CIAIAC

COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Final report IN-019/2010

Incident involving an AEROSPATIALE/ALENIA ATR-72-500 (212A), registration EC-HJI, operated by Air Nostrum L.A.M., at Madrid-Barajas Airport (Madrid – Spain), on 30 June 2010

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) nº 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1., 4. and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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Abbreviations

00:00:00	Hours, minutes and seconds (chronological time)
00°	Geometric degrees / Magnetic heading
00°00'00"	Degrees, minutes and seconds (geographical coordinates)
00 °C	Degrees centigrade
ACC	Area Control Center
AESA	Agencia Estatal de Seguridad Aérea
APP	Approach Control Unit
ATC	Air Traffic Control
ATPL(A)	Air Transport Pilot License – Airplane
CAVOK	Weather conditions that occur simultaneously, the following: Visibility 10 km or more, no clouds below the reference height and no cumulonimbus, and no significant weather phenomena
CIAIAC	Comisión de Investigación de Accidentes e Incidentes de Aviación Civil
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
EASA	European Aviation Safety Agency
FL	Flight Level
ft	Feet
h	Hour(s)
hPa	Hectopascal(s)
IAS	Indicated Airspeed
ILS	Instruments landing system
IR(A)	Instrument Rating (Aircraft)
ITT	Inter-turbine temperature
JAR-FCL	Joint Aviation Authorities - Flight Crew Licenses
km	Kilometer(s)
kt	Knot(s)
LEMD	ICAO code for Madrid airport (Spain)
LP	Low Pressure
LT	Local Time
m	Meter(s)
MHz	Megahertz(s)
S/N	Serial number
P/N	Part number
PCRT	Process Compensated Resonance Testing
PT	Power turbine
QNH	Altimeter sub-scale setting to obtain airport elevation above sea level when on the ground during takeoff and landing
QRH	Quick Reference Handbook
rpm	Revolutions per minute
TIC	Turbine Interstage Case
TWR	Aerodrome control tower
UTC	Universal Coordinated Time

Synopsis

Owner and operator:	Air Nostrum L.A.M.
Aircraft:	AEROSPATIALE/ALENIA ATR-72-500 (212A), registration EC-HJI
Date and time of accident:	30 June 2010 at 08:00:19 h[1]
Site of accident:	Madrid-Barajas Airport (Madrid – Spain)
Persons onboard:	4 crew and 64 passengers
Type of flight:	Commercial air transport – Scheduled – Domestic passenger
Phase of flight:	Climb to cruise level
Date of approval:	27 March 2014

Summary of accident

The aircraft took off at 07:53:11 from runway 36L at the Madrid-Barajas Airport as flight ANE-8790 en route to the Melilla Airport.

As the aircraft was reaching 9,000 ft and climbing, a slight mist was detected in the cockpit and the passenger cabin. Simultaneously, with the aircraft at 9,134 ft, a fire warning for the no. 1 engine was received; the crew carried out the relevant emergency procedure and the warning cleared after the second extinguisher bottle was discharged.

Once resolved the emergency, the crew requested priority to return to the airport, describing the problem that had occurred and requesting the presence of the airport's firefighting service.

The aircraft made the approach on a single engine and landed on runway 33L at Madrid-Barajas without further incident at 08:12:00, where it taxied under its own power to parking escorted by firefighting vehicles.

Once the aircraft stopped and it was verified that it was safe to disembark, its passengers exited the aircraft normally and the firefighters returned to the station.

The investigation has concluded that the incident was caused by the fracture, due to fatigue failure, of a rotor blade in the first stage of the power turbine in the aircraft's no. 1 engine, which led to a damage progression in the engine that resulted in a fire in said engine.

[1] All times in this report are local (LT). To obtain UTC subtract two hours from local time.

1. FACTUAL INFORMATION

1.1. History of the flight

On 30 June 2010, an AEROSPATIALE/ALENIA ATR-72-500 (212A) aircraft, registration EC-HJI, operated by AIR NOSTRUM, took off at 07:53:11 from runway 36L at the Madrid-Barajas Airport as flight ANE-8790 en route to the Melilla Airport.

As the aircraft was reaching 9,000 ft and climbing, the flight crew detected a slight mist in the cockpit. When they contacted the purser, she also reported that a mist was starting to appear in the passenger cabin.

While they were receiving this report, at 08:00:19 and with the aircraft at 9,134 ft, the fire warning for the no. 1 engine was received. The crew carried out the actions in the relevant emergency procedure and the warning cleared after the second extinguisher bottle was discharged. Once the fire was out, the crew requested priority to return to the airport, describing the problem that had occurred and requesting the presence of the airport's firefighting service.

