

COMMAND OF AERONAUTICS
AERONAUTICAL ACCIDENT INVESTIGATION AND
PREVENTION CENTER



FINAL REPORT
A - 012/CENIPA/2013

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|---------------------------|-------------------------|
| <u>OCCURRENCE:</u> | ACCIDENT |
| <u>AIRCRAFT:</u> | PR-TTI |
| <u>MODEL:</u> | ATR72-212 |
| <u>DATE:</u> | 21 February 2011 |



NOTICE

According to the Law 7565 of 19 December 1986, Article 86, the Aeronautical Accident Investigation and Prevention System - SIPAER – has the competence to plan, guide, coordinate, monitor and carry out the activities concerning the investigation and prevention of aeronautical accidents.

The preparation of this Final Report was based on contributing factors and hypotheses, being a technical document that reflects the result obtained by SIPAER in relation to the circumstances that contributed or may have contributed to trigger this event.

This report does not focus on quantifying the degree of contribution of the contributing factors, including the variables that conditioned human performance, whether individual, psychosocial or organizational, and that interacted, creating a scenario favorable to the accident.

The sole purpose of this report is to recommend the study and the establishment of preventive measures, while the decision on the pertinence of accepting them is the sole responsibility of the President, Director, Chief, or the person corresponding to the highest level in the hierarchy of the organization to whom they have been forwarded.

This report does not resort to any proof producing procedures for determination of civil or criminal liability, in conformity with item 3.1 of Annex 13 to the 1944 Chicago Convention, hosted by the Brazilian legal system through the Decree No. 21713 of 27 August 1946.

Moreover, it is worth stressing the importance of protecting the individuals who provided information on the occurrence of an aeronautical accident. The use of this Report for punitive purposes in relation to these individuals taints the principle of "non-self-incrimination" derived from the "right to remain silent," hosted by the Federal Constitution.

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

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

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SYNOPSIS

This is the Final Report of the 21 February 2011 aeronautical accident involving the ATR72-212 aircraft, registration PR-TTI. The accident was classified as System/Component Failure or Malfunction (landing gear).

After the aircraft landed in SBHT, its left main landing gear collapsed. The aircraft veered off to the left, exited the runway, and came to a stop in a grass area.

46 passengers and 4 crewmembers were onboard the aircraft. One of the passengers suffered minor injuries.

The aircraft sustained serious damage to the left main gear.

The BEA (*Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile*) from France designated an accredited representative for participation in the investigation.

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

| | |
|----------|----------------------------------------------------------------------|
| AD | Airworthiness Directive |
| ANAC | (Brazil's) National Civil Aviation Agency |
| APRS | Return-to-Service Approval |
| CCF | Medical certificate |
| CENIPA | (Brazil's) Aeronautical Accident Investigation and Prevention Center |
| CG | Center of Gravity |
| CHE | Enterprise Homologation Certificate |
| DCTA | (Brazil's) Department of Science and Airspace Technology |
| FAA | Federal Aviation Administration (USA) |
| FDAU | Flight Data Acquisition Unit |
| FDR | Flight Data Recorder |
| IAE | (Brazil's) Institute of Aeronautics and Space |
| IFR | Instrument Flight Rules |
| INFRAERO | Brazilian Airports Infrastructure Enterprise |
| LABDATA | CENIPA's Flight Recorders Data Readout and Analysis Laboratory |
| Lat | Latitude |
| Long | Longitude |
| SEM | Scanning Electron Microscope |
| MPI | Internal Procedures Manual |
| PN | Part Number |
| RBAC | Brazilian Civil Aviation Regulations |
| RBHA | Brazilian Aeronautical Homologation Regulation |
| RPQS | Technical Manager (Responsible for the Quality of Service) |
| RSV | Flight Safety Recommendation |
| SBBE | ICAO location designator – <i>Belém</i> Aerodrome |
| SBHT | ICAO location designator – <i>Altamira</i> Aerodrome |
| SB | Service Bulletin |
| SN | Serial Number |
| UTC | Coordinated Universal Time |
| VFR | Visual Flight Rules |

| | | |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| AIRCRAFT | Model: ATR-72-212 Registration: PR-TTI Manufacturer: AEROSPATIALE E ALENIA | Operator: TRIP Linhas Aéreas |
| OCCURRENCE | Date/time: 21FEB2011 / 21:45 UTC Location: Altamira Aerodrome (SBHT) Lat. 03° 15' 03"S – Long. 052°15'08"W Municipality – State: Altamira – Pará | Type: System/Component Failure or Malfunction (landing gear) |

1 FACTUAL INFORMATION

1.1 History of the occurrence

The aircraft departed from SBBE on an IFR flight plan, destined for SBHT.

The approach for landing in SBHT was visual and stabilized. The touchdown on the runway was smooth, with gradual deceleration, in which only the "ground idle" was utilized.

After the "70kt" callout, a strong noise was heard, and the left main gear collapsed, with the aircraft veering off to the left. The aircraft exited the runway and came to a stop in a grass area.

There were 46 passengers and 4 crew members on board. One of the passengers suffered minor injuries.

There was no damage to third parties.

1.2 Injuries to persons

| Injuries | Crew | Passengers | Third parties |
|-----------|------|------------|---------------|
| Fatal | - | - | - |
| Serious | - | - | - |
| Minor | - | 01 | - |
| Uninjured | 04 | 46 | - |

1.3 Damage to the aircraft

The aircraft sustained serious damage to the main landing gear, hydraulic system, engine number 1 propeller, and engine number 1, as well as light damage to the fuselage and wing, all of them on the left hand side of the aircraft.

1.4 Other damage

Nil.

1.5 Information on the personnel involved

1.5.1 Information on the crew

| HOURS FLOWN | | |
|-----------------------------------|----------|----------|
| | PILOT | COPILOT |
| Total | 6,000:00 | 1,210:00 |
| Total in the last 30 days | 63:50 | 50:00 |
| Total in the last 24 hours | 05:20 | 05:20 |
| In this type of aircraft | 2,600:00 | 50:00 |
| In this type in the last 30 days | 63:50 | 50:00 |
| In this type in the last 24 hours | 05:20 | 05:20 |

NB.: data provided by the operator.

1.5.1.1 Professional formation

The pilot earned his wings at the Piracicaba Aviation School (State of São Paulo) in 2002.

The copilot earned his wings at the HELISUL Aviation School in 2005.

1.5.1.2 Validity and category of licenses and certificates

Both the captain and the copilot had valid technical qualification certificates.

1.5.1.3 Qualification and flight experience

The pilots were qualified and had enough experience for the flight.

1.5.1.4 Validity of the medical certificate

The pilots had valid medical certificates.

1.6 Aircraft information

The ATR72-212 aircraft, manufactured by the AEROSPATIALE and ALLENIA in 1995, serial number 454, had a total of 32,886.50 hours of flight at the time of the accident.

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

The last aircraft inspection (Daily/Weekly type) was conducted on 21 February 2010, and the last overhaul (Check 1CFH) was conducted on 2 February 2010. Both the inspection and the overhaul were made at the premises of a workshop homologated for these types of service.

At the moment of the accident, the aircraft was within the *weight and center of gravity* limits specified by the manufacturer.

1.7 Meteorological information

Prevailing weather conditions were VMC.

1.8 Navigational aids

Nil.

1.9 Communications

Nil.

1.10 Aerodrome information

The SBHT aerodrome is public, under management of the INFRAERO, operating day-time/night-time VFR and IFR. It has an asphalt runway, thresholds 07/25, and measuring 2,003m x 38m, at an elevation of 369ft.

1.11 Flight recorders

The Fairchild F800 *Flight Data Recorder* (FDR), PN 17M800-261, SN 4141 and Modifications (*moddots* 08 and 22), was received by the CENIPA on 24 February 2011, and taken to the LABDATA, for the readout and subsequent evaluation of its stored data.

Although the recorder was in good shape, with no traces or evidence of external damage, with intact seals of the last inspection at a workshop in Brazil, and despite the fact

that the readout was made successfully, the data extrapolation made by means of the software being used at the laboratory did not manage to extract the data from the FDR file, since the files did not show the data magnitude.

According to the RBAC 121.343, the aircraft must be equipped with one or more approved flight data recorders, utilizing digital data recording/storing techniques, besides allowing a prompt data recovery.

During the Investigation, the following hypotheses were raised in order to determine the reason why the FDR did not show the data magnitude:

- Aircraft problems not allowing the flow of data into the FDR;
- Inadequate maintenance of the FDR equipment;
- FDAU reprogramming in discordance with the manufacturer's documentation;
- Incomplete verification of the recorded parameters by the hired maintenance operators;
- Partial verification of the readings and processing elements of the data channels, not guaranteeing a proper functioning of the channel as a whole;
- Inadequate installation in the aircraft;
- Failure to conduct the mandatory modifications (moddots) prescribed by the manufacturer in the *Aviation Recorders Component Maintenance Manual* Fairchild Model F800, Chapter 31 – 30 – 01, Rev 1 and 2, *Service Bulletins 01 thru 12*.

