine being considered more critical in the event of an engine failure in this type of aircraft.

1.18.5.1.1 Minimum speed for controlling the aircraft in flight ($V_{MCA}$)

A twin-engine airplane, with engines installed in the wings will experience asymmetric traction if one of the engines sustains either a total or partial loss of power.

Consequently, the airplane will yaw to the same side of the engine that failed. In this case, the pilot has to neutralize the asymmetric pressure momentum, by applying the rudder (pedal on the same side of the operating engine).

In the AFM, Section 3, item 3.11, in the detailed description of the takeoff engine failure emergency, there is an instruction to the pilot to eliminate the drifting effect right away, by applying the rudder and, if necessary, providing a 5º angle of bank to the side of the operating engine, in a way that the force exerted on the pedal does not exceed 667N (68Kg) at a speed of 81kt.

The effectiveness of the rudder will depend on the speed of the airflow on its entire surface. If the aircraft is decelerated, the aerodynamic speed may reach a value below which the rudder-generated yaw momentum will not be capable of balancing the momentum created by the asymmetric traction. From this moment on, directional control of the aircraft will be lost.

The minimum speed at which it is possible to maintain directional control of the aircraft with the critical engine inoperative is called $V_{MCA}$. For the L410 UVP-E20, according to the AFM, the $V_{MCA}$, with flaps at 18º, is 84kt.

When flying the aircraft at the $V_{MCA}$ with an angle of bank of 5º to the same side of the operating engine, the pilot should be able to maintain directional control of the aircraft.

In the process of certification of the L410, the aircraft maintained the flight at $V_{MCA}$ under specific conditions, with a requirement that controllability had to be maintained with the critical engine inoperative and with the autofeather armed, flying with a 5º angle of bank to the same side of the operating engine, takeoff power in the operating engine, landing gear retracted, flaps in the takeoff position, with the aircraft being with its maximum takeoff weight and loaded with the CG in its rearmost position.

1.18.5.1.2 Relationship between the angle of bank and the $V_{MCA}$.

When the airplane is banked to the same side of the operating engine, the wings develop a lateral force that makes the aircraft drift to the same side of the operating engine. This drifting creates a positive angle of attack of the airflow on the rudder.

In other words, when the airplane is inclined to the same side of the operating engine, the weight force develops a component in the direction of the aircraft wing span, and part of the weight starts to act as a lateral force.

In this situation, it is no longer necessary to generate such a strong drifting to the left (wind coming from the left), and the pressure on the pedal can be diminished. Then, one may reduce the flight speed even further, until the rudder latch is reached.

The US Federal Aviation Administration (FAA) publication FAA-H-8083-3A, with the title Airplane Flying Handbook includes an analysis of multi-engine handling techniques.

This publication states that banking to the same side of the operating engine would reduce the $V_{MCA}$ by approximately 3 KIAS per degree of bank. Inclining the aircraft to the same side of the inoperative engine would increase $V_{MCA}$ by a similar rate.

For the condition of weight, (approximately 6,561Kg), with flaps at 18° and an inclination of about 15°, the stall speed is around 76 KIAS (Figure 45). If the weight of 6,502,9kg (after deduction of anti-ice and catering service weights) is considered, the stall speed would be around 75 KIAS.

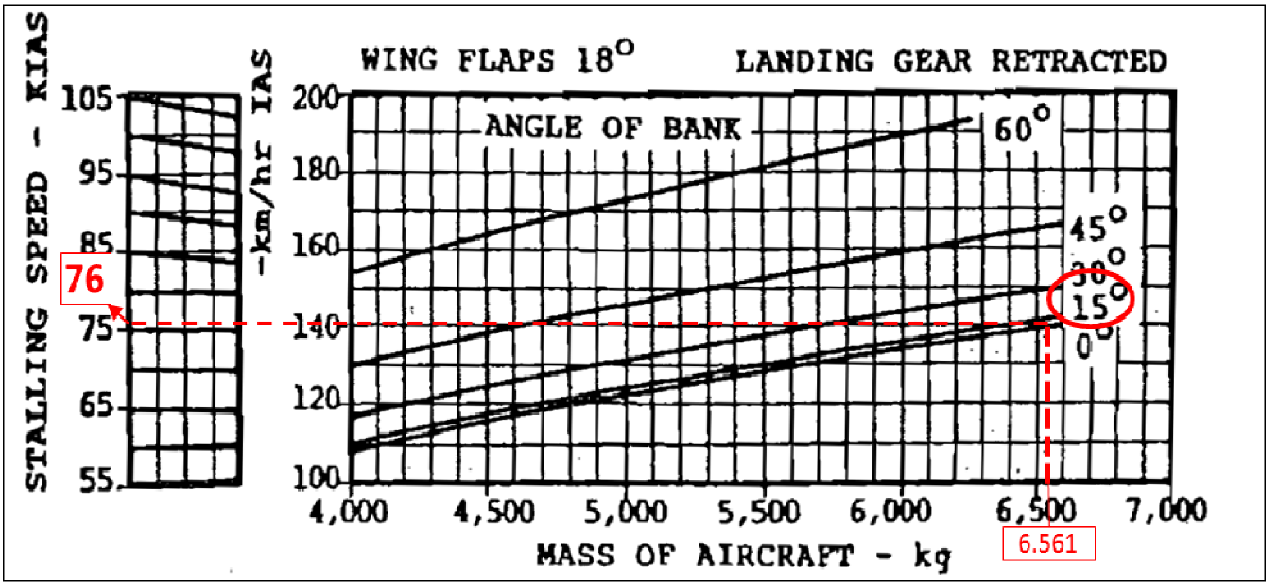



Figure 45 – Calculation of the stall speed (AFM, Section 5, page 7).

## 1.19 Additional information

1.19.1 Facts resulting from the runway excursion during the taxi after landing

On the night of 27 October 2010, the PIC was in the Flight 4878 from SBRF to SBMO. At 2125, while taxiing after the landing run, the aircraft excursed from the runway and stopped in a non-paved area (Figure 46). The PIC said that he had difficulty sighting the taxiway signage.

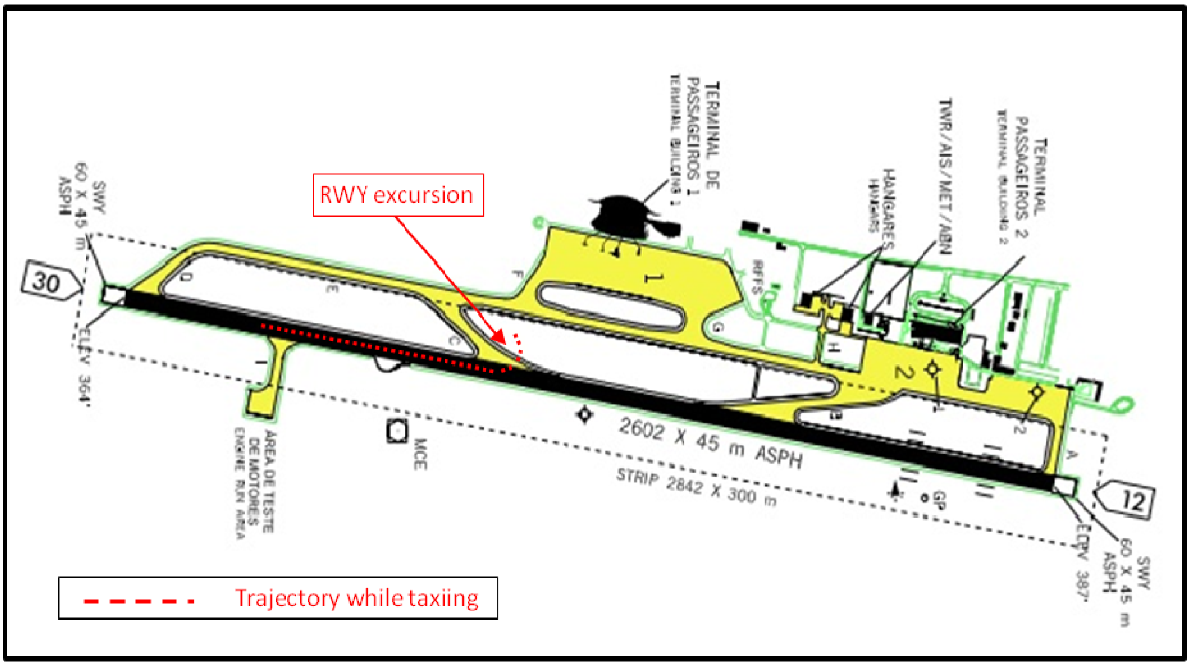



Figure 46 – Runway excursion in SBMO.

According to some of the pilots who used to fly with the PIC, he had a history of restrictions in relation to his night-vision acuity.

On account of the runway excursion and the facts mentioned in the paragraph above, a group of pilots decided to forward the problem to the company directors. Meanwhile, the situation was reported to the Director-President by the copilot, who was flying with the PIC on the day of the accident.

Initially, the company decided to remove the PIC from night flights and submit him to a reevaluation by three instructors. In addition, the company's decision was that he would be substituted as Director of Operations.

He was then submitted to a technical proficiency evaluation conducted by the ANAC on 21 December 2010 and 30 January 2011, and was considered apt.

According to members of the company, this situation created some reserve between the PIC and the group of pilots (the copilot included) who reported the Maceió event to the Director-President.

Due to contingencies that had affected the flights on the day before, it was necessary to change the schedule for the 13 of July, with the copilot making himself available to compose, together with the PIC, the crew of flight 4896.

### 1.19.2 Autofeather and ABC Systems

#### 1.19.2.1 The ABC System

This system aims at mitigating the tendency of the aircraft to roll when an inflight engine failure occurs, either during an approach or a takeoff. It consists of two independent surfaces located in front of the ailerons, one in each wing (Figure 47).