The aircraft made the approach on a single engine and landed on runway 33L at Madrid-Barajas without further incident at 08:12:00, where it taxied under its own power to parking escorted by firefighting vehicles. Once the aircraft stopped and it was verified that it was safe to disembark, its passengers exited the aircraft normally and the firefighters returned to the station.

1.2. Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Serious			
Minor			Not applicable
None	4	64	Not applicable
TOTAL	**4**	**64**	

1.3. Damage to aircraft

The aircraft was not damaged in the incident.

1.4. Other damage

There were no other damages.

1.5. Personnel information

1.5.1. *Pilot in command*

The pilot in command, of Spanish nationality and age 37, had a JAR-FCL Airline Transport Pilot License for Aircraft (ATPL(A)) issued in Spain, ratings for the ATR42/72 and instrument flight (IR(A)), and a class 1 medical certificate, all valid and in force at the time of the incident.

He had an experience of 5,432:31 total flight hours and 3,953:52 hours in type; he had made 59:05 flight hours in the last 30 days, 1:10 flight hours in the last 24 h and a rest previous to flight over 12 h.

1.5.2. *First officer*

The first officer, of Spanish nationality and age 37, had a JAR-FCL Airline Transport Pilot License for Aircraft (ATPL(A)) issued in Spain, ratings for the ATR42/72 and instrument flight (IR(A)), and a class 1 medical certificate, all valid and in force at the time of the incident.

He had an experience of 3,768:13 total flight hours and 3,189:47 hours in type; he had made 88:41 flight hours in the last 30 days, 1:10 flight hours in the last 24 h and a rest previous to flight over 12 h.

1.5.3. *Flight attendants*

Both flight attendants had the required licenses, ratings and medical certificates, all of which were valid and in force at the time of the incident.

1.6. Aircraft information

1.6.1. *Airframe*

Manufacturer:	AEROSPATIALE/ALENIA
Model:	ATR-72-500 (212A)
Serial number:	562
Year of manufacture:	1998
Registration:	EC-HJI
Operator:	AIR NOSTRUM L.A.M.

Total flight hours:	22,017 h
Total cycles:	26,485

1.6.2. *Certificate of airworthiness*

Number:	4609
Class:	Large Aircraft
Issue date:	06/07/2005
Airworthiness review certificate:	• Validity: 29/12/2010

1.6.3. *Maintenance record*

Total flight hours:	22,017 h
Total cycles:	26,485
Last C check:	10/03/2010
	• Hours: 21,342 h • Cycles: 25,582
Last A check:	10/03/2010
	• Hours: 21,651 h • Cycles: 26,015
Last weekly check:	30/06/2010
	• Hours: 22,016 h • Cycles: 26,484

1.6.4. *Engines*

Manufacturer:	PRATT&WHITNEY	
Model:	PW127F	
Position:	**No. 1**	**No. 2**
Serial number:	AV0056	AV0088
Installation date:	05/03/2010	20/05/2010
Total hours:	20,140 h	21,747 h

Position:	No. 1	No. 2
Total cycles:	24,022	25,916
Last overhaul:	10/02/2010	12/05/2010
Hours at last overhaul:	19,466 h	21,512 h
Cycles at last overhaul:	23,120	25,623

1.6.5. *General maintenance aspects*

The aircraft was maintained in accordance with the operator's Approved Maintenance Program, reference AN-ATR72-AMP, Rev. 08 dated 21/12/2009, approved by AESA on 23/12/2009.

Said maintenance program is based on the requirements specified in the respective manuals of the airframe, engine and propeller manufacturers, on their recommendations and on those of the component manufacturers, and on the operator's experience.

Air Nostrum's Maintenance Program for its ATR72-212A fleet is divided into several groups of tasks, which are in turn divided into three categories, depending on their frequencies: line maintenance, which includes groups of tasks that can be performed in less than 24 hours; base maintenance, which includes groups of tasks that need more than 24 hours to be carried out; and off-phase maintenance, which includes groups of tasks that, due to their frequency intervals, cannot be included in the previous categories.

Specifically, the engines were maintained in accordance with Pratt & Whitney Canada's Engine Maintenance Manual, Ref. 3037332.

Both the aircraft and the engines had been maintained in accordance with the Approved Maintenance Program.

1.7. Meteorological information

When the aircraft took off, the weather conditions at the airport of Madrid-Barajas were: Wind 360°/06 kt, CAVOK, temperature 18 °C and QNH 1,021 hPa.

The control tower reported to the aircraft that the wind was calm when cleared the aircraft for landing.

1.8. Aids to navigation

All aids to navigation along the path followed by the aircraft, and for the ILS approach to runway 33L of Madrid-Barajas Airport, were operational the day the incident occurred.

1.9. Communications

The aircraft was in contact with the Madrid Area Control Center (ACC), Approach (APP) and Tower (TWR).