In a visit of the flight data recorder maintenance facility, it was observed that the procedure performed by the maintenance provider was correct and adequate, and that the maintenance provider had forwarded the information relative to the equipment discrepancies to the *TRIP Linhas Aéreas* company, which, due to lack of definition of its own internal processes, did not manage to identify that the (PR-TTI) aircraft flight data were not being sent to the flight recorder.

The *TRIP Linhas Aéreas* company told CENIPA that the internal processes dealing with discrepancies of flight recorders installed in their aircraft were being revised and improved in order to prevent situations like those from happening again.

1.12 Wreckage and impact information

The accident occurred during the landing roll, with the aircraft exiting the runway through the left side. The aircraft sustained damage to its left main landing gear, left propeller and to the number one engine. The aircraft main structure was preserved, as can be seen in Figures 1 and 2.



Figure 1 – Trajectory of the aircraft after landing.



Figure 2 – Situation of the aircraft after the runway excursion.

1.13 Medical and pathological information

1.13.1 Medical aspects

Not investigated.

1.13.2 Ergonomic information

Nil.

1.13.3 Psychological aspects

1.13.3.1 Individual information

The captain was a qualified instructor in the equipment. On the day of the accident, he was giving training to the copilot.

He had joined the company over three years before.

The captain reported that, on the day of the accident, he had done the aircraft *walkaround*, since they were between 15 and 20 minutes behind schedule, but nothing special had drawn his attention. In the aircraft logbook, there weren't any records of abnormalities.

During the flight, the crew perceived no abnormalities, noises or vibrations. The landing was characterized as smooth, and was considered by the captain/instructor as the best (in technical terms) performed by the copilot under training.

The captain said that they were not able to identify what had gone wrong with the aircraft when it veered off to the left and that they made provisions for an emergency evacuation, following the prescribed procedures – information that was confirmed by the copilot.

The copilot had joined the company in October 2010. It was the first RBAC 121-ruled company he worked for, and his first experience with larger aircraft.

The instructor informed that the copilot under training had a satisfactory performance.

The copilot was totaling 50 hours of training in the equipment, all of them with the same instructor. The copilot felt he had done good training in the simulator.

The captain and the copilot denied having any physical or psychological problems that might have affected the flight, and said that they had had an adequate rest period.

1.13.3.2 Psychosocial information

Nil.

1.13.3.3 Organizational information

Nil.

1.14 Fire

There was no fire.

1.15 Survival aspects

Nil.

1.16 Tests and research

Two fractured pins, identified as D61999 MN 319 and D61000 E1 SN 25, belonging to the left main landing gear, were sent to the DCTA for analysis aimed at finding out the possible cause of the failures.

In the visual and stereoscopic tests of the pin D61999 MN 319 (Figure 3), it was possible to see that it had broken, showing signs of kneading and fracture with inclination of $\pm 45^\circ$, suggestive of overload.



Figure 3 – Aspect of the pin identified as D61999 MN 319.

In the visual and stereoscopic tests of the *AFT PIVOT PIN* (D61000 E1 and SN 25) (Figure 4), it was possible to see that it presented a fracture surface with an inclination of $\pm 45^\circ$ and a flat region with multiple initiations, indicative of a mechanism of fracture due to fatigue (Figure 5).



Figure 4 – Aspect of the pin identified as D61999 MN 319.



Figure 5 – Aspects of the pin (D61000 E1 SN 25). It is possible to see a flat fracture surface and another one at $\pm 45^\circ$ (a). It is possible to observe multiple fracture plans, indicative of play, with various initiations (indicated by arrows) (b).

In the SEM examination of the pin fracture surface, it was possible to observe multiple planes of fracture and beach marks, indicative of fatigue (Figure 6).

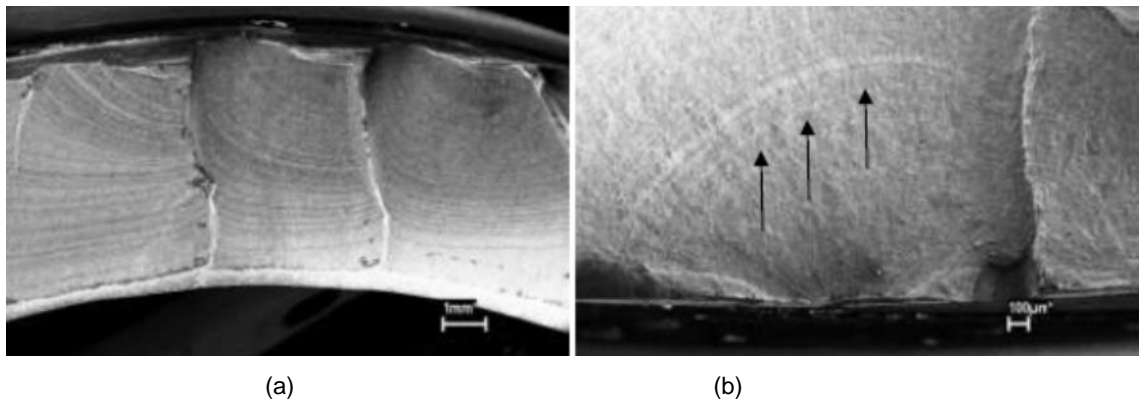


Figure 6 – Electrophotography. (a) Multiple planes of fracture can be observed. (b) The arrows point at beach marks, characteristic of fatigue.

In the stereoscopic exams of the pin external surface, in a region close to the fatigue fracture, it was possible to observe cracks that had initiated from scratches caused by the machining process (Figure 7).

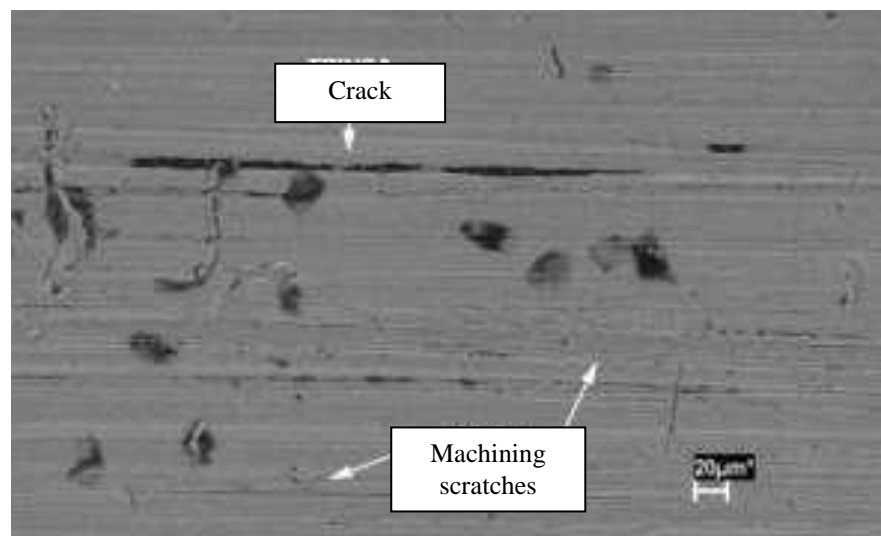


Figure 7 – Electrophotography: It is possible to observe cracks associated with machining scratches (indicated by arrows).

In the area of the pin where the overload-related fracture occurred, it was possible to observe that the machining process had generated an alteration of the part profile in the region of section transition, by bringing in a depression, as can be seen in Figure 8.



Figure 8 – Photographs showing the machined groove, and the area of the groove where the fatigue process occurred.

Still early in the investigation, it was seen that there was another pin (D61000 MN 254) which had not broken, and that had been subjected to the same maintenance process, in the same companies. It was installed in the right main gear of another aircraft (PR-TTJ) and was in permanent use. The investigator-in-charge requested the pin to be removed, and then sent to the DCTA so that possible defects could be identified.

Visual and stereoscopic examination of this pin, conducted after the protective paint was removed, revealed rough machining scratches and a crack in the chrome layer, in the same area where the fatigue-related crack of the pin D61000 E1 SN 25 had occurred (Figure 9).