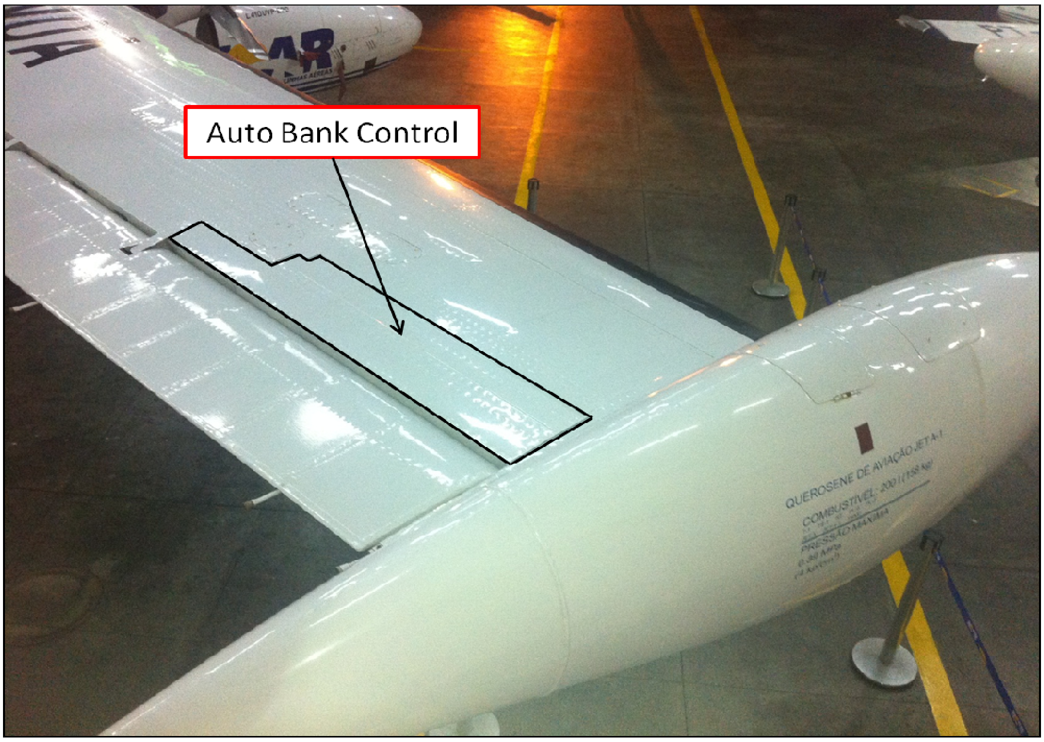



Figure 47 – Closed surface of the right wing auto bank control.

According to the Aircraft Maintenance Manual (AMM), Section 27.62.00, page 10, if the ABC system is operating and armed, and the speed is equal to or lower than 110kt, the ABC panel corresponding to the operating engine should open when the torque of the other engine drops to approximately 24%, provided that the circuit breaker propeller feathering and the ABC are energized (something which is made by the switches of these systems, located in the upper panel, as shown in Figure 48), and provided that the ABC is armed (something which is made by means of the respective switch in the central panel, as shown in Figure 49).

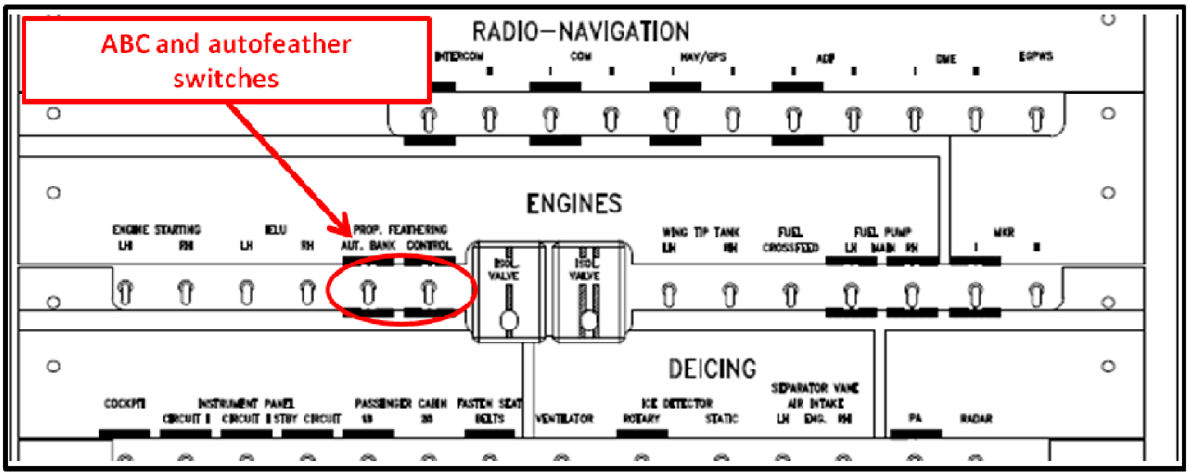


Figure 48 – Upper panel auto feathering and the ABC switches.

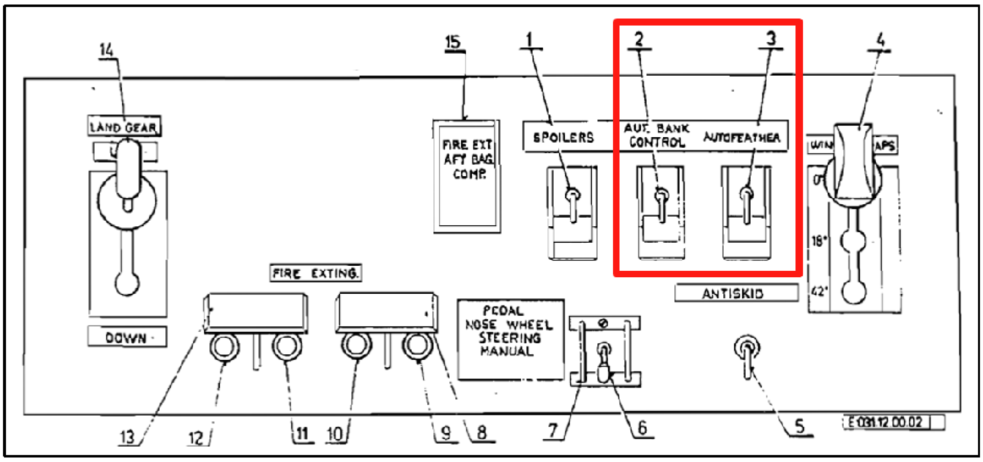


Figure 49 – Central panel auto feathering and the ABC switches.

1.19.2.2 The Autofeather System

According to the AFM (Section 3A), with the autofeather system armed, as shown in Figures 48 and 49, with the power control levers in a position which implies an Ng (gas generator) speed of at least 88% +/- 1% (or 92% +/- 1%, depending on the setting), the shutting down of the engine will cause the automatic feathering of its propellers.

1.19.2.3 Functioning of the Autofeather and ABC systems

For the functioning of the autofeather and opening of the ABC panel, the following conditions are necessary:

a) the autofeather and ABC switches are turned on;

b) autofeather and ABC switches on the pedestal panel are turned on;

c) both power control levers in a position to obtain at least a Ng of 88% +/- 1% (or 92% +/- 1%, depending on the setting);

d) speed equal to or less than 110kt, for the opening of the ABC panel;

e) when the above conditions are present, and the torque of one of the engines drops below 24%, a signal is sent to the control relay for the opening of the ABC on the wing of the operating engine, and then when the torque drops below 18%, the feathering of the propellers of the engine that failed is started.

With the information retrieved from the FDR, the graph shown in Figure 50 was made. From these parameters, it is possible to see that after 65 seconds (at 06:51:04) after the engines began to accelerate for the takeoff, the torque of the left engine dropped and remained below 24%, when the speed was below 95kt. Only 81 seconds later (at 06:52:25) did the ABC panel open.

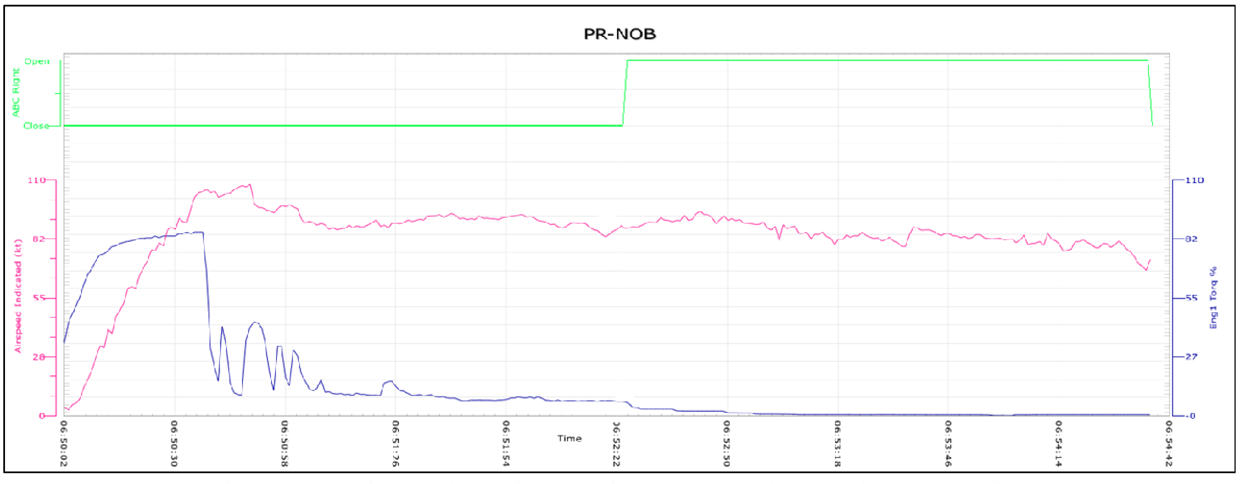



Figure 50 – Airspeed, engine number 1 torque drop and ABC opening.

### 1.19.4 Minimum Equipment List (MEL)

According to the Operative Specification, part D – Maintenance, the NOAR company did not have a MEL approved for any of its aircraft, and had to fully comply with the prescriptions of the section 135.179 of the RBAC 135 (24 Aug 2010), being forbidden to take off with any inoperative equipment or instruments.

**"RBAC 135.179 Inoperative instruments and equipment**

(a) The operator shall include in its systems of manuals an ANAC-approved Minimum Equipment List (MEL) for each type of aircraft having a published MMEL, so that the Pilot-in Command able to determine whether it is safe to start the flight or continue with it after any intermediate stop, when an instrument, equipment or system stops functioning;

(b) No aircraft will be allowed to take off with inoperative instruments and equipment installed, unless the following conditions are met:

(1) There must be an approved Minimum Equipment List (MEL) for the aircraft;

(2) There must be an ANAC letter authorizing operations in accordance with the approved MEL. Before each flight, the flight crew must have direct access to all items of information contained in the approved MEL through printed documents or other means

approved by the certificate holder and made available to them. A MEL approved as authorized by the operative specifications constitutes an approved change of an aircraft type design without requiring a new certification;

(3) The approved Minimum Equipment List (MEL) shall:

(i) Be prepared in accordance with the restrictions specified in the paragraph (b) of this section; and

(ii) Provide procedures for the operation of the aircraft with certain instruments and equipment in an inoperative condition;

(4) Information on inoperative equipment and instruments required by the paragraph (a)(3)(ii) of this section shall be made available to the pilot;

(5) The aircraft shall be operated in accordance with all the conditions and restrictions contained in the MEL and in the operative specifications authorizing its use."

The NOAR company submitted its MEL proposal to the ANAC on 31 August 2010, by means of the last dispatch of the SEGVOO Form 107 nº 002/M/10. However, by the date of the accident, the proposal had not been approved yet.

1.19.5 Performance data provided by the aircraft manufacturer

The Investigation Commission forwarded a series of questions relative to the aircraft performance to the manufacturer, and received the information listed below.