At 08:00:54, while in contact with the ACC, the crew requested priority to return to the airport of origin. They were given vectors and successive descent clearances to line the aircraft up with the runway 33L localizer. They were transferred to APP at 08:07:31.

While in contact with APP, the aircraft was cleared to make an ILS approach to runway 33L. Asked if they needed anything special, the crew of the aircraft explained the problem they had experienced and that they did not need anything special upon landing. The flight was transferred to TWR at 08:09:25.

Between 08:08:30 and 08:09:01, APP and TWR coordinated the flight, with APP informing TWR of the problem the aircraft had had, that the crew had requested priority and that an emergency had not been declared.

At 08:09:42 the crew contacted the Madrid-Barajas TWR, which cleared them to land as number one on runway 33L and asked if they needed any type of assistance. The crew replied that the fire was out and requested the firefighting service to verify it on the ground. The aircraft landed at 08:12:00, and was instructed 38 seconds later to exit the runway to the left and transferred to ground frequency.

1.10. Aerodrome information

The Madrid-Barajas Airport (LEMD) is located 13 km northeast of the city of Madrid with an elevation of 609 m (1,998 ft). It has 4 asphalt runways named 14R/32L (15R/33L at the date of the incident), 14L/32R (15L/33R at the date of the incident), 36R/18L and 36L/18R. The dimensions of runway 36L/18R are 4,179 × 60 m, and the dimensions of runway 14R/32L are 3,988 × 60 m.

1.11. Flight recorders

The aircraft had a digital flight data recorder (DFDR) and a cockpit voice recorder (CVR), both housed at the rear of the fuselage. Both were recovered in good condition and

with no apparent damage, and taken to the CIAIAC's flight recorder laboratory to have their data downloaded and processed.

1.11.1. *Digital flight data recorder (DFDR)*

The aircraft had installed in it an L3 Communications F1000 DFDR, part number (P/N) S800-200-00 and serial number (S/N) 02075. This is a solid state recorder with the capacity to store information on 218 parameters for the last 55 h of operation of the aircraft.

The information it contained was downloaded and transformed into engineering units.

The basic flight and engine operation parameters for the incident flight are shown below.