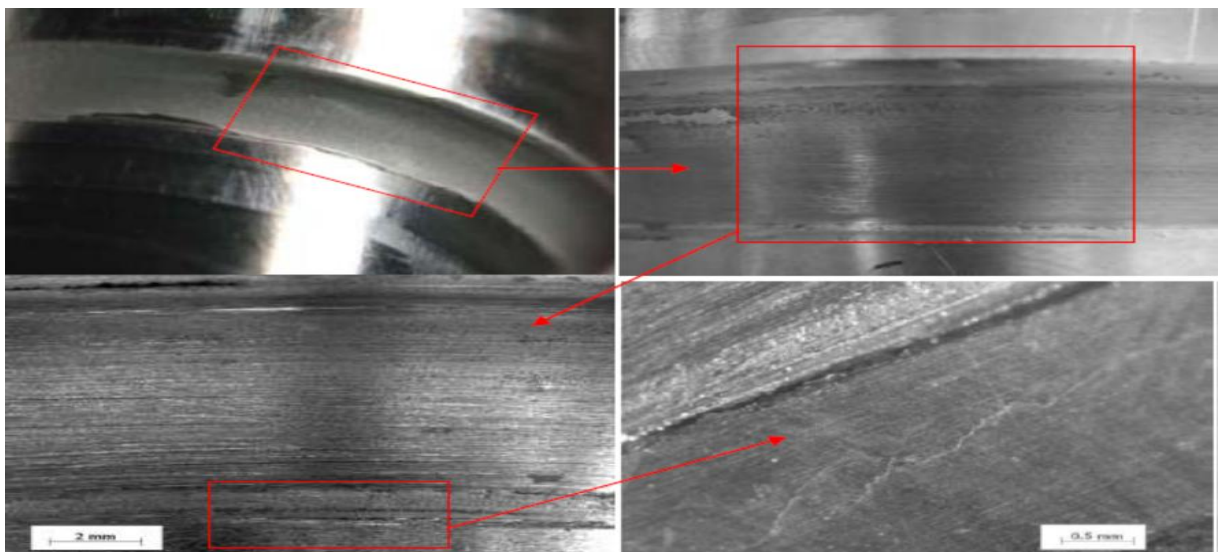


Figure 9 – Photographs. Surface of the pin D61000 MN 254, in the area of section transition, depicting the same position at which there was a fatigue-related rupture of the pin D 61000 E1 S/N 25. In the image detail, it is possible to see a rough machining aspect.

In metallographic examinations performed in the longitudinal section of the pin D61000 MN 254, in the same region where the fracture of the pin D61000 E1 SN 25 occurred, cracks were detected, associated with machining scratches, and also superficial overheating of the microstructure, probably due to the grinding process (Figures 10 and 11).

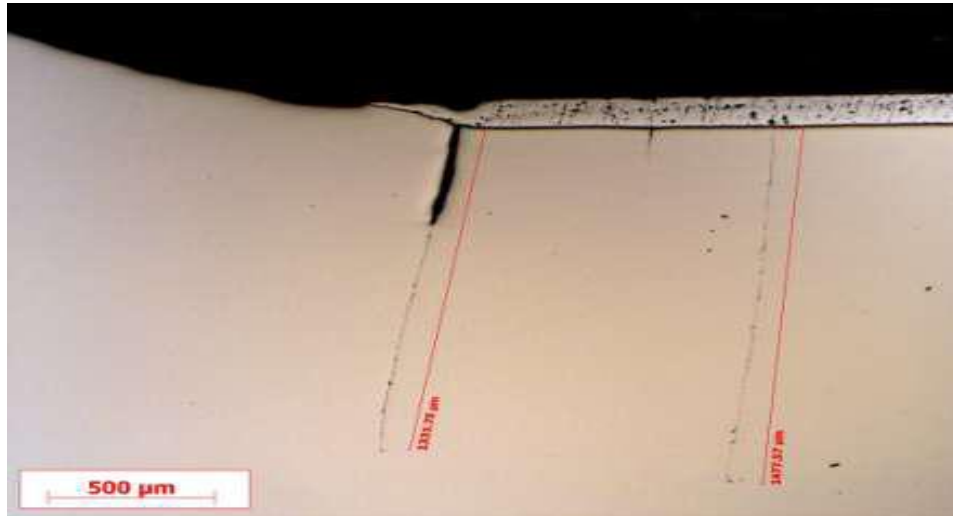


Figure 10 – Photomicrography. Region where the transition from shorter to longer diameter begins. It is possible to see two cracks with a depth of approximately 1.5mm, in addition to another smaller crack.



Figure 11 – Photomicrography. View of the section transversal to the crack, showing that the crack originated in a region that had sustained overheating.

During the work conducted at the DCTA, it was observed that, despite the different machining processes carried out in the section transition region of each pin, in both cases the coarse finish served as a facilitator for the initiation of the fatigue process in the pins. As for the pin E1 D61000 SN 25, the machining interference was more critical, because it altered the local geometry of the part significantly (Figure 12).



Figure 12 – Photomicrography. Comparison of the metallographic profiles between the pins D61000 MN 254 and D 61000 E1 SN 25, respectively, indicating that they were machined differently.

Based on the results obtained, it can be stated that the pin D61000 E1 SN 25 of the PR-TTI left main landing gear broke on account of fatigue, whose onset was facilitated by a machining process carried out in the section transition region of the pin.

As for the pin D61000 MN 254, installed in the aircraft PR-TTJ, it can be seen that it had similar defects in the machining process, leading to the hypothesis that the component would not probably reach the lifetime of 18,000 cycles related to the next overhaul.

According to the maintenance manual of the pin manufacturer (Messier-Dowty SA) D23191000, D23192000 COMPONENT MAINTENANCE MANUAL LEG STRUCTURE, 32-18-34, pages 698-2 and 698-3, dated 30 September 2010, there was not prescription of any type of machining in that region of the pins.

1.17 Organizational and management information

The *TRIP Linhas Aéreas* company had 42 aircraft in its operating specification, including the one involved in the accident. The company was in a phase of sound expansion, with a forecast increase in the number of aircraft, crews and bases. Its commercial structure had been recently transferred to São Paulo, but the Maintenance Center remained in Belo Horizonte.

As for the maintenance structure in each of its bases, the company had mechanics capable of making minor repairs.

In Belo Horizonte, the Maintenance Center had three hangars; however, according to the employees themselves, it was not meeting the work demand. Thus, some maintenance tasks were outsourced to other companies, as was the case of the overhaul of the defective landing gear.

1.18 Operational information

The determining and irreversible factor of the accident was the collapse of the LEFT MAIN LANDING GEAR ASSEMBLY (PN D23189000-19 and SN MN170), which failed with 5,130 cycles after the last overhaul.

The Maintenance Program Aircraft Model ATR72 Series, Rev. 2, dated 4 March 2008, of the *TRIP Linhas Aéreas* company, approved by the Civil Aviation Authority (SEGVOO 020/AER121/2008 number 111), established that the LEFT MAIN LANDING GEAR ASSEMBLY had to be overhauled every eight years or 18,000 cycles. It is a fact that the component failed with 12,870 cycles before the limit established for the next overhaul.

Based on this fact, the aircraft operator was requested to remove and send the items listed below for analysis of the failure by the DCTA - IAE - Materials Division.

- 01 *Side Brace* (PN D232119000-4, SN MN176) and integrated components.
- 01 *Barrel* (PN D60929-30, SN 101U408) and integrated components.
- 01 *Swinging Lever* (PN D60931-1, SN 042U391) and integrated components.

According to the results presented in the Failure Analysis Report No. 15-AMR/2011, a specific component of the assembly connecting the landing gear to the aircraft, the AFT PIVOT PIN D61000 SN 25 broke on account of fatigue, whose onset was facilitated by a machining process conducted in the pin section transition region.

After analysis of the CARD COMPONENT HISTORY LEFT MAIN LANDING GEAR ASSEMBLY (PN D23189000-19, SN MN170), it was found that the component had undergone two overhauls.

The first one was performed on 28 February 2001 at Aero Precision Repair & Overhaul, Inc. (APRO) - FAA NO. XPER689K and the Service Bulletin no. 631-32-125 was applied.

According to the records of the operator and maintainer of the aircraft at the time, both the Airworthiness Directive 2001-615-062 (B), issued by the Direction de L'Aviation Civile de France, dated 26 December 2001, and the Service Bulletin ATR 72-32-1042 were complied with.

On the occasion of the overhaul conducted at the APRO, the *AFT PIVOT PIN* (D61000 SN 25) was installed in the *RIGHT MAIN LANDING GEAR ASSEMBLY* (PN D23190000-19 and SN MN170), while the *AFT PIVOT PIN* (PN D61000 and SN MN254) was installed in the *LEFT MAIN LANDING GEAR ASSEMBLY* (PN D23189000-19 and SN MN170).

Such configuration was maintained until the subsequent overhaul, which was conducted at the premises of the *AV Indústria Aeronáutica Ltda.* (CHE 9507-02/ANAC) on 09 March 2009. In the process of completion of the overhaul, when the landing gear assembly was being reassembled, there was an inversion in the installation of the pins.

The *AFT PIVOT PIN* (PN D61000 and SN 25) was installed in the *LEFT MAIN LANDING GEAR ASSEMBLY* (PN D23189000-19 SN MN170); this configuration was observed, and maintained until the date of the accident.

According to the *COMPONENT HISTORY CARD*, the *LEFT MAIN LANDING GEAR ASSEMBLY* (PN D23189000-19 SN MN170) with 13,229 cycles since new, and the *AFT PIVOT PIN* (PN D61000 SN 25) with 3,786 cycles since new were installed in the PR-TTI aircraft on 13 March 2001.