In an engine failure at the altitude of SBRF, at a temperature of 23ºC, with the aircraft at the maximum takeoff weight (6,430Kg), one should expect the aircraft to develop either a rate of climb of 203ft/min with the ABC closed, or 183.3ft/min with ABC open;

The opening of the right wing ABC at 06:52:25, and its keeping this condition up to impact, would represent a reduction of 19.7ft/min in the rate of climb.

From the average of the values recorded by the FDR, the manufacturer estimated that, in the period between the engine failure and the propeller feathering, the left propeller was rotating at 1,456 RPM (70%), with a 17% torque (437 N.m).

Based on these values, the left engine was developing an average power of 67Kw and a thrust of 1,060N, representing an increase of 157ft/min in the rate of climb during the period.

The fact that the landing gear stayed in the down position until 06:51:30 represented a reduction of 98.4ft/min in the rate of climb.

For a flight condition with an inoperative engine with maximum takeoff weight, with the aircraft maintaining a V2 of 92kt, the pitch had to be 8º and the application of rudder had to be 13º.

To evaluate the drifting influence on the flight, the manufacturer informed that, with a drifting of 8º and 0º rudder, the calculated rate of climb decrease is 80.7ft/min. With a drifting of 13º and 0º rudder, the decrease would be around 254ft/min.

These data were analyzed by the investigation commission in conjunction with a team of professionals of the IPEV (Research and Flight Tests Institute).

**1.20 Utilization of other investigation techniques**

Nil.

## 2 ANALYSIS

The idea of creating the NOAR Linhas Aéreas came from the identification of a demand for new routes between major cities in the northeastern region of Brazil.

With the assistance provided by a professional who worked for the TEAM Linhas Aéreas, an operator which had experience with the L410, the initial steps to found the company were taken considering the model of that operator as a reference.

However, those steps were taken without evaluation of the potential operational differences between the NOAR and TEAM companies, their equipment, or even the cultural and regional differences. It was as if the TEAM organizational culture was replicated for the NOAR company, with no distinction between the two companies.

From the interviews, an impression was made that the employees received a “package” ready to be implemented, without knowing it very well. There were reports that they started operating the company with little knowledge even of the aircraft both on the part of the pilots and of the mechanics.

The aircraft involved in the accident was a model L410UVP-E20, equipped with M601E engines manufactured by the GE Aviation Czech, the maintenance of which was performed by the very manufacturer, since there were no authorized maintenance service providers for those engines in Brazil.

Due to a problem of wear in the combustion chamber, a replacement of some left engine parts was programmed during the P2 inspection, which was carried out two days before the accident.

The left engine failure during the takeoff of the Flight 4896 originated exactly from one of the items replaced: a blade of the GGT disk.

The development of the fatigue process that led to that failure could have occurred on account of a problem in the metallic composition of the blade, or exposure of the blade to abnormal vibration.

As presented earlier, the examinations couldn’t find evidence of problems in the metallic composition of the blade, allowing the commission to discard such possibility. This would potentially favor the hypothesis that the exposure to abnormal vibration would have been the cause of the fatigue process.

On the other hand, according to the dimensional analysis report provided by GE Aviation, no abnormal condition was found in the examined GGT disk and blades that could have produced such vibrations. Besides, the low amount of hours flown by this GGT assembly before the accident doesn’t seem compatible with the high cycle fatigue process observed in the blade T52A175.

In other words, the evidence indicates that there were neither problems in the metallic composition, nor abnormal vibrations in the blade T52A175 while it was part of the GGT rotor assembly installed in the accident aircraft.

In view of this apparent impasse, a hypothesis was raised that the fatigue had had its origin while the blade was still installed in the GGT rotor assembly of the aircraft flown by the Russian operator. In this case, it would be necessary to accept that the inspection method (FPI) employed by GE Aviation Czech in the February 5, 2011 evaluation of the blades for purposes of reutilization was not capable of detecting the beginning of the fatigue process.

The non-detection of the crack could have occurred if it was still sub-surface, or if it was too small, in a way that the crack closure phenomenon (due to residual tensile compression) could have hindered its detection. CENIPA has already observed this type of problem in other investigations.

However, it should be noted that, according to the GE Aviation: "*GE Aviation Czech's state-of-the-art, robust inspection methods were correctly applied and resulted in no finding of any anomaly*". Yet, GE Aviation admits that "*it's not feasible for any inspection method to guarantee that every single small crack will be detected, especially sub-surface cracks*".

The evidence available in this investigation did not allow confirming or discarding this hypothesis, nor establish the probability associated with it.

With regards to the logging of the maintenance services provided by GE Aviation Czech, the writing used by their technicians led to a misunderstanding related to the replacement of the disk assembly. This confusion could only be clarified because the replaced item remained in Brazil. Otherwise, the references that would allow the identification of items replaced would only be found resorting to the documentation that remains with the manufacturer (in the Czech Republic). This, associated with the fact that the engine maintenance was carried out directly by the manufacturer, eventually left the operator itself in a condition of spectator, making supervision more difficult.

The TEAM company was hired to provide the maintenance service levels from P2 to P4, as well as to give training to the NOAR mechanics that would carry out the P1 inspections.

The TEAM company was also in charge of delivering both the theoretical and practical training to the first group of pilots hired by the NOAR company (the PIC was in this group). From the examination of the FAPs filled in during the course, no evidence was found that the takeoff engine failure above V1 emergency training had been given to all the pilots.

As for the PIC, the only entry of records concerning a takeoff engine failure above V1 emergency training was done on the occasion of the training of the differences between the TEAM aircraft and the PR-NOA NOAR aircraft. Even so, according to the information collected, the training did not comply with the prescriptions of the PrTop, having been done with a real takeoff, and finished at the end of the second segment at an altitude of 400ft, from which the aircraft joined the downwind leg.

The training of the second group of company pilots, who were hired later, was delivered by captains from the first group of pilots.

Reports made by several pilots in interviews indicated that the practical training given within the NOAR company followed the same standard of the one done by the first group, with no records of takeoff engine failure above V1 emergency training.

The inadequacy of the FAP, which did not have a specific field for the evaluation of this procedure, could even explain the lack of records, if the instructor, by not finding the proper field for those comments, simply refrained from writing about the details of the trained procedures.

However, according to the persons interviewed during the investigation, this kind of emergency was not trained by part of the company pilots. In addition, the training sessions did not follow the procedures described in the PrTop, but consisted of a simulation of failure during a real takeoff (and not from a safety height), following the procedure up to 400ft, leading to an equivocal conditioning, without observance of the third segment.

At this point, it is worth questioning the oversight capacity of the authority relative to the operator's compliance with the approved training program, on account of the lack of records in the FAPs concerning the training of certain procedures during the courses which were delivered.

The company started the operations with passengers in June 2010, adopting a very dense transport net, with little margin for the unexpected, something that caused a work overload in order to prevent or minimize delays.

These operations started a little before the beginning of the theory training of the second group of pilots, and limited the availability of captains for the instruction, which had its quality worsened, with the students having to do the ground training without being monitored by the instructor.

The training of the copilot involved in the accident took place within this context. In the FAPs received by him, there are no records of takeoff engine failure above V1 emergency training given to him.

The support documentation translated by the aircraft manufacturer to the English language did not favor the operation of the aircraft, since it contained confusing texts, differences within the same subject when dealt with by distinct documents, and translation errors, making it difficult to understand, therefore posing a risk to operation.

In this sense, the discrepancies between the procedures prescribed for takeoff engine failure presented by the checklist and by the AFM may have even contributed to the consummation of the accident.

Beginning with the fact that the checklist would only be read from the moment the aircraft passed 400ft during the climb, favoring the non-execution of the ABC switch-off at 200ft (a prescribed action not marked with an asterisk, thus not characterized as a memory item in this document). In the AFM, however, the description of the procedures related to this failure has that action (ABC switch-off) as a memory item.

It is worth having in mind that the AFM is an extremely important document for both the initial training and maintenance of the technical capability of the pilot, since it is the place where he will find the aircraft operation explained in detail. In other words, it is based on the AFM that the pilot develops the knowledge that will provide him with the theoretical support to the future systematic execution of the procedures contained in the checklist.

The checklist, in turn, is simply a list of procedures, a tool routinely used in real operations, listing the actions that have to be executed, without any further explanation (the pilot is supposed to have acquired knowledge from the AFM and undergone a training process). In essence, the checklist is thought to be an AFM extract, from which the explanatory texts and reference figures were removed.

In a simplified manner, one can say that, in the theoretical phase of the initial training, the pilot aims at knowing and understanding the operation of the aircraft by means of studying the AFM, so that later, during the practice phase (flight) he can operate the aircraft, performing the prescribed procedures with the assistance of the checklist. The repetition of the practice training, in which one uses the checklist, will provide the pilot with the necessary conditioning to recognize both routine and non-routine operational situations and react accordingly (also with the help of the checklist).

In addition, the checklist functions as a reference that allows minimizing the quantity of memory items, reducing the possibility of errors in the procedures.

It is, therefore, inconceivable there to be differences between the two documents in relation to the same procedure, such as the ABC turning off, which is prescribed as a memory item in the AFM, but not in the checklist.

These differences should have been identified in operational safety surveillance actions during the company certification process before the start of operations.

As previously mentioned in detail, the NOAR Flight 4896 departed from Recife, destined for Natal.

Based on the SSFDR information associated with the performance data received from the manufacturer, an evaluation of the flight performance was made with the support of the IPEV, the results of which are dealt with in this analysis.

At 06:49:54, the engines were accelerated for takeoff.

At 06:50:25, the aircraft lifted off the ground. At that moment, the engine number 1 (left) reached 83% torque, with the thrust lever angle at 78%, while the engine number 2 (right) reached 83% torque, with the thrust lever angle at 88%.

Soon after the aircraft lifted off the ground with a positive rate of climb, the PIC requested retraction of the landing gear, but the copilot did not retract the landing gear at once.

At 06:50:37, with the aircraft at about 20ft AGL, the engine number 1 had a failure, with the respective torque beginning to drop, and reaching a minimum value of 16%, oscillating around 25% for approximately 20 seconds, gradually decreasing down to zero.

The engine failure at takeoff occurred just after the first request by the PIC for the landing gear to be retracted, a request that was made after the aircraft “rotated”.

Thus, it is possible that the copilot’s attention may have been drawn to the possibility of returning to the runway (on account of the failure), since it was a procedure listed in the SOP, and mentioned by the PIC in the takeoff briefing. Thus, an engine failure at takeoff above V1 could be the reason for a return to the runway, something that goes against the very concept of V1presented by the legislation in force.

This would explain why the landing gear was not retracted in response to the first request made by the PIC.

In fact, as soon as the engine failure was recognized by the pilots, the copilot suggested “aborting” the takeoff, although the aircraft had already lifted off, with the PIC replying that there was not enough space to return to the runway.

As mentioned before, the presence of an advance seal in the thrust control lever of the right engine indicates that the extra power resource was not utilized by the crew. However, when one evaluates the performance of the aircraft after the occurrence of the failure, one realizes that the aircraft flew with a positive rate of climb at a speed of 93 Kt, which can be regarded as a satisfactory condition for the flight with one engine inoperative.