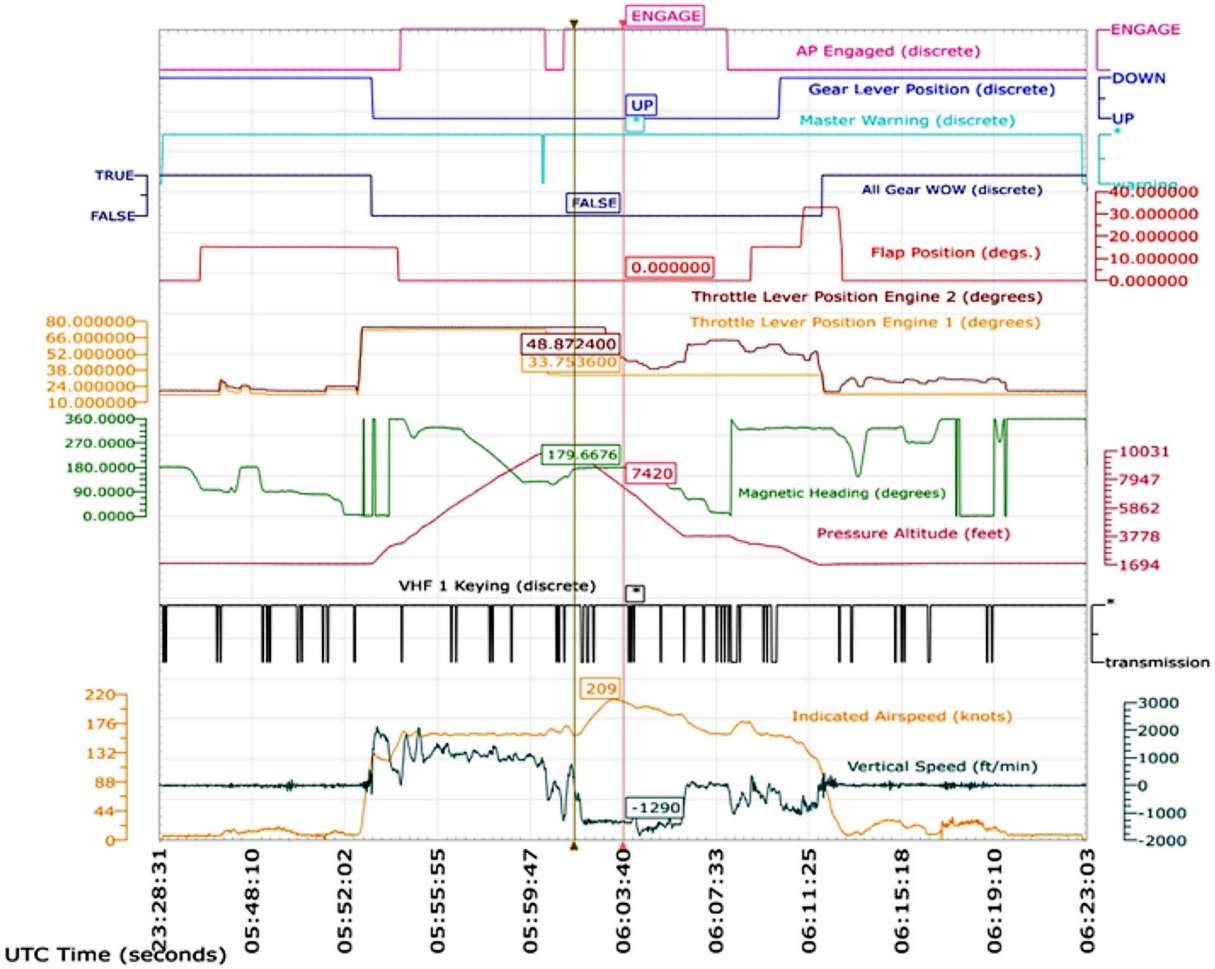

Figure 1. Flight parameters

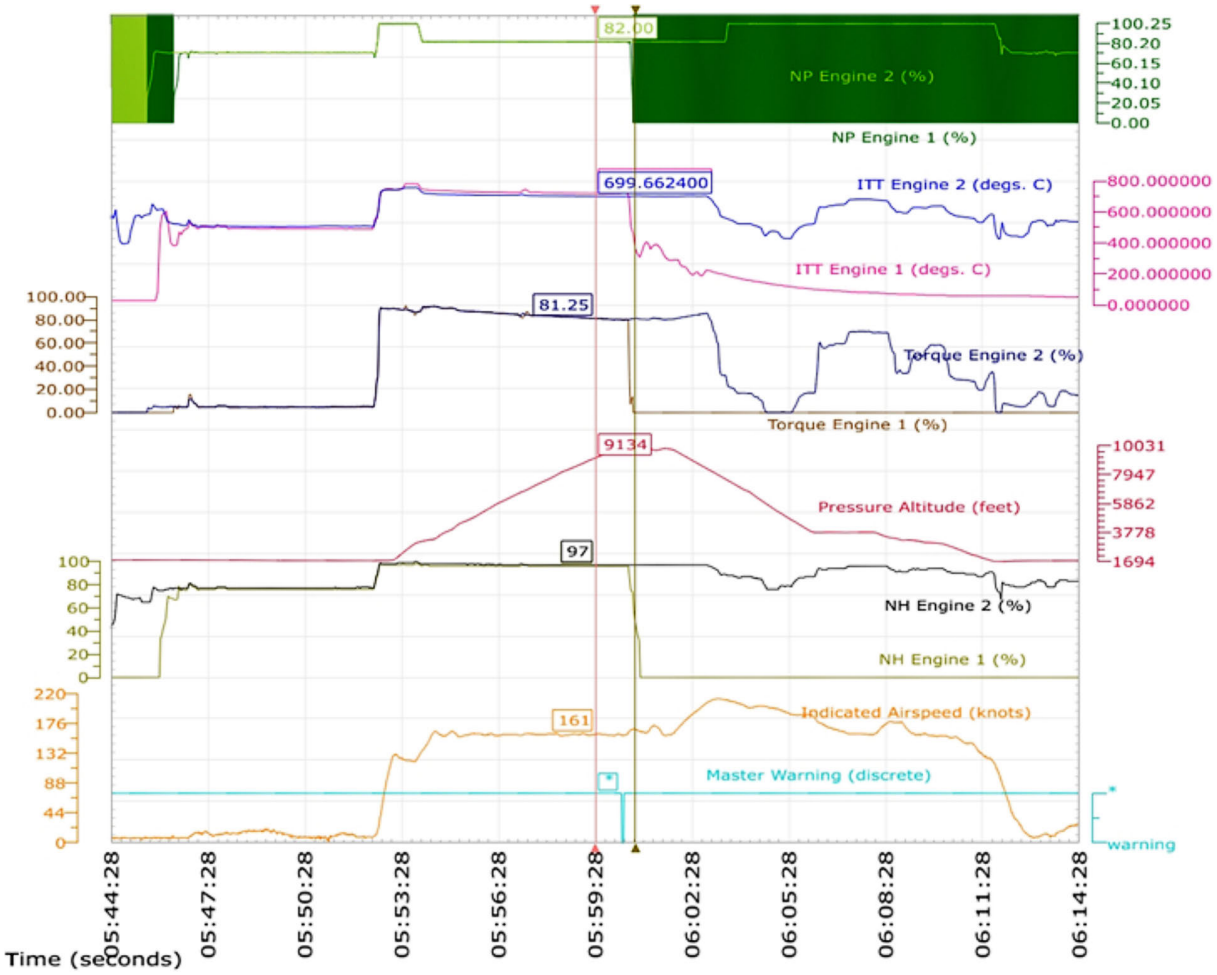

Figure 2. Engine parameters

1.11.2. *Cockpit voice recorder (CVR)*

Installed on the aircraft there was a Fairchild A200S CVR, P/N S200-0012-00 and S/N 01689. This is a solid state recorder that can record a total of six tracks, four of them in high quality lasting 30 minutes, and two of them in standard quality lasting 2:04 hours.

The information it contained was downloaded and the recordings for the incident flight, which lasted 40 minutes, were transcribed.

1.11.3. *Information on the incident flight*

Once the information involving the incident flight taken from the two recorders was processed, it was synchronized using the UTC time recorded on the DFDR as a reference.

The table below shows the information on the incident that was obtained from the flight recorders. The local time was calculated by adding two hours to the UTC time stamp on the DFDR.

Local time	Flight information
07:44:17	Start of CVR and DFDR recording. No. 2 engine start-up.
07:46:06	No. 1 engine start-up.
07:46:52	Cleared to taxi to runway 36L.
07:48:52	Aircraft cleared to taxi into position on runway 36L and hold.
07:52:22	Aircraft cleared to take off from runway 36L.
07:53:07	"V1" heard on CVR. Indicated airspeed (IAS) 109 kt.
07:53:08	"Rotate" heard on CVR. IAS 113 kt.
07:53:11	Landing gear in the air. IAS 122 kt.
07:53:15	Gear lever up. IAS 129 kt.
07:54:19	Flaps 0º. IAS 148 kt.
07:54:24	Autopilot engaged. IAS 157 kt.
07:54:37	The captain notes that both engines are running high.
07:56:04	ATC instructs them to climb to FL160. Altitude 5,974 ft.
07:58:53	ATC instructs them to climb to FL230.
07:59:20	Message from flight attendant to passengers instructing them to remain seated. Altitude 8,996 ft.
07:59:56	The flight attendants inform the flight crew that there is some kind of mist in the cabin, on the left side of the aisle. Altitude 9,600 ft.
08:00:19	Master Warning activated. Altitude 9,922 ft.
08:00:23	Master Warning deactivated.
08:00:27	Autopilot disengaged. Altitude 10,017 ft.
08:00:29	Autopilot disengage warning.
08:00:33	The position of the no. 1 engine throttle lever goes from 73.132º to 34.105º.
08:00:40	No reading on the no. 1 propeller rpm indicator (same value as before engine start). The torque for the no. 1 engine goes to 0.