Ratified by the Maintenance Program Aircraft Model ATR72 Series, Rev. 2, dated 04 March 2008, these landing gear assemblies installed in the PR-TTI aircraft were again removed on 27 February 2009 (removal tags 07898 and 000 689) and sent to be overhauled in the *AV Indústria Aeronáutica Ltda.* The *LEFT MAIN LANDING GEAR ASSEMBLY* had 31,684 cycles since new and 18,095 cycles since the last overhaul (i.e., 95 cycles in excess), according to the Aircraft Maintenance Program Model ATR72 Series, Rev. 2 04 / 03/2008, of the *TRIP Linhas Aéreas* company.

As for the cycles of the *AFT PIVOT PIN* (D61000 SN 25), it was not possible to confirm either the number of cycles since new or since the last overhaul, because the last official records dated back to the overhaul performed by APRO in the United States in 2001.

The *AV Indústria Aeronáutica Ltda.* company, in charge of conducting the second overhaul, had been certified to perform this type of inspection, as specified in the list attached to the Addendum, Revision no. 11, dated 05 January 2009, accepted by the ANAC Official Document No. 0173/2009-GGAC/SAR.

On 09 March 2009, the (left and right) legs of the PR-TTI main landing gear were received at *AV Indústria Aeronáutica Ltda.* in order to be overhauled, under the Service Order No. BHZ-000321/2009-0.

The *AV Indústria Aeronáutica Ltda.* disassembled the legs of the landing gear (service order records BHZ-000321/2009-0) and, on account of not possessing, at the time, technical qualification and/or the prescribed equipment for reconditioning the AFT PIVOT PIN), outsourced the execution of the tasks (which will be described later on in this report).

The following companies were subcontracted by *AV Indústria Aeronáutica Ltda.*:

- *Tecgal Indústria de Tratamento de Superfície* (surface treatment industry) – a company not certified by the Civil Aviation Authority.
- *Raeder Indústria e Comércio Ltda.* – a company not certified by the Civil Aviation Authority.
- *Focal Engenharia e Manutenção Ltda.* – a company certified by the Civil Aviation Authority (CHE 0712-03/ANAC).

Aiming to certify the quality of the services provided by the subcontractors, the *AV Indústria Aeronáutica Ltda.* conducted external audits of the three companies involved in the process, as established by the Inspection Procedures Manual (MPI) of the company, accepted by the Civil Aviation Authority, in accordance with the Official Document no. 1365/2009-GGAC/SAR. They audits were the following:

- External Audit N° AV/001/08, dated 11 November 2008, of the *Tecgal Indústria de Tratamento de Superfície Ltda.*
- External Audit N° AV/002/09, dated 02 April 2009, of the *Raeder Indústria e Comércio Ltda.*
- External Audit N° AV/001/09, dated 23 January 2009, of the *Focal Engenharia e Manutenção Ltda.*

The audits conducted by the *AV Indústria Aeronáutica Ltda.* did not identify that those companies did not possess qualified personnel, manuals and the machinery needed for the work with aeronautical products.

In relation to the operational information associated with the maintenance, with the process of aeronautical equipment reconditioning and with the failure of the component, only the inspection procedures related to the AFT PIVOT PIN (D61000 SN 25) will be dealt with.

The AFT PIVOT PIN (D61000 SN 25) belongs to the assembly which attaches the landing gear to the aircraft structure. For this item, there are specific procedures concerning its cleaning, dimensional inspection, detection of cracks, treatment against corrosion and reconditioning.

All the tasks are formalized and standardized in the manufacturer's manuals below:

- 32-09-01 - *STANDARD REPAIR PRATICES* – section 1 to 72 (*COMPONENT MAINTENANCE MANUAL*) - Messier – Bugatti.
- 32-18-33 - *LEG ASSEMBLY* - Messier-Dowty SA.

- 32-18-34 - *LEG STRUCTURE* - Messier-Dowty SA.

The inspection stages prescribed in the aforementioned manuals are shown below:

Stage 1:

Application of the procedures established in the 32-18-34 - *LEG STRUCTURE* - Messier-Dowty SA:

- *Removal of pin* (page 304)
- *General check* (page 501) – in which the dimensional examination of the item is performed, according to the section *FITS AND CLEARANCES* (page 801)
- *Special check* (page 502) – which establishes the execution of scouring, removal of bushings, *Stress Relief* and *Magnetic Particle Inspection*.

These procedures were performed by *AV Indústria Aeronáutica Ltda.*, and, considering that the results obtained in these inspections were compatible with the limitations imposed by the manufacturer, a decision was made to recondition the item - Chromium Plating Process Type III – a procedure contained in the manual 32-18-34 - *LEG STRUCTURE* - Messier-Dowty SA (pages 698-2 and 698-3).

Stage 2 (Reconditioning of the item):

In this stage of the process, the *AV Indústria Aeronáutica Ltda.* subcontracted a number of services for which it did not possess qualified personnel and/or appropriate equipment.

The application of the procedures established in the 32-09-01 - *STANDARD REPAIR PRACTICES - section 2 (COMPONENT MAINTENANCE MANUAL)* - Messier – Bugatti was performed as shown below:

- *Preliminary operations* (page 5) – mandatory service – performed by *AV Indústria Aeronáutica LTDA.*
- *Chromium stripping* (page 6) – mandatory service – performed by *Tecgal Indústria de Tratamento de Superfície.*
- *Embrittlement relief after chromium stripping* (page 7) – mandatory service – it was not possible to confirm whether or not it had been performed.
- *Machining – grinding* (page 8) – service not mandatory, to be performed according to necessity – not done in the item under investigation.
- *Corrosion removal* (page 8) – service not mandatory, to be performed according to necessity – done by *Tecgal Indústria de Tratamento de Superfície.*
- *Grinding defect detection* (page 9) – mandatory service, not performed on the item under investigation.
- *Stress relief, embrittlement relief and stoving operations* (page 9) – mandatory service – performed by *Tecgal Indústria de Tratamento de Superfície.*
- *Magnetic particle inspection* (page 10) – mandatory service – performed by *Focal Engenharia e Manutenção Ltda.*
- *Shotpeening* (page 10) – mandatory service – performed by *Focal Engenharia e Manutenção Ltda.*
- *Gritblasting* (page 11) – service not mandatory, to be performed according to necessity – done by *Focal Engenharia e Manutenção Ltda.*

- *Chromium plating* (page 11) – mandatory service – performed by *Tecgal Indústria de Tratamento de Superfície*.
- *Embrittlement relief baking after chromium plating* (page 19) – mandatory service – performed by *Tecgal Indústria de Tratamento de Superfície*.
- *Grinding of chromium* (page 20) – mandatory service – performed by *Raeder Indústria e Comércio Ltda.*
- *Fluorescent penetrating inspection* (page 22) – mandatory service – performed by *AV Indústria Aeronáutica LTDA.*
- *Stress relief treatment* (page 23) – mandatory service – performed by *AV Indústria Aeronáutica Ltda.*
- *Polishing – Smoothing* (page 24) – service not mandatory, to be performed according to necessity – not performed on the item under investigation.
- *Inspection* (page 24) – mandatory service – performed by *AV Indústria Aeronáutica Ltda.*

As for the service order BHZ-000321/2009-0, it was not possible to determine the time line and the sequence of the process stages described above.

The failure-analysis report issued by the DCTA reads: "Based on the results obtained, it can be said that the pin (D 61000 E1 SN 25) of the PR-TTI aircraft left main landing gear broke on account of fatigue, whose onset was facilitated by a machining process conducted in the section transition region of the pin. In the pin D61000 E1 SN 25, the machining intervention significantly altered the local geometry of the part, which served as a facilitator for the onset of the fatigue process in the pin. "

According to the pin maintenance manual (Messier-Dowty SA, COMPONENT MAINTENANCE MANUAL LEG STRUCTURE, 32-18-34, pages 698-2 and 698-3, dated 30 September 2010), no machining was expected to be carried out in this region of the pins.

In only one stage of the reconditioning process of the pin in question, is it possible to see that a machining task had been performed, i.e., Grinding of chromium (page 20) - performed by the *Raeder Indústria e Comércio Ltda.* company.

Although the *AV Indústria Aeronáutica Ltda.* possesses a structured technical library with up-to-date manuals for the referred inspection, the company made up a summary list of the tasks mentioned above, and had it translated into Portuguese by an unofficial translator. In the list, each stage of the process was described, and the respective source is cited for purposes of contingent consultation.