Besides, one must take into account that the use of that extra power would increase the asymmetry condition, implying a greater effort to maintain a controlled flight.

Thus, the flight continued, with the aircraft gaining height and slightly turning to the left.

During the entire flight, the rudder trim tab was not utilized, and the flaps remained in the 18º position.

According to information provided by the manufacturer, for an engine failure at the altitude of SBRF, at a temperature of 23ºC, with the aircraft at the maximum takeoff weight (6,430Kg), maintaining a V2 of 92kt, the expected rate of climb would be 203ft/min with the ABC closed, or 183.3ft/min with the ABC open.

The dispatch of the aircraft, during the operations, was assisted by a type of software that, among other functionalities, calculated the maximum takeoff weight. However, the investigation found out that, sometimes, the calculated weight was wrong.

In the accident flight, the maximum takeoff weight provided by the software had an excess of 170Kg in relation to the weight obtained from the performance documentation issued by the manufacturer.

Considering the criteria contained in the MGO for calculation of the flight 4986 weight, there was an excess of 131Kg, which would imply a decrease of 39ft/min in the rate of climb of 203ft/min, calculated for the single-engine condition. Even if one subtracted the anti-ice and catering service weights, the excess would still be 72.9Kg, resulting in decrease of the rate of climb.

From the average of the values recorded in the FDR, the manufacturer estimated that, in the period between the engine failure and the propeller feathering, the left propeller rotating speed was 70% (1,456 RPM), and the torque of the right engine was17% (437N.m).

Based on these values, the left engine was developing an average power of 67Kw and traction of 1,060N, representing an increase of 157ft/min in the rate of climb during that period.

The residual torque produced by the troubled engine contributed to the climb.

Since these are average values, it is possible that, from a certain moment, the residual torque produced was equivalent to the power condition similar to the one of a feathered propeller, although this aspect will not be considered at this moment.

At the time of the engine failure, the landing gear was extended and remained so up to 06:51:30, representing a reduction of 98.4ft/min in the rate of climb.

By 06:52:01, the aircraft was able to reach the height for the beginning of the third segment of departure with a speed of 93kt (V2+1kt), characterizing a gain of energy (see Table 2, extracted from the FDR). This was possible in spite of the penalties produced by the drag of the landing gear (which took a long time to be retracted), by the non-actuation of the automatic feathering, and by the excess in the maximum takeoff weight, which were counterbalanced by the residual traction of the left engine up to the moment of feathering and by the non-immediate opening of the ABC.

Upon reaching 400ft, the crew started a turn to the right, aiming to return to the runway, without doing the third segment prescribed for the takeoff engine failure above V1 emergency procedure in the AFM (acceleration to 104 Kt, retraction of flaps, acceleration to 107 Kt, and climb to 1,500 ft).

At this moment, the differences between the AFM and the checklist relative to the takeoff engine failure above V1 emergency procedure, together with the training phase deviations, may have intensified the already-high level of anxiety, influencing on the pilot's decision.

It is worth taking into account that training is a tool that enables a professional to do his/her work with expertise, and has the objective of exploring the learning potential and the productive capability of people; thus, when training is not appropriately conducted, it compromises the effective doing of the work, mainly in an emergency situation, in which an individual accesses the most conditioned contents of his/her memory.

As already commented above, while the AFM has its use more strongly tied to the learning of theory, the checklist has an eminently practical application, and may function as a powerful conditioner of the pilot's reaction.

It is also worthwhile to have in mind that the PIC was one of the few company pilots whose adaptation-to-aircraft records confirm the training of takeoff engine failure above V1 emergencies.

Furthermore, the commission found out that, for the training of the differences, the sequence of procedures progressed only to the beginning of the third segment, without concern to continue up to 1,500ft. And here it is important to remember that, during the training done by the PIC, the aircraft's take-off weight was about 1,000 Kg less than the maximum takeoff weight allowed, favoring the performance.

From the fact that the training of the procedure for the engine failure above V1 was performed only partially when compared with the operator's training program (which, by the way, was similar to manufacturer training program), one can imagine that the pilots may have become conditioned to understand that the actions in response to that failure would finish at 400ft, at the end of the second segment.

This would explain the pilots' decision to not perform the third segment of the procedure, and choosing to make a right turn, aiming at returning to the aerodrome from the height of 400ft, without considering the possibility of continuing in the climb until reaching a more comfortable height (1,500ft) in order to proceed to land in a single-engine condition.

Between 06:51:35 and 06:52:01, it is possible to observe a practically constant longitudinal attitude (pitch), altitude gain, almost constant speed, and banking increase from 5º to 15º. Up to this point, despite the increase in banking, which penalizes the performance, it is still possible to observe a gain of energy. One can also observe that the radius of turn was not tight enough to align the aircraft on the final approach to runway 36.

From this point, the aircraft starts losing speed, increasing the pitch oscillation, which reaches 14º at 06:52:19, with 84kt, an indication that the energy management balance was no longer positive.

Although the information was not available in the AFM, the manufacturer informed that, at maximum takeoff weight, maintaining a V2 of 92kt, the pitch had to be 8º.

Thus, the 14º attitude would increase drag, compromising the performance. In parallel, there was an increase in banking, reaching 20º, when the recommended banking for this phase of the flight was 5º, at the most, to the side of the operational engine. This also represented an increase in drag, penalizing the aircraft performance even further.

Consequently, the aircraft started losing altitude without increasing speed, which, conversely, began to drop (see Table 2).

The right wing ABC opened at 06:52:25, and remained open up to impact, implying a reduction of 19.7ft/min in the rate of climb, according to data provided by the manufacturer.

A few seconds after the opening of the ABC, perceiving that the autofeather system had not been activated, the PIC decided to feather the propeller manually (something done by means of the control lever #1 at 06:52:37.

From the moment the propeller was feathered, a positive potential contribution of the left engine residual torque for the rate of climb ceased to exist.

The CVR data indicate a change in the emotional state of the PIC on account of the aircraft adverse condition, to which he had to respond with an operational procedure that was different from the one for a normal flight situation.

The copilot, in turn, in his communications, gives the impression of being highly tense on account of the emergency situation.

This became clear with the delay of the copilot in retracting the landing gear, and in the PIC's initiative to "feather" the propellers that had already been feathered by the copilot, after an order given by the very PIC.

The evident anxiety identified in the cockpit is reflected in the barriers and filters that influenced the process of communication between the two pilots, sensitively affecting the PIC's situational awareness.

Moreover, it is a known fact that non-routine situations can cause a rise in one's level of anxiety, but such alteration of the emotional state may be intensified when one does not have enough knowledge to manage the circumstance, and this interferes in the analysis of the scenario and adoption of appropriate measures.

At 06:52:37, with the feathering of the engine number 1, the estimated 1,060N extra residual traction was lost. Such residual traction would correspond to an average value of 157ft/min in the rate of climb. However, it is worth reminding that this additional traction was not included in the forecast rate of climb of 203ft/min (aircraft in single-engine flight at maximum takeoff weight of 6,430Kg, maintaining a V2 of 92kt) whose calculation considers the propellers feathered.

Thus, at 06:52:37, considering the data provided by the manufacturer, the following factors would be present in the vertical speed of the aircraft:

| | | |
|---|---|---|
| *Forecast rate of climb (6,430Kg, at V2)* | | +203 ft/min |
| *Excess weight of 131Kg* | | -39.4 ft/min |
| *ABC open* | | -19.7 ft/min |
| Final rate of climb | = | +143.9 ft/min |

If one considers only the factors above, the aircraft should be capable of maintaining a rate of climb of 143ft/min after 06:52:37, something that did not occur.

The engine number 2 functioned normally, and, at 06:53:33, an increase of power was commanded which reached 100% torque eight seconds later, with this power being maintained until impact.

In order to identify the reason why the aircraft was not able to maintain the positive rate of climb of 143ft/min, one has to take into account the values relative to the application of rudder.

According to the manufacturer, the rudder application for this condition of flight with one engine inoperative should be 13º.

Considering the data from Table 2, one verifies that the actuation on the pedals was maintained practically constant, but with values that were smaller than the ones indicated by the manufacturer for that condition of flight. As a matter of fact, the variation was from 0º to 5º between 06:52:19 and 06:54:00.

Besides, the investigation of the medical aspect of the PIC did not reveal any condition that might have restricted his ability of flying an aircraft.

The SSFDR data indicate that, as early as turning to the right, the aircraft gradually started to have its performance degraded.

As already commented in 1.18.5 above, the flight with asymmetric power requires wing banking and rudder deflection to the same side of the operating engine, in order to eliminate the tendency to yaw produced by the asymmetry.

The attitude to be maintained by the aircraft during the flight with one engine inoperative is very different from the one applied to a flight with symmetric power, rendering it more difficult for the pilot to do his work of searching a more efficient way of flying with respect to the performance of the aircraft, and this reinforces the importance of training.

So, it is possible to notice that, at the beginning of the first turn, the aircraft does not drift, maintaining a roll of approximately 5º to the right. However, as the lateral inclination to the right increases (reaching a maximum of 20º for a moment), a negative drifting begins (relative wind from the left), further degrading performance. At this moment, the pitch value reaches 14º.

Still during this turn, the ABC system deflected the corresponding surface on the right wing, resulting in a decrease of the vertical speed. The negative impact of the ABC on the vertical speed is estimated by the manufacturer to be approximately 20ft/min, for a straight-and-level flight condition.

It is also important to point out that there is not a prescription of engine failure training with the ABC deflected. In a real situation, this lack of training-prescription may hinder the identification of the ideal aircraft attitude to be chosen by the pilot.

At 6:52:49, the PIC started a turn to the left, possibly due to imagining that he would not be able to align the aircraft with the final to the runway by turning to the right. Another reason might have been the existing buildings in the direction towards which the aircraft was flying, since the aircraft had lost height during the turn.

In itself, a turn to the side of the inoperative engine is not recommendable from the standpoint of efficiency in an asymmetric flight, since it is the side to which the operating engine generates a yaw momentum in a natural way.

For this reason, there is a culture among pilots emphasizing the need to make turns only to the same side of the “good” (operating) engine. In consequence, in single-engine flight trainings, more often than not, the turn to the side of the “bad” (inoperative) engine is not practiced.

With 8º drifting and 5º rudder, the rate of climb loss is calculated to be 80.7ft/min, while with 13º drifting and 0º rudder, the loss would be around 254ft/min.

The values of drifting and rudder for the aircraft flight profile during the turn to the left vary around these parameters, where the differences between the track flown and the aircraft heading were observed in order to obtain the drift angle.

When one considers the average of these values, one obtains a rate of climb decrease in the order of 167.35ft/min. Thus, if the losses from the excess banking are not taken into account, the vertical speed would be 147ft/min minus 167.35ft/min (resulting in a negative rate of climb of – 24.35ft/min).