08:00:53	The rpm's for the no. 1 engine high-pressure turbine drop to 0.
08:00:54	The crew requests priority from ATC to return to the airport.
08:01:03	ATC instructs them to head south and descend to 8,000 ft. Altitude 9,936 ft. Magnetic heading 134º.
08:01:13	Autopilot engaged. Altitude 9,804 ft.

Local time	Flight information
08:02:45	The captain informs the flight attendants that they have had an engine fire, that it is out and they are returning to the airfield. He instructs them to secure the cabin. Altitude 8,640 ft.
08:02:59	Start of Engine Fire checklist.
08:03:09	Engine Fire checklist complete.
08:03:22	Start of Single Engine Operation checklist.
08:04:04	ATC clears them to descend to 4,000 ft. Altitude 6,907 ft. Magnetic heading 178º.
08:05:27	The cabin crew reports cabin secured. Altitude 4,863 ft.
08:05:41	Single Engine Operation checklist complete. The captain addresses the passengers and tells them of the fault in the no. 1 engine and that they are returning to the airport.
08:06:53	ATC instructs them to turn left heading north and follow the 33L localizer. Altitude 3,791 ft. Magnetic heading 062º.
08:07:31	ATC transfers them to final approach on 127.5 MHz. Altitude 3,778 ft.
08:07:54	The captain asks for the Approach checklist. Altitude 3,796 ft.
08:07:58	ATC clears them to do an ILS approach to runway 33L. Altitude 3,795 ft.
08:08:03	Autopilot disengaged. Altitude 3,796 ft.
08:08:07	ATC asks if they have any special needs. Altitude 3,787.
08:08:13	The crew informs ATC of the problem they had and that they do not require anything special on landing.
08:08:38	Approach checklist resumed. Altitude 3,414 ft.
08:09:03	Flaps 15º. Altitude 3,227 ft.
08:09:12	Approach checklist complete.
08:09:14	They decide to wait for the landing gear to lower. Altitude 3,238 ft.
08:09:25	ATC transfers them to 118.15 MHz (TWR frequency).
08:09:42	The crew contacts the Madrid-Barajas control tower.
08:09:44	TWR clears them to land as number 1 on runway 33L and asks if they need any kind of assistance.
08:09:54	The crew reports that the fire is out but requests the firefighting service to confirm it.
08:10:09	Gear down requested by the captain.
08:10:15	Gear lever selected to down position. Altitude 2,951 ft.
08:10:35	The first officer instructs the cabin crew to prepare for landing.
08:10:53	Cabin crew reports cabin secured.
08:11:10	Start of Before Landing checklist.
08:11:13	Flaps 30º.