During the process of investigation, there were visits of the following companies:

- *TRIP Linhas Aéreas – Manutenção Belo Horizonte.*
- *AV Indústria Aeronáutica Ltda.*
- *Tecgal Indústria de Tratamento de Superfície.*
- *RAEDER Indústria e Comércio Ltda.*

In these visits, it was possible to observe that the subcontractors (*Tecgal Indústria de Tratamento de Superfície* and *Raeder Indústria e Comércio Ltda.*) performed the services without the presence of a professional of the contracting company, and without adequate consultation of the instructions contained in the manufacturer's manuals. They just followed the simplified instructions of the summary list translated into Portuguese and

issued by the *AV Indústria Aeronáutica Ltda.* company. As for the subcontractors, it was found that they had neither a technical library, nor professionals qualified for performing services on aeronautical items and analyzing pertinent technical aeronautical publications.

1.19 Additional information

The Brazilian Code of Aeronautics establishes the following:

Art. 66: It is the duty of the aeronautical authority to promote flight safety, and set the minimum safety-standards:

I – relative to design, materials, labor, construction and performance of aircraft, engines, propellers and other aeronautical components; and

II – relative to inspection, maintenance at all levels, repair and operation of aircraft, engines, propellers and other aircraft components.

§ 1° The minimum standards shall be established in the Brazilian Aeronautical Homologation Regulations, and shall be effective from the date of publication.

§ 2° Standards may vary on account of the type and purpose of the product.

Art. 70. The aeronautical authority shall issue homologation certificates to the companies dealing with overhaul, repair and maintenance of aircraft, engines, propellers and other aeronautical products.

§ 2° Every aircraft operator shall perform or make perform the maintenance of aircraft, engines, propellers and other components **in order to preserve the safety conditions of the approved design.**

The RBHA 43 reads:

Item 43.2 – OVERHAUL AND RECONDITIONING REGISTER

[...] no-one is allowed to certify that an airframe, engine, propeller, rotor, equipment or component part has been reconditioned or repaired, unless it has been disassembled, cleaned, inspected, repaired as needed, reassembled and tested for the same tolerances and limits...

Item 43.3 – PERSONS AUTHORIZED TO PERFORM MAINTENANCE, PREVENTATIVE MAINTENANCE, RECONDITIONING, MODIFICATIONS AND REPAIRS

[...] a person working under the supervision of an aircraft maintenance mechanic is allowed to perform services of maintenance, preventative maintenance, repairs and alterations for which his or her supervisor is authorized by the aeronautical authority, since the supervisor in person monitors the execution of the work to the extent required, to ensure that it is being done properly, and remains readily available, in person, to answer queries from the individual doing the service.

Item 43.13 IMPLEMENTATION RULES (GENERAL)

[...] every person performing maintenance, preventative maintenance, alterations or repair to an aircraft, airframe, engine, propeller, equipment or component part must: - use methods, techniques and practices established in airworthiness directives of the latest revision of the manufacturer's maintenance manual or in the instructions for continued airworthiness prepared by the manufacturer; - use other acceptable methods, techniques, and practices.

[...] one must use the tools, equipment and test devices necessary to ensure the implementation of the work in accordance with generally accepted industry practices. If the

manufacturer involved recommends special equipment and test devices, the person must use such equipment and devices or approved equivalents.

[...] every person doing a service of maintenance, modification, repair and preventative maintenance must perform this work in such a manner and use materials of such quality that the conditions of the aircraft, airframe, propeller, or equipment worked on stay at least equal to the original condition or be appropriately modified (with respect to the aerodynamic function, structural strength, resistance to vibration and deterioration, and other qualities affecting airworthiness).

The RBHA 145 reads:

Item 145.45 – INSPECTING SYSTEMS

[...] the applicant for a company homologation certificate or an addendum thereto, must possess an inspection system capable of producing a satisfactory control of quality, and of meeting the requirements [...]

[...] the applicant's inspection personnel must be thoroughly familiar with the methods, techniques and inspection equipment to be used in their specialty to determine the quality or airworthiness of the product being maintained, modified or repaired. In addition they must [...]

[...] possess and understand information relative to airworthiness and current specifications involving tolerances, limitations and inspecting procedures established by the manufacturer of the product being inspected and by the aeronautical authority; and

Item 145.51 – PREROGATIVES OF THE COMPANY HOMOLOGATION CERTIFICATE

[...] do maintenance, make alterations or repairs, in a location outside the workshop, of any items for which the company has been homologated, provided that:

- (1) The work is done in the same manner it would in the workshop;
- (2) All necessary personnel, equipment, materials and technical information are made available at the location where the work will be done; and
- (3) The inspecting procedures manual of the company establishes the approved procedures, disciplining the work to be done in places other than the workshop.

The RBHA 121 reads:

Item 121.363 – RESPONSIBILITY FOR AIRWORTHINESS

(a) Each certificate holder is primarily responsible for:

(1) The airworthiness of the aircraft fleet, including airframes, engines, propellers, equipment and parts thereof; and

(2) Implementation of maintenance, preventative maintenance, alterations and repairs in the aircraft, including airframes, engines, propellers, routine/emergency equipment and respective components, in accordance with its manual and the rules of the RBAC.

(b) A certificate holder may hire another person to perform any maintenance, preventative maintenance, repair, or alteration service. However, this does not relieve the certificate holder of the responsibility specified in the paragraph (a) of this section.

Item 121.367 – PROGRAMS OF MAINTENANCE, PREVENTATIVE MAINTENANCE, ALTERATIONS AND REPAIRS

Every certificate holder must establish an inspecting program and, also, a program encompassing maintenance, preventative maintenance, modifications and repairs, capable of assuring that:

(a) The maintenance, preventative maintenance, modifications and repairs that are performed either by certified individuals or other persons is undertaken in accordance with the prescriptions contained in the manual;

(b) There is availability of qualified personnel, in addition to adequate facilities and equipment for the proper implementation of the services; and

(c) Every airplane released for flight is airworthy and has been provided with proper maintenance under this regulation.

Item 121.373 – CONTINUED MONITORING AND ANALYSIS

(a) Every certificate holder shall establish and maintain a system of continued monitoring and analysis of the implementation and effectiveness of their programs, inspections and maintenance, preventative maintenance, alterations and repairs, in order to correct discrepancies or deficiencies in these programs. Such system must monitor the implementation of all the work in progress, whether executed by the very certificate holder, or by an external contractor.

Item 121.375 – MAINTENANCE AND PREVENTATIVE MAINTENANCE TRAINING PROGRAM

Every certificate holder, or person performing maintenance or preventative maintenance for the certificate holder, shall establish a training program to ensure that every one (including compulsory inspections' personnel) in charge of determining the adequacy of the work done is fully informed about procedures, techniques and new equipment in use, and is competent to perform their duties.

Item 121.378 – PERSONNEL QUALIFICATION REQUIREMENTS

[...] Every person directly responsible for services of maintenance, preventative maintenance, alterations and repairs, and every person performing compulsory inspections must hold a qualification or registration certificate issued by the ANAC.

The *TRIP Linhas Aéreas* Inspection Procedures Manual, accepted by the Civil Aviation Authority, reads:

Section I – Facilities

[...] *TRIP Linhas Aéreas SA* undertakes to provide appropriate facilities for the implementation of the proper maintenance allowed by regulations. It is the responsibility of the Technical Coordinator to identify existing needs in this regard, and submit requests for supply of resources to the General Management.

Section IV – Duties and Responsibilities

Item 2.1 - President

The President is also responsible:

[...] for providing the resources necessary for appropriate training, and availability of the facilities, equipment, materials and personnel competent regarding the execution of the *TRIP Linhas Aéreas* maintenance service, so that the company can meet all the applicable RBHA's requirements , manufacturers' maintenance plans [...];

[...] for stimulating and encouraging the continuous improvement of the technical and safety levels of the *TRIP Linhas Aéreas* Maintenance;

Item 2.2 – Technical Coordinator (RPQS)

[...] The Technical Coordinator (RPQS) is responsible for the management of the implementation and quality of the maintenance, for the handling and technical control of aircraft equipment, and for the flight safety aspects related to maintenance, technical control and maintenance for safety of flight related to the maintenance activity, in order to guarantee that they have proper operational functioning.

[...] The Technical Coordinator is also responsible for directing, planning and designing details and standards, methods and procedures concerning maintenance, preventative maintenance, alterations and repairs used by *TRIP Linhas Aéreas*, aiming to meet the RBHA's requirements and the manufacturers' specifications and recommendations.

[...] the Technical Coordinator's duties are [...] to supervise the maintenance performed, as a prerogative of the *TRIP Linhas Aéreas'* CHE;

[...] to determine that neither defective nor unairworthy parts be installed in any component released for return to service;

[...] The Technical Coordinator may delegate its duties fully or partially to one or more certified and qualified individuals, if necessary, but such delegation does not relieve him/her from the overall responsibility for the maintenance and airworthiness of aircraft being serviced by the *TRIP Linhas Aéreas* company.