As an aggravator, on account of the forces present in this condition, the turn to the side of the inoperative engine requires less effort on the part of the pilot, since the very asymmetry generates the tendency to turn. Consequently, there was a relief of the pedal deflection. However, the aircraft was allowed to develop an excessive drift, which varied between 10º and 15º (relative wind from the right).

There was a significant loss of energy, on account of the drift, and the aircraft, besides losing altitude, had its speed reduced, despite the reduction of the longitudinal attitude, which came to a value of 1º pitch-up at 06:53:37.

Although the angles of banking could be observed, their impact was not taken into account. It is possible to see that the banking to the side of the inoperative engine reached 20º, contributing to the reduction of the vertical speed up to values smaller than the aforementioned -24.35ft/min.

The great difficulty resides in identifying the ideal degree of application of the controls to guarantee the least detrimental aircraft attitude. At this point, once again, training has an important role to play.

In the case of the accident, when making the turn to the left, the aircraft was allowed to fly in a condition of drift to the right, whereas the ideal situation would be a drift to the left, in order to balance the asymmetric forces according to the exact measure of the desired rate of turn, minimizing the adverse effect resulting from the turn to this side.

From the flight recorders' data, it is possible to observe the loss of energy during the whole turn, which took a little over one minute to be made, to the sound of the alerts "Don't sink! Don't sink!"

From 06:53:50, at an altitude of 150ft RA, the aircraft was no longer capable of maintaining a speed above $V_{MCA}$ (84kt), with the performance being further penalized by the gradual increase of the longitudinal attitude, which reached 18º.

The aircraft flew at speeds below the $V_{MCA}$, utilizing an angle of bank higher than 5º to the same side of the operational engine (Table 2).

At the end of the turn, which lasted a little over one minute, the aircraft reached a height of approximately 120ft (loss of about 200ft) and a speed of 80kt (loss of about 10kt). This shows the critical condition of the flight at that moment.

From this point onwards, the disagreement in the cockpit worsened. The personal features of the crew, reported by their workmates, seemed to make the relationship between them difficult.

The flight crew was not the one initially assigned for that flight, since changes had to be made in the schedule. The copilot made himself available to compose the crew with the

PIC, despite the potential mutual restrictions they might have in relation to one another, and that, apparently, had already been overcome.

The PIC’s years of experience in aviation may have contributed to his developing an excessive degree of self-confidence, something that may have diminished his ability to critically analyze the situation he was in, and ended up leading him to persist in the idea of landing on the runway.

On the other hand, the copilot made it evident that he was aware of the inflight emergency, that is, he had perception of the aircraft loss of altitude and speed, as well as of the impossibility of returning to the runway, and insistently attempted to convince the PIC to make an emergency landing on the beach.

However, his decision-making difficulty may have interfered with his assertiveness, when he gave his suggestion relative to what he thought would be the best to do in flight.

As a matter of fact, in that scenario, although one could find the best performance attitude for making the correction of the drifting, it would be difficult to regain a timely recovery of the altitude and speed necessary to get to the aerodrome.

For that weight condition (approximately 6,561Kg), with flaps at 18º, and a banking of about 15º, the stall speed is approximately 76KIAS (Figure 45). If one considers the weight of 6,502.9Kg, after subtracting the anti-ice and catering service weight values, the stall speed would be around 75KIAS.

The landing on the beach, in turn, also posed risks, since the available sand strip was narrow and had some stones. Ditching on the water was possibly a better option at that moment.

Anyway, it was clear that the integration of the crew was compromised.

The presence of antagonist ideas concerning the actions to be taken and the incisive posture of the captain may have interfered with the possible exchange of knowledge and experiences, necessary for choosing the best alternative for a safe landing.

The cockpit management was also affected. The CRM was not put to practice, since there was not an effort of better crew coordination for the operation of the aircraft, aiming at performing safer procedures.

Such circumstance of flight may have been a remnant of previously experienced situations which had created a climate of divergence.

Although the stall alert had been sounding continuously during 19 seconds, there is no evidence that the aircraft changed its trajectory or flight profile in the final seconds, except when it was already stalling (stall began at 06:54:35), with indication of wing roll quickly increasing the inclination to the left until crashing into the ground.

The FDR data indicate that the speed dropped below 75KIAS. However, since the outflow on the right wing was being energized by the propeller blow, an asymmetric stall occurred.

Initially, only the left wing stalled, in a way that an uncontrollable left roll momentum was created due to the right wing lift, leading to loss of control and subsequent impact with the ground.

# 3 CONCLUSIONS

## 3.1 Facts

a) the pilots had valid medical certificates;

b) the pilots had valid technical qualification certificates;

c) the pilots had qualification for the flight;

d) the aircraft had a valid airworthiness certificate;

e) the aircraft was out of its weight limits during the takeoff;

f) the software used by the operator for the aircraft dispatch calculated the maximum takeoff weight with error;

g) the very engine manufacturer was the provider of the engine maintenance services;

h) the terminology used in the writing of the records concerning the provision of maintenance services to the left engine (executed on July 10, 2011), led to misunderstanding, potentially generating difficulties in the traceability of the services;

i) at takeoff, with the aircraft at 20ft AGL, a failure occurred in engine number 1, and its torque began to drop;

j) three out of four engines originally installed in the airplanes of the operator presented wear of internal parts beyond the limits established in the service bulletin M601E/40R-1, leading to their replacement well before the TBO was reached;

k) the GGT disk of the left engine, which had been installed in the aircraft three days before, included used blades that had passed engine manual inspection and were considered serviceable by GE Aviation Czech;

l) the S/N T52A175 blade, which occupied the position 27 in the left engine GGT disk, ruptured on account of a high cycle fatigue process;

m) the FPI inspection does not guarantee the detection of small sub-surface cracks;

n) some of the operator's pilots did not do the takeoff engine failure above V1 emergency training;

o) the training of the takeoff engine failure above V1 emergency did not comply with the profile established by the manufacturer in the AFM;

p) there were discrepancies between the AFM and the checklist from the manufacturer relative to the procedure to be performed in case of takeoff engine failure above V1;

q) during the accident flight, the crew did not perform the actions prescribed for the third segment of the takeoff engine failure above V1 emergency procedure;

r) the application of the right-hand-side pedal during the single-engine flight, after the second segment of the takeoff engine failure above V1 emergency procedure, fell short of what was needed for a better performance of the aircraft;

s) there is no training prescription regarding a single-engine flight with the ABC open;

t) while flying with only one engine in operation, during the turn to the left, the aircraft lost approximately 200ft in altitude and 10kt in speed;

u) the aircraft was totally destroyed by the crash and post-impact fire; and

v) the fourteen passengers and both crewmembers perished in the crash site.

## 3.2 Contributing factors

### 3.2.1. Human Factor

#### 3.2.1.1 Medical aspect

a) Anxiety - undetermined

The perception of the danger, especially on the part of the copilot, affected the communication, and may have inhibited a more assertive posture, which might have led to an emergency landing on the beach and minimize the consequences of the accident.

#### 3.2.1.2 Psychological aspect

#### 3.2.1.2.1 Individual information

a) Attitude - undetermined

The operational actions taken in face of the emergency may have resulted from the high level of the PIC's self-confidence obtained in his years of experience in aviation, as well as from his resistance to accept opinions that were different from his own.

b) Emotional state - undetermined

From the CVR data, it is possible to observe an accentuated level of anxiety and tension in face of the abnormal situation. These components may have influenced the judgment of the conditions affecting the operation of the aircraft.

**c) Decision making process – a contributor**

The PIC's insistence on proceeding to runway 36 after the onset of the emergency, even after the copilot's realization that they were no longer able to reach the aerodrome, reflects an inappropriate judgment of the operational information presented.

**d) Stress evidence - undetermined**

The unexpected emergency situation during the takeoff and the lack of preparedness to deal with it may have generated a level of stress in the crew, affecting their operational response.

#### 3.2.1.2.2 Psychosocial information

**a) Interpersonal relationship – undetermined**

The history of divergences involving the two pilots possibly hindered the exchange of information between them, creating a barrier for dealing with the adverse situation.

**b) Team dynamics – a contributor**

The presence of diverging ideas in relation to the actions to be taken and the way they were treated, revealed cockpit integration and coordination problems that made it difficult to choose the best option for a safe landing when the aircraft could no longer reach the aerodrome.

**c) Work-group culture – undetermined**

The company was informally divided into two groups, whose interaction was difficult. It is possible that this interaction difficulty was reflected in cabin management during the emergency, since this flight had a crewmember from each group.

**3.2.1.2.3 Organizational information**

**a) Training – a contributor**

The failures that occurred in the company's training process affected the performance of the crew, since they did not have a conditioned behavior regarding the adoption of safe actions in response to the emergency.

**b) Organizational culture – a contributor**

The actions taken by the company indicate informalities that resulted in incomplete operational training and in acts that compromised safety.

**3.2.1.3 Operational aspect**

**3.2.1.3.1 Concerning the operation of the aircraft**

**a) Application of flight controls – a contributor**

According to the FDR data, the pedal was not applied in a way that would allow a deflection of the rudder sufficient to maintain the coordination of the aircraft from a certain moment of the flight with asymmetric power.

The drift values obtained on account of the inadequate application of the pedal penalized the aircraft performance, rendering it impossible to maintain a climb gradient or even a leveled flight.

In the final phase of the flight, even with the decrease of the speed to values below the $V_{MCA}$, in the midst of the continuous sound of the stall alert and repeated requests by the copilot to not "hold the nose so as not to stall", the PIC continued actuating in the pitch control until the aircraft reached a longitudinal attitude of 18º and stalled.

**b) Cockpit coordination – a contributor**

The delay in retracting the landing gear after the first request made by the PIC, the command of the PIC to feather the propeller blades when they had already been feathered, and the request made by the copilot asking the PIC to turn towards the airport when the aircraft was already turning, were indications that the flow of tasks in the cockpit was not well coordinated.

The emergency procedures prescribed in the checklist were not complied with. In the final moments of the flight, there was not agreement between the pilots as to defining the least critical option, i.e., either return to the aerodrome or land on the beach.

**c) Forgetfulness – undetermined**

It is possible that, in face of the emergency and under a feeling of anxiety, the pilots forgot to perform the third segment of the procedure prescribed for the takeoff engine failure above V1 emergency, attempting to return to the aerodrome just after the conclusion of the second segment, still at an altitude of 400ft.

**d) Training – a contributor**

The lack of training of the takeoff engine failure above V1 emergency, in the exact way it is prescribed in the Training Program, favored an inadequate performance in face of the problem they were confronted with.

The pilots did neither follow the flight profile recommended for the emergency, nor executed the checklist items prescribed after the 400ft.

**e) Pilot judgment – a contributor**

The pilots judged that their priority would be to return for a landing on the runway, but in the opposite direction from the one they had used for taking off, with the turn starting at 400ft, a fact that made it more difficult to fly the aircraft.

Up to 400ft, the aircraft maintained a straight flight profile and developed a positive climb gradient. This flight condition favored the accomplishment of the emergency checklist items, in accordance with the prescriptions of the Training Program, with little variation in the application of the flight controls.