Local time	Flight information
08:11:33	Before Landing checklist complete.
08:11:42	Synthetic voice ONE HUNDRED. Altitude 1,808 ft.
08:11:45	Synthetic voice FIFTY.
08:11:46	Synthetic voice FORTY.
08:11:47	Synthetic voice THIRTY.
08:11:48	Synthetic voice TWENTY.
08:11:49	Synthetic voice TEN.
08:12:00	The All Gears Weight on Wheels parameter value indicates TRUE.
08:12:38	TWR instructs them to exit the runway to the left and contact ground on 121.85 MHz.
08:12:51	Flaps 0º.
08:19:58	The no. 2 engine torque value drops to 0.
08:23:02	The no. 2 engine high-pressure turbine rpm's drop to 0. End of CVR and DFDR recording.

1.12. Wreckage and impact information

Not applicable.

1.13. Medical and pathological information

Not applicable.

1.14. Fire

There was no fire, apart from the declared in the engine.

1.15. Survival aspects

Not applicable.

1.16. Tests and research

1.16.1. *Inspection of the aircraft*

The aircraft was inspected at the Madrid-Barajas Airport with the support of personnel from the aircraft's operator. The only damage found was to the no. 1 engine, as described below.

Initially, when mechanics tried to move the propeller, the engine would not rotate since the power turbine was jammed.

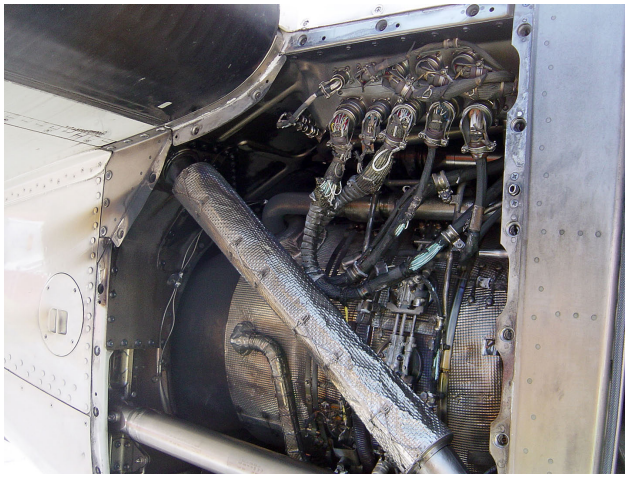

Figure 3. Area affected by the fire

Once the fairings were removed, it was noted that the engine had oil stains from the mid-section aftward. The oil level in the tank was checked and determined to be practically full.

There was evidence of a fire outside the hot part of the engine, behind the firewall; specifically, on the right side and in the lower center part of the engine. The fire had affected various cables and lines.

In addition to the burned areas, several engine components were damaged, namely: the lubricating oil vent line for the nos. 6 and 7 bearings was broken; the fastening screws on the tubing from the nos. 6 and 7 bearings to the oil scavenge pump were loose; and various cable and piping brackets were damaged.

When the engine was examined from the exhaust nozzle, several broken blades were found on the last disc of the power turbine. The corresponding stator was severely damaged, and a section spanning some 25 degrees of arc was perforated on the abrasion seal.