Item 2.3 – Quality Manager

It is the Quality Manager's duty:

[...] to ensure that neither defective nor unairworthy parts be installed in any of the components or items released by the company;

Item 2.4 – Hangar Manager

Hangar Manager's duties:

[...] to determine that neither defective or unairworthy parts are installed in any component or items released by the company;

[...] to plan the sequence and employment of the labor available, and identify the needs for expansion of the subordinate staff board, in accordance with the service levels envisaged by the *TRIP Linhas Aéreas* Management;

Item 2.6 – Inspectors

The Maintenance Inspectors are responsible before the Company's Quality Manager for the supervision of all inspections performed on aircraft in terms of quality, compliance with Flight Safety rules and this MPI. These are the Maintenance Inspectors' duties:

[...] to ensure that all inspections are properly conducted and that all finished services have their respective records entered before the aircraft is released for flight;

[...] to ensure that neither defective nor unairworthy items be installed in any component or in the aircraft;

[...] to verify that no uncertified/qualified technician is involved in maintenance (this phrase was copied from the *TRIP Linhas Aéreas MPI – the original text contained some incongruity*);

[...] responsible for the direction, planning and design of details of the standards, methods and inspection procedures used by the company, aiming to meet the applicable requirements of the RBHA/RBAC and of the manufacturers' specifications and recommendations.

Section V – Inspection System

Item 36 – Quality Audits

[...] *TRIP Linhas Aéreas* strives to improve its practices and procedures in a continuous manner, and understands that audits serve as an important tool for this purpose.

During a given audit, when an irregularity is detected, it generates an RNC (Non Conformity Report), which will become the primary document for the implementation of the necessary correction, with a deadline for compliance. After the audit is completed, a summary of the non-compliances found is issued and, with all this information, one seeks to pinpoint what caused the irregularities (lack of knowledge, lack of control, etc. ...) in order to solve them, preventing the same problem from happening again.

External audits are performed at least annually or in the event of occurrence of any abnormality, relevant deviation, according to the judgment of the Technical Coordinator of the Group of Dependability, or use of the services provided by a new homologated workshop.

Item 40 – SUBCONTRACTED MAINTENANCE

The Technical Coordinator, or his/her properly trained and qualified delegate, has the competence to receive the products under the custody of the Company Maintenance, in addition to the records of any maintenance services performed by external parties.

[...] The Technical Coordinator shall always seek to assess the quality of the services performed by third parties, in order to guarantee that they meet the required quality levels [...] if, during or after any service performed by third parties, a situation is found that jeopardizes the airworthiness status, it is the duty of the Technical Coordinator to evaluate the corrective actions required, and make provisions for their implementation.

[...] Upon completion of the inspection of the item received, the material shall be labeled, stored or forwarded to the maintenance sector. NB: Under no circumstances is the Technical Supply Section allowed to release a part made or repaired by third parties, without previous approval granted by the Quality Supervisor, or person authorized by him/her, concerning the availability of the item [...] the Quality Supervisor is the one responsible for inspecting such material coming from third parties;

The *AV Indústria Aeronáutica's* Inspection Procedures Manual (MPI), accepted by the Civil Aviation Authority, reads:

Section II – COMPANY ORGANIZATION

Item II-3-1-1 – Required Qualifications

The Technical Manager (Responsible for the Quality of Service) [...] has the final responsibility in relation to all the services provided by the Company.

No item II-4 – DUTIES AND RESPONSIBILITIES

II.4.1 - Chief Executive Officer [...] these responsibilities include the supervision and monitoring of technical and administrative sectors, including inspection and execution personnel involved with maintenance, modification and repair of components, equipment, tools and accessories for accomplishment of tasks and staff training;

[...] to establish guidelines to be adopted in their area of responsibility, in accordance with the regulations in force;

II.4.2 – The Technical Manager (RPQS) - is responsible, before the Chief Executive Officer, for the technical issues related to the execution of maintenance, preventative maintenance, alteration and repair of components, and has the final authority in matters related to Return-to-Service (APRS) approval, ensuring that all procedures in the MPI and the legislation in force are known to and complied with by all personnel involved with the maintenance of components, and he/she is also responsible for defining the methods and inspection procedures used by the Company.

The Technical Manager (RPQS) is also responsible for:

[...] ensuring that all maintenance work on components is done within the technical standards and procedures approved, in accordance with the manufacturer's specifications;

[...] ensuring that the work of subcontractors is done in accordance with the existing requirements, especially the regulations governing the homologation 145;

II.4.3 – The Chief Inspector is responsible for:

[...] ensuring that defective, non-repairable and unairworthy parts be not installed in any components or items released by the Company;

[...] ensuring that the work of subcontractors is done in accordance with the existing requirements, especially the regulations governing the homologation 145;

[...] ensuring that all the work accomplished be appropriately inspected so that the Return-to-Service Approval can be granted, and, also, ensuring that maintenance and inspection records have been duly entered;

[...] inspecting all work requiring specialized mechanics [...];

II.4.5 – The Aeronautical Inspector is responsible for:

[...] attesting and guaranteeing the service approval conditions in accordance with the pertinent requirements and aeronautical publications in force;

[...] ensuring that defective, non-repairable and unairworthy parts be not installed in any component or item released by the Company;

Section IV – INSPECTION SYSTEMS

Item IV-1 – OBJECTIVE

[...] This section presents the Inspection System of the *AV Indústria Aeronáutica Ltda.*, and the way it is structured to adequately meet the requirements of the applicable legislation, describing its organization, form of action and maintenance/inspection policies related to maintenance, alteration and repair of aeronautical components and/or accessories.

[...] the inspector shall monitor the prescribed maintenance services, performing inspections for either hidden or progressive failures, as applicable;

Section V – COMPLEMENTARY SYSTEMS

Item V-2 – QUALITY AUDITS

The duty of the Quality Audit is to ensure that the *AV Indústria Aeronáutica Ltda.*'s MPI is followed in all locations where maintenance services are performed.

The Quality Audit is based on comprehensive records and controls existing in the Maintenance Records Section, in which all the maintenance information is made available. At least once a year, the Technical Manager (RPQS) (or person/staff designated by him), performs internal audits of the workshops, in accordance with the procedures described in the Audit Program.

Item V-6 – CONTRACTED MAINTENANCE

Any work performed by an organization not homologated by the Aviation Authority shall be inspected by the Technical Manager (RPQS), or other person designated by him, as to the conformance of the execution of the service to the approved standards and procedures, as well as to the origin, condition and documentation of the material applied, among others.

All the material serviced by contractors will be kept segregated in stock until being inspected for application.

Item V-6 – SUBCONTRACTED MAINTENANCE

Any work done by a company homologated by the Aeronautical Authority, and outsourced by *AV Indústria Aeronáutica Ltda.* to conduct maintenance on equipment and components, must meet the quality standards and be in accordance with good maintenance practices.

The subcontracted services will be inspected by the Technical Manager (RPQS) or by another person designated by him/her, to ensure that the requirements of this manual have been carefully met.

1.20 Utilization of other investigation techniques

Nil.

2 ANALYSIS

Accidents occur mostly when latent conditions turn into active failures.

Active failures, such as actions (including errors and violations), have immediate (or almost immediate) consequences. Active failures are directly related to latent conditions, which are defined as conditions present in a system well before the accident, and that become apparent after the occurrence.

The consequences of latent conditions can remain dormant for a long time, considering that such conditions are neither regarded as dangerous nor as failures. The latent conditions are usually caused, triggered or permitted at the management level of an organization. Examples of latent conditions are: internal communication problems, passive acceptance of the non-utilization of manuals, and non-observance of rules and regulations. With this in mind, the analysis of the data relative to the PR-TTI accident aircraft is as follows:

During the PR-TTI landing roll, the left main landing gear collapsed, as a result of the fracture of the AFT PIVOT PIN (D61000 SN 25). According to the aircraft manual, the entire landing gear must be overhauled after every eight-year period or 18,000 cycles.

The *TRIP Linhas Aéreas* company sent this assembly to be overhauled at the *AV Indústria Aeronáutica Ltda.* on 27 February 2009, with 18,095 cycles (an excess of 95 cycles in relation to the manual, although this fact did not contribute to the accident).

The *AV Indústria Aeronáutica Ltda.* outsourced some of the services, on account of not possessing technical capability and suitable machinery for the tasks of reconditioning the AFT PIVOT PIN (D61000 E1 SN 25). The following companies were subcontracted:

- *Tecgal Indústria de Tratamento de Superfície* – a company not homologated by the Civil Aviation Authority;
- *RAEDER Indústria e Comércio Ltda.* – a company not homologated by the Civil Aviation Authority; and
- *Focal Engenharia e Manutenção Ltda.* – a company homologated by the Civil Aviation Authority (CHE 0712-03/ANAC).

The RBHA145 establishes parameters to be observed by a CHE holder for maintenance, modification or repair of aeronautical equipment at a location outside the workshop. Among them is the company's Inspection Procedures Manual (MPI), which must establish procedures and discipline the work to be done in other places rather than in the workshop.