Upon starting the turn, it would be necessary to find a new measure of pedal deflection compatible with the new condition of banking, and, at the same time, perform the checklist procedures. Therefore, the turn itself represented an increase in the workload. It is worth stressing that the operating engine had appropriate power for the maintenance of the flight.

**f) Management supervision – a contributor**

The supervision by the management did not detect that the instructions given omitted items of the syllabus contained in the Training Program relative to the takeoff engine failure above V1 emergency, both in the ground curriculum and in the flight curriculum segments.

No-one identified that the software being used by the company for the dispatch of the aircraft performed the calculation of the maximum takeoff weight, attributing to the maximum takeoff weight for a takeoff from Recife a value that was in fact the maximum structural weight (6,600Kg).

On the day of the accident, there was a weight limitation on account of the temperature. Due to the inbuilt failure of the software, the aircraft took off with an excess in the takeoff weight, resulting in a reduction of the rate of climb.

**3.2.2. Material Factor**

**3.2.2.1 Concerning the aircraft**

**a) Manufacturing – undetermined**

Considering the hypothesis that the fatigue process in the blade T52A175 had its origin while the blade was still installed in the Russian operator engine, the method utilized by the engine manufacturer for the evaluation and later reutilization of the used blades would not have been able to guarantee the quality of that blade, which ended up being installed in the position number 27 of the accident aircraft left engine GGT disk.

**b) Design – undetermined**

The aircraft documentation translated to the English language by the manufacturer did not favor the operation of the aircraft, as it contained confusing texts, differences within a same topic when dealt with by distinct documents, along with translation errors, which made it difficult to be understood, and which may have contributed to the non-execution of the proper procedure relative to the takeoff engine failure above V1 emergency.

Especially in regard to the "ABC switching off" action, to be taken at 200 ft, the divergence between the ways it is presented by the checklist and the AFM may have contributed to its non-execution by the pilots, degrading the performance of the aircraft.

## 4 FLIGHT SAFETY RECOMMENDATION (RSV)

***It is the establishment of an action that the Aeronautical Authority or SIPAER-Link issues to its respective area of actuation, aiming at eliminating or mitigating the risk of a latent condition, or the consequence of an active failure.***

***From the perspective of SIPAER, it is essential for the operational safety, refers to a specific hazard, and shall be complied with by a certain deadline.***

**Safety Recommendations made by the CENIPA:**

**To LET Aircraft Industries:**

**RSV (A) 305 / 2011 – CENIPA Issued on 29/Sept/2011**

1) Eliminate the differences between the Checklist of Emergency L410 UVP-E20 Brazilian Airplane Flight Manual and the L 410 UVP-E20 Flight Manual, Section 3, Emergency Procedures, in relation to the items marked with an asterisk in the Engine Failure during Takeoff – Above V1 emergency, and inform the operators on the update.

**RSV (A) 306 / 2011 – CENIPA Issued on 29/Sept/2011**

2) In the L 410 UVP-E20 Flight Manual, Section 3, Emergency Procedures, page 15, item 6, clarify whether the altitude 1,500ft is AGL or above the altitude of the aerodrome, and inform the operators on the update.

**RSV (A) 307 / 2011 – CENIPA Issued on 29/Sept/2011**

3) In relation to the Checklist of Emergency L410 UVP-E20 Brazilian Airplane Flight Manual, page E-4, item 08 (Airspeed 107KIAS), include the information to maintain 107KIAS up to 1,500ft, as described in Section 3, Emergency Procedures, page 15, item 06, and the Section 5, Performance, item 5.6, pages 33, 34, and 35 of the L 410 UVP-E20 Flight Manual, and inform the operators on the update.

**RSV (A) 308 / 2011 – CENIPA Issued on 29/Sept/2011**

4) In the L 410 Aircraft Pilot Type Training Program, Chart 6, page 29, establish the minimum altitude for starting turns when there is not interference from obstacles, taking into consideration the segment 3b of the takeoff profile with one engine inoperative (L 410 UVP-

E20 Flight Manual, Section 5, Performance, item 5.6), and inform the operators on the update.

**RSV (A) 309 / 2011 – CENIPA Issued on 29/Sept/2011**

5) With reference to the Checklist of Emergency L410 UVP-E20 Brazilian Airplane Flight Manual, page E-4, in the Engine Failure during Takeoff – after V1 emergency, reevaluate the fact that the item 5 (AUTO BANK CONTROL switch OFF) although requiring the action to be made 200ft above the runway, is not marked with an asterisk.

**A – 019/CENIPA/2013 – RSV 001 Issued on 18/July/2013**

Study the feasibility of establishing the training of single-engine flights with the Auto Bank Control surface deflected, so as to allow the pilot to get acquainted with the reaction of the aircraft when such devise is being used.

**A – 019/CENIPA/2013 – RSV 002 Issued on 18/July/2013**

Study the feasibility of providing operators with the thrust setting that corresponds to the equivalent drag of a feathered propeller to be used in training of simulated single-engine flight. Emphasize that retarding the power lever to flight idle position will result in significantly increased drag from the wind milling propeller.

**To GE Aviation Czech:**

**A – 019/CENIPA/2013 – RSV 003 Issued on 18/July/2013**

Reevaluate the method utilized for the exam of the blades, in order to fully guarantee the inexistence of processes of fatigue in all the blades selected for reutilization.

**A – 019/CENIPA/2013 – RSV 007 Issued on 18/July/2013**

Establish mechanisms to ensure that the records of the maintenance services provided on site have effective identification of each of the parts and components utilized, so as to facilitate their traceability.

**To NHT Linhas Aéreas:**

**RSV (A) 310 / 2011 – CENIPA Issued on 29/Sept/2011**

1) Deliver the training of emergencies during the initial training (ground practice) in accordance with the manufacturer’s Training Program (L410 Aircraft Pilot Type Training Program), item B, page 10.

**RSV (A) 311 / 2011 – CENIPA Issued on 29/Sept/2011**

2) Deliver both the initial and recurrent trainings related to “Engine Failure During Takeoff – above V1”, in accordance with the L410 Aircraft Pilot Type Training Program, item 5, pages 13 And 14.

**To NOAR Linhas Aéreas:**

**RSV (A) 312 / 2011 – CENIPA Issued on 29/Sept/2011**

1) Deliver the training of emergencies during the initial training (ground practice), in accordance with the manufacturer’s Training Program (L410 Aircraft Pilot Type Training Program), item B, page 10.

**RSV (A) 313 / 2011 – CENIPA** **Issued on 29/Sept/2011**

2) Deliver both the initial and recurrent trainings related to "Engine Failure during Takeoff – above V1", in accordance with the L410 Aircraft Pilot Type Training Program, item 5, pages 13 and 14.

**To SOL Linhas Aéreas:**

**RSV (A) 314 / 2011 – CENIPA** **Issued on 29/Sept/2011**

1) Deliver the training of emergencies during the initial training (ground practice) in accordance with the manufacturer's Training Program (L410 Aircraft Pilot Type Training Program), item B, page 10.

**RSV (A) 315 / 2011 – CENIPA** **Issued on 29/Sept/2011**

2) Deliver both the initial and recurrent trainings related to "Engine Failure during Takeoff – above V1", in accordance with the L410 Aircraft Pilot Type Training Program, item 5, pages 13 and 14.

**To TEAM Linhas Aéreas:**

**RSV (A) 316 / 2011 – CENIPA** **Issued on 29/Sept/2011**

1) Deliver the training of emergencies during the initial training (ground practice) in accordance with the manufacturer's Training Program (L410 Aircraft Pilot Type Training Program), item B, page 10.

**RSV (A) 317 / 2011 – CENIPA** **Issued on 29/Sept/2011**

2) Deliver both the initial and recurrent trainings related to "Engine Failure during Takeoff – above V1", in accordance with the L410 Aircraft Pilot Type Training Program, item 5, pages 13 and 14.

**To ANAC:**

**RSV (A) 318 / 2011 – CENIPA** **Issued on 29/Sept/2011**

1) Closely follow the execution of L410 operators' training programs, in order to make sure that the practice part of the initial emergency training meets, at least, the requirements established in the manufacturer's Training Program (L410 Aircraft Pilot Type Training Program), item B, page 10.

**RSV (A) 319 / 2011 – CENIPA** **Issued on 29/Sept/2011**

2) Closely follow the execution of L410 operators' training programs, in order to make sure that both the initial and recurrent training of the Engine Failure during Take-off – Above V1 emergency meets, at least, the requirements established in the manufacturer's Training Program (L 410 Aircraft Pilot Type Training Program), item 5, pages 13 and 14.

**A – 019/CENIPA/2013 – RSV 005** **Issued on 18/July/2013**

Study the feasibility of altering the pilot evaluation form (FAP), by including specific fields to be filled in with records of emergency maneuvers and procedures, in order to allow more detailed information on these records to be available, in addition to better monitoring and supervision of the maneuvers practiced.

**A – 019/CENIPA/2013 – RSV 006 Issued on 18/July/2013**

Establish mechanisms of oversight by the Agency, in order to ensure that operators adhere to the approved training programs.

**A – 019/CENIPA/2013 – RSV 007 Issued on 18/July/2013**

Establish mechanisms to ensure that, for the dispatch of an aircraft, any software adopted by the air operator working under the RBAC 135 or RBAC 121 calculates the performance data, including the ones relative to maximum takeoff weight, in conformity with the parameters prescribed by the manufacturer of the aircraft.

**A – 019/CENIPA/2013 – RSV 008 Issued on 18/July/2013**

Refine the mechanisms for the verification of compliances during the airline certification process, and the mechanisms of post-certification oversight, in order to identify conceptual failures, such as the prescription of returning to the runway in case of takeoff engine failure above V1, which is contained in the SOP of the NOAR company.

## 5 CORRECTIVE OR PREVENTIVE ACTION ALREADY TAKEN

The Safety Recommendations numbers 305 through 319 were issued on 29 September 2011.

## 6 DISSEMINATION

– ANAC;

– Brava Linhas Aéreas;

– EASA (via Investigation Authority of the Czech Republic);

– GE Aviation Czech (via Investigation Authority of the Czech Republic);

– ICAO (International Civil Aviation Organization)

– LET Aircraft Industries (via Investigation Authority of the Czech Republic);

– NOAR Linhas Aéreas;

– SOL Linhas Aéreas; and

– TEAM Linhas Aéreas.

## 7 APPENDICES

### 7.1 Comments from the Czech Republic

Below, there is a list of all the comments forwarded to CENIPA by the Czech Republic, i.e., the ones made by the aircraft manufacturer (Aircraft Industries – AI), and the ones made by the engine manufacturer (GE Aviation Czech). The comments are those which were not incorporated in the text of the Final Report. They are followed by an explanation on the reason for the non-acceptance.