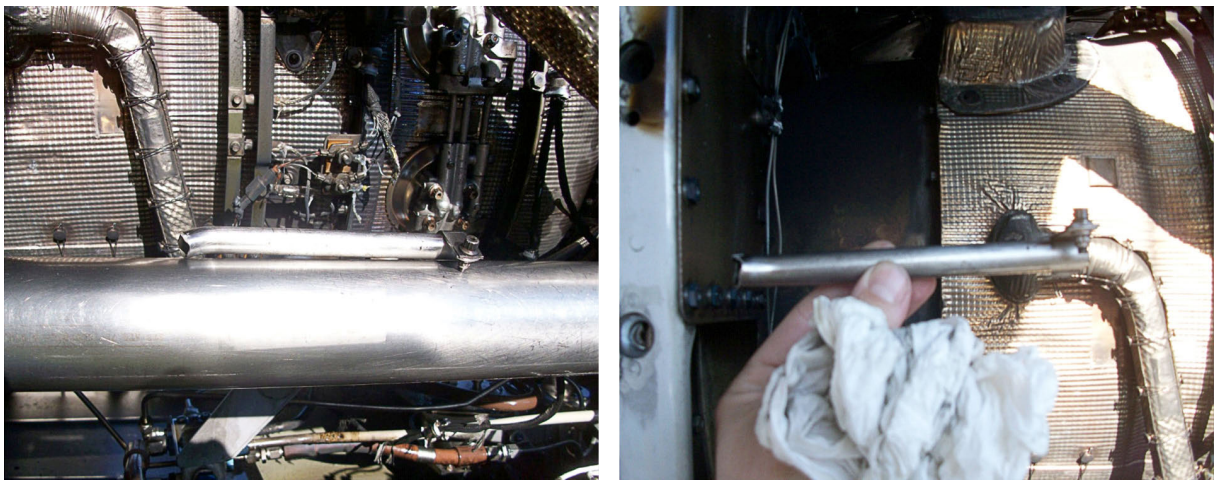

Figure 4. Lubricating oil vent line for the nos. 6 and 7 bearings

The engine intake diffuser exhibited impact damage on the intake lip and the remains of a bird were lodged in the radiator. The low- and high-pressure compressors were clean and rotated freely with no apparent resistance.

The no. 1 engine was removed and prepared for shipping to a facility where it could be properly studied.

Figure 5. Intake diffuser

1.16.2. *Analysis of the engine*

The engine was taken to the EASA Part-145 authorized maintenance center where it had last been overhauled for analysis and return to service.

1.16.2.1. Engine disassembly and inspection

A Senior Field Support Engineer from the manufacturer assisted with the disassembly and inspection of the engine and with the analysis of the findings.

The damage to the engine is described below:

- First stage rotor in the power turbine (PT1): two sequential blades were broken, damage to every blade and to the disc from detached debris.
- Second stage rotor in the power turbine (PT2): three sequential blades broken, damage to every blade and to the disc from detached debris.
- Air seal between the two power turbine stages: damage from detached debris.
- First stage stator in the power turbine (PT1): one blade segment missing and damage to the diffuser.
- Second stage stator in the power turbine (PT2): blade segments missing, severe damage from detached debris and deep friction marks in the abrasion seal.
- Housing for nos. 6 and 7 bearings: found loose with all its attachment bolts sheared.
- Heat exchanger piping at nos. 6 and 7 bearing housing: wear marks.
- Nos. 6 and 7 bearing vent lines: broken near the rear fastening brackets for the line and the T6 cable bracket.
- T6 cables: insulation burned.
- Low-pressure turbine (LP) abrasion ring: friction marks between the 1 and 3 o'clock positions.
- Casing between the low-pressure and power turbine stages (TIC): marks in the screw holes for the nos. 6 and 7 bearings, and in the surrounding coupling area. Extensive wear on the abrasion seal.

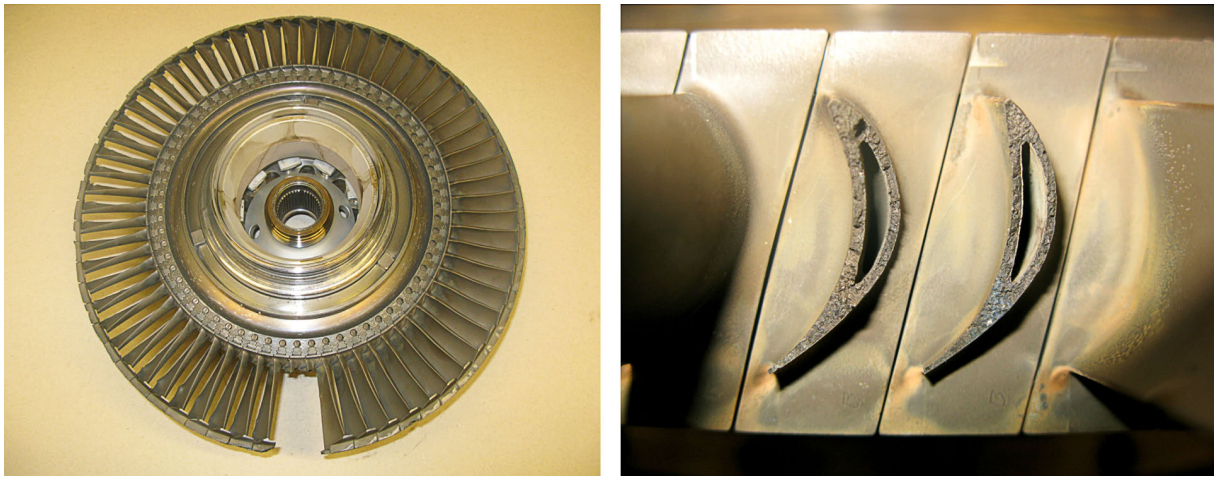

Figure 6. First-stage rotor of the power turbine and close-up

- Power turbine shaft labyrinth seal: severe wear along the edges of the grooves.