The *AV Indústria Aeronáutica Ltda.*'s MPI, accepted by the Civil Aviation Authority, prescribed that any work done by an organization not homologated by the Civil Aviation Authority had to be inspected by the Technical Manager (RPQS) or another person designated by him/her, as to the adequacy of the implementation of the service to the standards and approved procedures, to the origin, condition and documentation of the material applied, among others. In summary, it was possible to outsource the services under the Technical Manager's due supervision.

The *AV Indústria Aeronáutica Ltda.* company had a structured technical library with all the necessary up-to-date manuals for the inspection in question. Nevertheless, the company chose to prepare a Portuguese translation of the list of the tasks prescribed in the manufacturers' manuals, which were originally written in English.

Not all tasks were accurately translated and, particularly, did not address important information that could jeopardize flight safety if not complied with, for example, information on the process of machining of the pin in question.

During the investigation, it was found that, despite being a workshop structured to perform machining services and other types of repairs, the *Raeder* company neither possessed nor made use of the aircraft manuals when doing the services discussed in this report. Thus, it failed to comply with the established parameters and limits when machining the AFT PIVOT PIN (D61000 E1 SN 25) (latent condition).

According to the Messier-Dowty SA's pin maintenance manual D23191000, D23192000 COMPONENT MAINTENANCE STRUCTURE MANUAL LEG, 32-18-34, pages 698-2 and 698-3, dated 30 September 2010, there was no plan for any type of machining in the pin section transition region. The resulting inadequate machining finish in the region served as a facilitator for the onset of the fatigue process in the pins (active failure).

The inspection tasks were carried out at *TECGAL* in the same way as at *RAEDER*, i.e., using only the translated list provided by *AV Indústria Aeronáutica Ltda.* (latent condition).

The investigation also identified that, since it was not common for the TEGAL to work with aeronautical products, one of its professionals referred to the list provided by *AV Indústria Aeronáutica Ltda.* and produced another list to facilitate and further simplify the understanding of the inspection tasks. In other words, the professionals responsible for the inspection tasks utilized a simplified version that was based on the translated list of the *AV Indústria Aeronáutica Ltda.* (latent condition).

Despite the prescriptions contained in the MPI of the *AV Indústria Aeronáutica Ltda.*'s MPI, there was no participation and/or supervision by any of its professionals. This fact, besides going against RBHA 43, item 43.3 in, against RBHA145, item 145.5, and against the company's own MPI, item II-4, jeopardized the safety of the flight (latent condition).

Also according to the MPI of the *AV Indústria Aeronáutica Ltda.*, item V-2, quality audits were to be conducted annually, under the supervision of the RPQS, in order to ensure that the MPI was faithfully complied with.

The outsourced companies were audited by *AV Indústria Aeronáutica Ltda.*, but the audits did not include important points for the prevention of accidents, such as: the relationship between the services to be contracted and the need for aircraft manuals; the interpretation of the technical English language by professionals of those companies; and the technical capability, involving labor and equipment to perform the services requested. It was evident that these audits were not conducted in thorough manner, something that directly jeopardized the safety of the flight (latent condition).

Also in accordance with RBHA 43, item 43.13, professionals performing maintenance services must use methods, techniques and practices that ensure continued airworthiness. According to the RBHA 145, item 145.45, the CHE holder must possess an inspection system capable of ensuring a satisfactory control of quality, and meet a series of requirements, all of which related to the keeping of a safety minimum standard.

In the case of the outsourced companies, the required methods, techniques and parameters were not observed for the reasons previously commented, namely: lack of manuals, as well as lack of skill and knowledge in relation to the characteristics of the maintenance of certified aeronautical products (latent condition).

It was also observed that, at the time of the accident, the *AV Indústria Aeronáutica Ltda.* did not possess an inspection system capable of ensuring the quality of the service under its responsibility, especially when these services were outsourced (latent condition).

The MPI of *TRIP Linhas Aéreas*, accepted by the Civil Aviation Authority, prescribed external audits as a way to improve its routines and procedures when using the services of an homologated workshop. During the process of investigation, it was found that the *AV Indústria Aeronáutica Ltda.* had been audited by *TRIP Linhas Aéreas* on 17 July 2008, but the aim of the audit was to investigate the "cause" of a component-related aircraft incident that had occurred at that time.

This above mentioned audit never attempted to identify whether the company needed to outsource some of its services, especially those related to the overhaul of the *LEFT MAIN LANDING GEAR ASSEMBLY*. During this audit, nobody found that the supervision processes of the *AV Indústria Aeronáutica Ltda.* were limited for the task, and that when the services were outsourced to the *AV Indústria Aeronáutica Ltda.*, the pertinent legislation in force was not taken into consideration, something that, among other consequences, allowed those companies not to use the aeronautical component manufacturer's manuals for performing the maintenance services (latent condition).

Still according to the MPI of *TRIP Linhas Aéreas*, the maintenance supervision was the Technical Coordinator's responsibility, as a prerogative of the company's CHE. This manual also reads that he had general responsibility over the maintenance and airworthiness of the *TRIP Linhas Aéreas* aircraft fleet. In the case of the outsourced maintenance, the Technical Coordinator had responsibility for the assessment of the quality of the outsourced services (latent condition).

The MPI of *TRIP Linhas Aéreas* also read that the Quality Manager, the Hangar Manager and the Inspectors were responsible for ensuring that no unairworthy parts could be installed in aircraft belonging to the company's operating specifications. The Inspectors also had the following duties: supervise the aircraft inspections being conducted, for compliance with the flight safety norms (Civil Aviation Authority Regulations included), and verify that no technician lacking qualification or training participated in the activities of maintenance of the company aircraft fleet.

Considering the failures that occurred during the services performed by *Raeder and TECGAL*, it was found that several topics listed in the MPI's of *TRIP Linhas Aéreas*, relative to supervision activities performed by the different *actors* of the company aimed at ensuring a minimum level of safety, were no longer complied with, with a resulting increased risk of aircraft accidents (latent condition).

TRIP Linhas Aéreas outsourced an aircraft maintenance company to perform services for which it (*Trip Linhas Aéreas*) had no equipment and/or trained personnel. However, this fact, in accordance with the RBAC 121, would not relieve the company from its responsibility for the airworthiness of the aircraft fleet.

This same regulation determines that certificate holders must have inspection programs to ensure that repairs performed by third parties are conducted in accordance with the aircraft manuals. Still in accordance with the RBAC 121, *TRIP Linhas Aéreas* had to have a continuous monitoring and analysis system, allowing to correct discrepancies or deficiencies in their inspection and maintenance programs. Such a system aimed at monitoring the implementation of all the work in progress, even those under external contract.

The last point* in the chain of events leading to the accident (*active failure) was the nonuse of the manufacturer's manuals in some stages of the overhaul of the LEFT MAIN LANDING GEAR ASSEMBLY (PN D23189000-19 SN MN170), in particular in the services performed in the AFT PIVOT PIN (D 61000 E1 SN 25). However, before this active failure, a series of actions had functioned as latent conditions.

Still in relation to *TRIP Linhas Aéreas*, the lack of a proper maintenance process of the aircraft flight data recorder (FDR) could have hindered the investigation if the accident had reached catastrophic proportions.

Complying with the legislation in force, the Civil Aviation Authority supervised (and inspected) the companies directly involved in the accident. Nevertheless, relatively to the legislation in force, it found no conducts and processes that could have, unnecessarily, increased the chain of latent conditions with a potential to lead to the aeronautical accident.

Summing up what has been discussed so far, it can be seen that some of the maintenance services were performed by subcontractors, which were audited by the Civil Aviation Authority and the very *TRIP Linhas Aéreas*, by means its Sector of Quality. The landing gear was one of the items that underwent maintenance by a subcontractor. The company that performed the service in the accident aircraft, although homologated by the Civil Aviation Authority, did not possess technical capability to carry out all the phases of the

landing gear overhaul service, and this led it to subcontracting other ones. The conclusion is that the maintenance work was not done properly, definitely contributing to the aeronautical accident.