#### 7.1.1 Comments made by Aircraft Industries

a) <u>COMMENT #1</u>

<u>Aircraft Industries' argumentation:</u>

"Chapter 2 – Analysis" brings the following text:

*"The support documentation translated by the aircraft manufacturer to the English language did not favor the operation of the aircraft, since it contained confusing texts, differences within the same subject when dealt with by distinct documents, and translation errors, making it difficult to understand, therefore posing a risk to operation".*

The AFM is a document which is approved during certification process by the pertinent aviation authority. AI didn't receive any comment/suggestions from aviation authorities by which the L410 UVP-E20 airplane was certified including ANAC, even in the case of L420 model AFM which is similar to L410 UVP-E20 model AFM and which was approved by the FAA.

CENIPA's comment:

The argumentation was not accepted, since the erros existing in the publications are being clearly shown in the Final Report and require immediate correction, independently of the fact that the certification authority did not perceive or question the manufacturer about them. Problems such the ones listed below were found:

- the AFM shows confusion in relation to the definition of the memory items in the takeoff engine failure emergency procedure:

- the emergency Checklist, in the takeoff engine failure emergency procedure, show a non-memory item at 200ft (ABC – which is importante in this event);

- The maufacturer's Training Program is rather confusing in relation to the definitions of the number of exercises and time allotted for each training flight.

b) COMMENT #2

Aircraft Industries' argumentation:

"Chapter 2 – Analysis" brings the following text:

*"The negative impact of the ABC on the vertical speed is estimated by the manufacturer to be approximately 20ft/mi, for a straight-and-level flight condition. However, this impact may have been bigger, on account of the flight profile being maintained.*

*It is also important to point out that there is not a prescription of engine failure training with the ABC deflected. In a real situation, this apparent omission in the training may hinder the identification of the ideal aircraft attitude to be chosen by the pilot".*

The impact of the ABC tab to the airplane performance can be counted as constant and can't be influenced by the flight profile or the other effect.

Concerning to low influence of the ABC tab onto airplane performance it seem to be redundant to add the training of flight with one engine inoperative and extended ABC tab to the training program.

Further the final report pay a lot of attention to the extended ABC tab which in fact should be classified as a second order issue. In contrary to that the role of proper application of the rudder is the key factor of correct flight with one engine inoperative.

With regards to ABC tab the report doesn't comment the cause of its late extension. Based on FDR records AI opinion is that ABC tab was extended as a result of the crew action.

CENIPA's comment:

The argumentation was not accepted, due to the fact that the ABC reduces the rate of climb, although this occurs at an approximate rate of 20ft/min, according to data from the manufacturer. The question of non-application of the pedal with the purpose of coordinating the flight with asymmetric power was presented, even with the calculations that indicate the quantitative measure of this influence. In relation to the late opening of the ABC surface, the CVR did not show any action by the crew in order to cause this effect in the aircraft.

A recommendation made by the CENIPA to the manufacturer reads: "Study the feasibility of establishing the training of single-engine flights with the Auto Bank Control surface deflected, so as to allow the pilot to get acquainted with the reaction of the aircraft when such devise is being used."

The argumentation presented herein, as well as other aspects considered relevant by the manufacturer, shall be presented in conjunction with the result of the study of feasibility recommended by the CENIPA.

### 7.1.2 Coments made by GE Aviation Czech

a) COMMENT #1

GE Aviation Czech' argumentation:

Item 1: Synopsis; 1st paragraph. The draft final report classified this accident as an inflight engine failure. GE Aviation recommends that the accident classification be changed to a Propulsion System Malfunction plus Inappropriate Crew Response, or PSM + ICR.

Reasoning: This accident involved an inflight engine failure, but that was followed by an inappropriate crew response. The report should not classify the accident merely as an inflight engine failure. The accident also meets the criteria of a CAAM Level 4 event of severe consequences with fatalities and loss of aircraft. CAAM stands for "Continued Airworthiness Assessment Methodologies" and is defined in FAA AC 39-8 and used by GE Aviation in assessing field events. In this event the propulsion system malfunction was the gas generator turbine blade separation at takeoff which resulted in loss of engine power at position 1. The LET410 aircraft is certified for single engine operation after V1. The flight crews are required to be trained for single engine operation after V1 as an emergency procedure. The cause of the NOAR accident was a result of the flight crew's inappropriate actions after the loss of engine position 1.

Recommendation: Change the accident classification to a "Propulsion System Malfunction plus Inappropriate Crew Response" or PSM + ICR.

CENIPA's comment:

The classification of an occurrence is done in accordance with the taxonomy and procedures of the State of Occurrence (in charge of the investigation). It is worth remarking that there is not a standard or recommended practice issued by the International Civil Aviation Organization regarding this issue. Moreover, there is not an internationally approved classification in force.

In Brazil, the occurrence is classified in accordance with the first one of the chain of events.

Finally, the reasoning that has been presented mentions rules of the FAA (Federal Aviation Administration) and this is an ICAO investigation (the FAA is not an investigation authority before the ICAO).

b) COMMENT #2

GE Aviation Czech argumentation:

Item 2: Event Table; “Type”. Please reference item 1 regarding that the accident classification be changed to “Propulsion System Malfunction plus Inappropriate Crew Response”, or PSM + ICR.

CENIPA’s comment:

The classification of an occurrence is done in accordance with the taxonomy and procedures of the State of Occurrence (in charge of the investigation). It is worth remarking that there is not a standard or recommended practice issued by the International Civil Aviation Organization regarding this issue. Moreover, there is not an internationally approved classification in force.

In Brazil, the occurrence is classified in accordance with the first one of the chain of events.

Finally, the reasoning that has been presented mentions rules of the FAA (Federal Aviation Administration) and this is an ICAO investigation (the FAA is not an investigation authority before the ICAO).

c) COMMENT #3

GE Aviation Czech argumentation:

The “Section 2 – Analysis” of the Report has the following text:

*“Examination of the disk and its blades discarded the possibility that the failure could have occurred on account of a problem in the metallic composition, favoring the possibility that the fatigue could have been caused by vibration. In this case, the few hours flown by the disk in the engine installed in the PR-NOB suggest that the vibration (as well as the fatigue) could have started in the engine disk it had been operating before being installed in the PR-NOB.”*

Reasoning: The report notes that there is merely a “possibility” that the metal fatigue in the blade “could have been” caused by vibration, and this vibration “could have started” when the blade was being operated in the prior engine before installation in the event engine. There is no evidence that any of the blades in the inspection lot were subjected to vibration levels resulting in metal fatigue before they were inspected at GE Aviation Czech.

The GE Aviation Czech’s state-of-the-art, robust inspection methods were correctly applied and resulted in no finding of any anomaly - In addition, there is nothing in the report suggesting that there are other more reliable or robust inspection techniques available to GE Aviation Czech that should have been employed.

51 of the 55 GGT blades which were in the event engine were operating in the former aircraft, installed in ESN 873-026. These 51 blades were FPI’d on Feb. 5, 2011 and all passed. They were installed in the event GGT rotor. After the event, 50 of the 51 blades were re-FPI’d in the Oct. – Nov. 2011 time period and all passed. No FPI indications after operating in ESN 873-026 and No FPI indications after the event.

Recommendation: Replace the paragraph with:
51 of the 55 GGT blades which were in the event engine were operating in ESN 873-026 in another aircraft. These 51 blades were FPI’d on Feb. 5, 2011 and all passed. They were installed in the event GGT rotor. After the accident event, 50 of the 51 blades were re-FPI’d

in the Oct. – Nov. 2011 time period and all passed. There were no FPI indications after operating in ESN 873-026 and there were no FPI indications after the event.

CENIPA's comment:

Based on the total hours flown by the GGT rotor disk installed in the PR-NOB aircraft, and on the vibration test carried out by the GE Aviation four days prior to the accident, the Final Report Analysis Section presented the following hypothesus: the onset of the blade metal fatigue due to vibration before the installation of this turbine disk in the engine that failed. Besides, the FPI inspection does not guarantee the detection of small subsurface cracks.

d) COMMENT #4

GE Aviation Czech argumentation:

The "Section 2 – Analysis" of the Report has the follwoing text:

*"According to this reasoning, there is evidence that the evaluation of the used blades performed by the GE Aviation Czech for purposes of reutilization was not able to guarantee that they met the quality requirements which would allow them to be installed in another disk."*

Reasoning: The report states there is "evidence" that GE Aviation Czech's inspection process "was not able to guarantee" that the blades "met the quality requirements which would allow [the blades] to be installed in another disk." Presumably the report is saying that, because the blade failed, then GE's inspection of the blade was necessarily flawed. This is highly speculative and uses conclusory logic that is flawed. There is no evidence that any of the blades in the inspection lot were subjected to vibration levels resulting in HCF before they were inspected at GE Aviation Czech. To the contrary, GE Aviation Czech's state-of-the-art, robust inspection methods were correctly applied and resulted in no finding of any anomaly.

Recommendation: delete this paragraph.

CENIPA's comment:

The paragraph was maintained, based on the information presented by GE Aviation stating that the FPI inspection does not guarantee the detection of small subsurface cracks.

e) COMMENT #5

GE Aviation Czech argumentation:

The "Section 2 – Analysis" of the Report has the following text:

*"Besides, problems were found in the records of the services provided, which, associated with the fact that the maintenance was performed directly by the manufacturer, ended up leading the very operator to not participate in the process."*

Reasoning: First item, if the "problems" which were found in the records of the services provided was in regards to the "S/N b45" documentation please reference item 4. The GE Aviation Technician listed in the appropriate records the correct S/N or Set Number.

The assembly Set Numbers (S/N) are same because it describes the same GGT assembly number / drawing number. This item has nothing to do with the accident, and did not lead to NOAR personnel being excluded from any process.

Second item: The statement “problems were found in the records of the services provided” which “ended up leading the very operator to not participate in the process”, is not accurate. The report presents no facts to support this statement, which is in the factual section of the report.

More important, the report does not note what “problems” in the records are being referred to or how such “problems” could possibly relate to the accident. Please recall that when the GE Aviation Czech technicians completed all required maintenance and testing associated with the GGT rotor disk replacement, they made a record of their work on the GE Aviation Czech Technical Record, dated July 10, 2011, and signed and stamped the work as being completed.

The Record was counter-signed by NOAR’s lead engineer who was present for the maintenance and testing. During the post-maintenance ground engine testing, the NOAR lead Engineer was in the cockpit left seat, one GE Aviation Czech technician was in the cockpit right seat, and the other technician was in a passenger seat. The GE Aviation Czech technician signed the EASA Form 1 “Authorized Release Certificate” on July 10, certifying that ESN 101-001 was repaired and was ready for release to service. The Technical Record and the EASA Form 1 were left with the ESN 101-001 log book in Recife.

Recommendation: This statement should be deleted from the report.

CENIPA’s comment:

The problems related to the terminology used in the records of the SN b45 replacement services were better explained in the factual information section.

The information concerning the non-participation of the operator in the maintenance process of replacement of the turbine disk is based on the fact that no workshop in Brazil is qualified for this level of maintenance in M601E enignes.