3 CONCLUSIONS

3.1 Facts

- a) The pilots had valid medical certificates;
- b) The pilots had valid technical qualification licenses and certificates;
- c) The pilots were qualified and had enough experience for the flight;
- d) The aircraft documentation was valid;
- e) The aircraft departed from SBBE on an IFR flight plan, destined for SBHT;
- f) The approach to Altamira aerodrome was visual and stabilized. The touchdown was smooth, with gradual deceleration;
- g) After the 70kt "callout", a loud noise was heard, and left main landing gear collapsed, causing the aircraft to veer off to the left.
- h) The aircraft veered off the runway and came to a stop to the left side of the runway, sustaining serious damage to its left main landing gear, left propeller and left engine;
- i) The LEFT MAIN LANDING GEAR ASSEMBLY (PN D23189000-19 and SN MN170) collapsed, failing with 5,130 cycles after the last overhaul.
- j) A specific component (pin) of the assembly connecting the landing gear to the airframe, the AFT PIVOT PIN (P / N D61000, S / N 25), broke on account of fatigue, whose onset was facilitated by a machining process carried out in the pin section transition region.
- k) The ANAC-approved ATR72 Series Aircraft Maintenance Program of the *TRIP Linhas Aéreas* company read that the LEFT MAIN LANDING GEAR ASSEMBLY had to undergo overhaul every eight years or 18,000 cycles.
- l) On 27 February 2009, the PR-TTI landing gear was removed and, on 09 March 2009, was sent to be overhauled by the *AV Indústria Aeronáutica Ltda.* It had 31,684 cycles since new and 18,095 cycles since the last overhaul.
- m) *AV Indústria Aeronáutica Ltda.* was homologated for conducting such inspection, as specified in the List attached to the Addendum, Revision no. 11, dated 05 January 2009, and accepted by means of the Official Document no. 0173/2009-GGAC/SAR, issued by the Civil Aviation Authority.
- n) The *AV Indústria Aeronáutica Ltda.* company disassembled the legs of the landing gear, and outsourced some of the tasks for not possessing technical knowledge and/or appropriate machinery (necessary for the process of reconditioning the AFT PIVOT PIN (D61000 SN 25).
- o) Two of the three companies outsourced by *AV Indústria Aeronáutica Ltda.* were not homologated by the Civil Aviation Authority.
- p) The *AV Indústria Aeronáutica Ltda.* company conducted external audits of the three companies involved in the overhaul.

q) The audits carried out by *AV Indústria Aeronáutica Ltda.* were not sufficient to identify that the contractors lacked qualified personnel, manuals and the machinery necessary to work with aeronautical products.

r) The *AV Indústria Aeronáutica Ltda.* Technical Manager did not supervise the overhaul inspections and services performed by the contracted companies.

s) The AFT PIVOT PIN (D61000 SN 25) is part of the assembly that connects the landing gear to the airframe.

t) All revision tasks were described in the manuals of the manufacturer.

u) The AFT PIVOT PIN (D61000 SN 25) failure-analysis report stated that the PR-TTI aircraft left main landing gear collapsed on account of fatigue, whose onset was facilitated by a machining process carried out in the section transition region of the pin.

v) The manufacturer's maintenance manual did not refer to any machining work in that region of the pin.

x) In only one stage of the pin reconditioning process was it possible to observe that a machining task was required, namely, the *Grinding of chromium*.

z) The aircraft sustained serious damage to the main landing gear, hydraulic system, engine number 1 propeller, engine number 1, as well as minor damage to the fuselage and wing, all of which on the left side.

aa) All occupants of the aircraft got out unharmed, except for a passenger who suffered minor injuries.

3.2 Contributing factors

3.2.1 Human Factor

3.2.1.1 Medical aspect

Nil.

3.2.1.2 Psychological aspect

Nil.

3.2.1.2.2 Psychosocial information

Nil.

3.2.1.2.3 Organizational information

a) Capacitation – a contributor

The lack of capacitation and training of the subcontractors' professionals for handling aircraft material hindered the execution of an efficient maintenance work as prescribed by the manufacturer's manual, culminating in inadequate machining during the maintenance process.

b) Organizational Processes – a contributor

The lack of an effective process of supervision, both on the part of *TRIP Linhas Aéreas* and on the part of the other contractors and subcontractors allowed the existing maintenance services' latent failures not to be checked and corrected, in a way capable of subsidizing, in an adequate and safe manner, the execution of the landing gear maintenance service.

The process of supervision of the *TRIP Linhas Aéreas* and the *AV Indústria Aeronáutica Ltda.* companies by the Civil Aviation Authority, prescribed by specific legislation in force, was not enough to mitigate the latent conditions present in the accident in question.

3.2.2 Operational Factor

3.2.2.1 Concerning the operation of the aircraft

a) Aircraft maintenance – a contributor

According to the technical opinion issued by the DCTA, the *AFT PIVOT PIN* (D61000 and SN 25) presented fracture surfaces with $\pm 45^\circ$ inclination, as well as a flat area with multiple initiations, indicative of a fracture mechanism related to fatigue.

In examinations of the external surface of the pin, in a region close to the fatigue fracture, cracks were observed that had initiated from scratches created by an inadequate maintenance machining process.

In the region where the overload-related fracture occurred, it was also possible to identify that the machining process had modified the profile of the part in the section transition region, by producing a depression. Thus, it can be said that the *AFT PIVOT PIN* (D61000 and SN 25) of the PR-TTI left main gear broke on account of fatigue, whose onset was facilitated by an inadequate machining process that had been performed in the section transition region of the pin.

3.2.3 Material Factor

Not a contributor.

4 FLIGHT SAFETY RECOMMENDATION (RSV)

A safety recommendation is the establishment of an action which the Aeronautical Authority or SIPAER-Link issues to their respective area of responsibility, aiming at eliminating or mitigating the risk of a latent condition or the consequence of an active failure.

From a SIPAER perspective, a safety recommendation is essential for the safety of flight, refers to a specific hazard and has to be complied with by a certain deadline.

Flight Safety Recommendations issued by the CENIPA:

To the National Civil Aviation Agency (ANAC):

A - 012/CENIPA/2013 – RSV 001

Issued on: 29/11/2013

Enhance audit processes in *RBHA145*-regulated companies which provide outsourced maintenance services, with the purpose of ensuring an appropriate minimum level of maintenance of aeronautical products accepted by the Civil Aviation Authority.

A - 012/CENIPA/2013 – RSV 002

Issued on: 29/11/2013

Enhance audit processes in *RBHA121/135*-regulated companies which provide outsourced maintenance services, with the purpose of ensuring an appropriate minimum level of maintenance of aeronautical products accepted by the Civil Aviation Authority.

A - 012/CENIPA/2013 – RSV 003**Issued on: 29/11/2013**

Enhance the procedures, standards and obligations ensuring the quality of the maintenance services performed on aircraft components by companies which are not holders of the CHE issued by the Civil Aviation Authority.

A - 012/CENIPA/2013 – RSV 004**Issued on: 29/11/2013**

Considering that the companies involved in the accident in question (*TRIP Linhas Aéreas* and *AV Indústria Aeronáutica Ltda.*) had procedures and processes defined in their Maintenance Programs and Inspection Procedures Manual, approved and accepted by the Civil Aviation Authority; considering that they complied with the prescriptions contained in the programs and in the Brazilian Civil Aviation Regulations concerning this activity, and that, even so, latent conditions turned into active failures:

Reevaluate the periodicity and quality of the inspection processes in order to prevent aeronautical accidents, as prescribed by the relevant legislation in force.

5 CORRECTIVE/PREVENTATIVE ACTION ALREADY TAKEN

Early in the investigation process, another AFT PIVOT PIN (D61000 MN 254) was identified, which had not broken, although having been submitted to the same maintenance process by at the same companies. This pin had been installed and was in permanent use in the right landing gear of another aircraft (PR-TTJ) of the *TRIP Linhas Aéreas* fleet. The Investigator-in-charge requested the aircraft operator to remove the pin and send it to the DCTA so that possible defects could be identified.

Based on the results obtained, the conclusion is that the AFT PIVOT PIN (D 61000 E1 SN 25) of PR-TTI aircraft left main landing gear broke on account of fatigue, whose onset was facilitated by a machining process conducted in the pin section transition region. The AFT PIVOT PIN (D61000 MN 254), installed in another aircraft (PR-TTJ), had similar imperfections resulting from an inadequate machining process, leading to the suspicion that the component would not probably reach the expected useful life of 18,000 cycles related to the next overhaul, and would probably cause another aeronautical occurrence.

Still during the investigation of the accident, the CENIPA made Flight Safety Recommendations to the National Civil Aviation Agency:

RSV (A) 014/2011 – CENIPA**Issued on: 12/03/2011**

Determine, to the Brazilian companies operating ATR-72 and ATR-42 aircraft, the inspection of all their ATR-72 and ATR-42 aircraft AFT PIVOT PINs overhauled at the *AV Indústria Aeronáutica Ltda.* company (CHE 9507-02/ANAC), in order to verify the existence of cracks and imperfections that could lead to the occurrence of fatigue.

RSV (A) 015/2011 – CENIPA**Issued on: 12/03/2011**

Carry out an inspection of the *AV Indústria Aeronáutica Ltda.* company (CHE 9507-02/ANAC) in order to verify the conformity of the maintenance services performed for the overhaul of the ATR-72 and ATR-42 aircraft AFT PIVOT PINs with the prescribed requirements.

6 DISSEMINATION

- *Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile* (BEA – France);
- (Brazil's) National Civil Aviation Agency – ANAC;
- *TRIP Linhas Aéreas*;
- *AV Indústria Aeronáutica Ltda*;
- *Azul Linhas Aéreas*.

7 APPENDICES

Nil.

On 29 November 2013.