The Final Report has not pointed at the problems of terminology used in the records of the SN b45 assembly services as contributors to the accident.

Although the NOAR chief-engineer has sign the records of the services done in the engine, the quality of the services could only be attested by the GE Aviation personnel.

f) COMMENT #6

GE Aviation Czech argumentation:

Item 12: Section 2 Analysis; Request that CENIPA adds to Section 2 the following.

Reasoning: Should be documented that the NOAR flight crews were not arming the Autofeather system prior to takeoff.

Recommendation: Add to this section to reflect the fact that the NOAR flight crews were not arming the Autofeather system prior to takeoffs.

CENIPA’s comment:

There is no evidence allowing one to affirm that this was taking place.

g) COMMENT #7

GE Aviation Czech argumentation:

Item 13: Section 2 Analysis; Request that CENIPA adds to Section 2 the following:

Reasoning: It should be documented that during the event flight takeoff, the Torque of both

engines was increased during the aircraft take-off ground roll, reached approximately 80% of maximum torque and was further slowly increased up to 85% at the moment of lift-off (WOW signal in Air level).
However, the GE M601 Operation Manual, P/N 0982404, in chapter 2 - Standard Practices, section 5 – Take-Off Rating, p. 2-5, states “The engine control lever is to be put to a position when some limit of torque or ITT or of gas generator speed in accordance with the pertinent Table of Operation Limits for take-off rating has been reached.” Table 1-1, M601E/E21 Operation Limits, specifies for take-off power rating max. 100% nG gas generator speed to reach max. 100% torque and power 560kW (751 shp).

This rating process was not used on both engines.
Recommendation: Add to section 2 to reflect the fact that the NOAR flight crew in the event takeoff did not use the M601 Operation Manual takeoff power setting process.

CENIPA’s comment:

Knowledge of the GE M601 Operation Manual is not required from the pilots, since, according to their perspective, the operation of the aircraft is carried out in accordance with the AFM.

In the case of the L410, it is a well-know fact that, in some instances, the ITT limit does not allow the torque to reach 100% at the beginning of the takeoff roll, when the aerodynamic effort of the engine propeller is small, affecting the torque values in some measure. This aerodynamic effort increases with speed, at the same time that ITT decreases (due to the increase of the admission of air into the engine), allowing the torque to reach its limit.

There are no ITT parameters recorded in the SSFDR.

h) COMMENT #8

GE Aviation Czech argumentation:

The “Section 2 – Analysis” of the Report has the following text:

*“In fact, as soon as the engine failure was recognized by the pilots, the copilot suggested “aborting” the takeoff, although the aircraft had already lifted off, with the PIC replying that there was not enough space to return to the runway.”*

Item 14: Section 2 Analysis; Amend above paragraph.

Reasoning: 6 seconds past the partial loss of thrust on the left engine, the rating of the right engine was decreased to 70% torque. This decreased rating was held for 14 seconds. Increase to approx. 87,5% followed. 97,5% torque on right engine was set 40 seconds after the loss of the thrust on the left engine. The 97,5% torque rating was held for 30 seconds. Another decrease to an average 90% torque followed, for a duration of 108 seconds. The last segment of 60 seconds was operated at 100% torque on the right engine.

GE M601 Operation Manual, P/N 0982404, Table 1-1, M601E/E21 Operation Limits, specifies for take-off power rating max. 100% nG gas generator speed, max. 100% torque and power 560kW (751 shp). This rating was not used continuously during the OEI flight.

Table 1-1 specifies Max. Take-off rating max. 102% nG gas generator speed, max. 106.5% torque for 595kW (798 shp).

The FDR data and position of engine control lever in the cockpit does not indicate usage of this rating.

The GE M601 Operation Manual, P/N 0982404, states in chapter 3 – Emergency Procedures, section 9 – In-Flight Shaft Power (Gas Generator Speed) Drop, p. 3-21, item d) “In case of shaft power drop accompanied by decrease of oil pressure below the permitted value and/or by high ITT, stop the engine. In case the propeller has not been automatically feathered, feather the propeller by depressing the push button in the cockpit. Displace the propeller control lever to the “FEATHER” position.

The Autofeather system was not armed. Feathering of the left propeller was performed 120 seconds after the loss of thrust on the left engine.

Recommendation: Add to section 2 to reflect the fact that the NOAR flight crew in the event takeoff:

1) Reduced thrust on engine position 2 after the partial thrust loss on engine position 1 and kept engine position 2 at that setting for approximately 14 seconds.

2) Did not use the M601 Operation Manual takeoff power setting process.

3) Did not arm the autofeather system.

4) Did not use the M601 max thrust take off setting of 102%.

CENIPA’s comment:

It became clear to the investigating team that the non-utilization of 100% of the torque available in the remaining engine, in the initial climb phase up to 400ft was not relevant, since the aircraft was climbing at 93kt up to the enf of the second segment of the emergency procedure, still with residual power in the engine that had a failure. Thus the momentary reduction of the engine number 2 favored the controllability of the aircraft during the flight with asymmetric power, without a negative impact on the performance of the aircraft.

As already mentioned earlier, the pilots have to utilize the AFM to operate the aircraft.

There isn’t any evidence allowing to affirm that the crew did not arm the authofeather system.

i) COMMENT #9

GE Aviation Czech argumentation:

The “Section 3 – Conclusions, 3.1 Facts, l” of the Report has the following text:

*l) “the FPI inspection does not guarantee the detection of small cracks”;*

Reasoning: It is not feasible for any inspection method to “guarantee” that every single “small crack” will be detected, especially sub-surface cracks. The current inspection methods employed at GE Aviation Czech are state-of-the-art and robust. Moreover, there is no evidence that the blade was even cracked at the time of FPI inspection. The existence of a crack during FPI is speculative and this type of supposition should not be included in the factual conclusions of an accident report.

Recommendation: This statement should be deleted.

CENIPA’s comment:

The sentence was not excluded. Instead, it has been rewritten, based on a comment made by the very GE Aviation.

Sentence corrected: "*l) “the FPI inspection does not guarantee the detection of small subsurface cracks”;*

COMMENT #10

GE Aviation Czech argumentation:

The “Section 3 – Conclusions, 3.1 Facts, o” of the report has the follwoing text:

o) *“there were discrepancies between the AFM and the Checklist relative to the procedure to be performed in case of takeoff engine failure above V1”*

Recommendation: The following statement should be added to the above description: The autofeather system was not armed prior to the take-off on the event flight. The take-off rating, max. 100% nG gas generator speed, max. 100% torque and power 560kW (751 shp), was not used on both engines during take-off procedure

CENIPA’s comment:

There isn’t any factual evidence that the crew did not arm the autofeather system before takeoff.

The power used during takeoff was in conformity with the procedures described in the AFM.

j) COMMENT #11

GE Aviation Czech argumentation:

The “Section 3 – Conclusions, 3.1 Facts, q” of the report has the follwoing text:

*“q) during the accident flight, the crew attempted to return to the aerodrome without performing the third segment of the takeoff engine failure above V1 emergency”*

Reasoning: The following statement should be added to the above description: The take-off torque setting of the right engine (torque values in range 97,5% to 100%) was held for 90 seconds out of the total 238 seconds of OEI flight. Max. Take-off rating max. 102% nG gas generator speed, max. 106.5% torque for 595kW (798 shp) was not used. Feathering of the left propeller was performed 120 seconds past the loss of the thrust on the left engine.

CENIPA’s comment:

In case of engine failure above V1, the crew has to follow the emergency checklist. This publication does not mention the use of 102% Ng and 106.5 torque at takeoff.

The analysis section of the Final Report shows the exact moment of the engine failure, as well as the time at which the manual feathering of the left propeller was performed. In addition, according to the aircraft manufacturer, the left engine was producing, after the failure and before the feathering, a residual power which helped in the intial climb up to 400ft.

k) COMMENT #12

GE Aviation Czech argumentation:

Add to “Section 3 – Conclusions” the following item:

3.2.1.3.1 b) Application of Engine Controls – a contributor

The take-off rating, max. 100% nG gas generator speed, max. 100% torque and power 560kW (751shp), was not used on both engines during the event take-off. The torque setting of the right engine was decreased 6 seconds after the partial loss of thrust on left engine. The torque setting of the right engine was decreased to 70% torque. This decreased rating was held for 14 seconds. The take-off rating of the right engine (torque values in the range 97,5% to 100%) was held for 90 seconds of the total 238 seconds of OEI flight. The max. take-off torque setting, max.102% nG gas generator speed, max. 106.5% torque for 595kW (798 shp), was not used.

Feathering of the left propeller was performed 120 seconds after the loss of thrust on the left engine.

CENIPA’s comment:

These words are in disagreement with the publications issued by the aircraft manufacturer (AFM and emergency checklist). In case of engine failure above V1, the crew must follow the emergency checklist. This publication does not mention the use of 102% Ng and 106.5% torque at takeoff.

Besides, the contributing factors used by the CENIPA follow a taxonomy prescribed by the Brazilian legislation, which does not contemplate the factor suggested above by GE Aviation Czech.

l) COMMENT #13

GE Aviation Czech argumentation:

The “Section 4 – Safety Recommendations” has the following recommendation:

*“Reevaluate the method utilized for the exam of the blades, in order to fully guarantee the inexistence of processes of fatigue in all the blades selected for reutilization”.*

Reasoning: This safety recommendation directly relates to the conclusion that manufacturing was a contributing factor in the accident. As stated earlier, it is not feasible for any inspection method to “fully guarantee” that a blade will never fail in HCF. The current inspection methods employed at GE Aviation Czech are state-of-the-art and robust. CENIPA does not recommend any alternate method of inspection to be employed.

Recommendation: This proposed safety recommendation should be deleted.

CENIPA’s comment:

The conclusion of the Final Report does not point at manufacturing as a contributing factor. However, since there isn’t any inspection method to guarantee that the blade will never fail in HCF, manufactuirng was considered an “undetermined factor”.

m) COMMENT #14

GE Aviation Czech argumentation:

The “Section 4 – Safety Recommendations” has the following recommendation:

*“Establish mechanisms to ensure that the records of the maintenance services provided on site have effective identification of the parts and components utilized, so as to facilitate their traceability.”*

Reasoning: This safety recommendation is requesting that the maintenance records provided on site have effective identification of the parts and components used (installed and removed) for traceability. The maintenance records involved in the event aircraft did identify the parts and we were able to identify for CENIPA the disk serial numbers of the GGT assemblies involved in the investigation. Please recall that the GGT assembly removed by GE Aviation Czech was still at the NOAR facility. We do not understand how records facilitating and traceability, which assists us in post-accident investigations, would have prevented this event.

Recommendation: This proposed safety recommendation should be deleted.

CENIPA’s comment:

The maintenance records made by the GE Aviation technician were not considered as a contributing factor to the accident. However, the written terminology used has to facilitate the identification of both the item removed and the item installed.

It is also worth considering that the purpose of the recommendations is to improve the aviation safety levels, preventing future accidents.

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On 18 July 2013.