The laboratory analyses of the two broken blades from the first stage of the power turbine (PT1) showed that one had experienced a fatigue fracture, and that the other had fractured as a result of the damage caused by the piece that detached from the first blade; both fractured blades exhibited fatigue cracking originating in areas of casting micro-porosity in the airfoils.

All of the fractures present in the engine's external components (vent line for the nos. 6 and 7 bearings, brackets and flanges) showed signs typical of low cyclic loading fatigue.

1.16.2.2. Probable engine failure sequence

In light of the damage found in the engine, and based on the manufacturer's experience, a probable failure sequence for the engine was established as described below:

1. The two blades in the first stage pressure turbine (PT1) rotor fracture. This induces mechanical vibrations and alters the flow of gases inside the engine. As a result:

    a) Fuel flow is increased to maintain engine torque. This raises the temperature between the low- and high-pressure turbines (ITT).
    b) The vibrations cause misalignments and oscillations in the housing for the nos. 6 and 7 bearings, which causes the attachment bolts to shear.
    c) The detached components cause damage to every element they come in contact with, especially those located toward the rear (second stage stator and rotor in the power turbine).

2. Vibrations are transmitted throughout the engine and its associated components. As a result:

   a) Piping and cable fastening components break.
   b) The vent line for the nos. 6 and 7 bearings breaks.

3. Oil issues from the broken vent line, which ignites when it contacts the outer surface of the hot part of the engine.
4. The crew immediately stops the engine, thus preventing further damage.

1.16.3. *Analysis of the operation*

In its manuals, the operator has established criteria and procedures applicable to the operation of its fleet, of which the following are applicable to this incident:

- Part B Operations Manual, Chapter 2.2.0, Abnormal and Emergency Procedures. Overview, which establishes the operator's criteria in connection to this type of procedure.
- Part A Operations Manual, Chapter 8.3.0, Section J.2, which establishes the criteria for using the operator's abnormal and emergency procedures (QRH).
- The abnormal and emergency procedures (QRH) themselves, which include checklists with memory items to be carried out first and then read out.
- Operations Manual, Part A, Chapter 11.0.0, Section B.2.1, Declaration of Emergency by the Crew, which establishes the operator's criteria as regards emergency declarations, including the following: *In case of fire or smoke if the application of the relevant procedure does not succeed in extinguishing it.*

In this case, the crew carried out the procedures specified by the operator, namely:

- A warning was received.
- The warning was cancelled.
- The fault was confirmed.
- They executed the memory items from the engine fire checklist (55 seconds).
- They disengaged the autopilot twice (increasing their workload) and then engaged it.
- They read four checklists.
- They were interrupted by ATC and by the cabin crew.
- The pilot in command spoke with the purser and addressed the passengers.
- They landed with all the checklists read and all their items verified.

A total of 11:41 minutes elapsed from the time the warning was received until all wheels were on the ground.

As for a possible emergency declaration, the engine fire was extinguished as per the relevant procedure, meaning that the requirements specified in the operator's Operations Manual for declaring an emergency were not met.

1.17. Organizational and management information

Not applicable.

1.18. Additional information

1.18.1. *Manufacturer actions*

The engine manufacturer reported that the rate of fractures for blades in the first stage of the power turbine (PT1) in this type of engine was low and within allowable limits.

With reference to blades in the first stage of the power turbine the engine manufacturer has in place improved blade inspection methodologies. Furthermore, there is engineering activities ongoing towards improving the blade manufacturing and durability.

The manufacturer, Pratt & Whitney Canada, is currently developing an improved blade design to eliminate the casting core pocket to improve manufacturability and reduce the probability of and susceptibly to shrinkage porosity.

In addition, the manufacturer Pratt & Whitney Canada took the following mitigating actions to address the problem of micro porosity in the PT1 blades:

- Issued Service Bulletins for the replacement at shop visit of blades manufactured during the period of 2005 to 2008 which exhibit a statistically higher prevalence of shrinkage porosity.
- Issued Service Bulletins for the replacement of specific blade serial numbers which were determined, through re-evaluation of manufacturing inspection records, to exhibit unacceptable levels of shrinkage porosity.
- Improved X-ray inspection method at casting manufacture.
- Added X-ray inspection to the latest manufacturing standard at shop visit, as mandated by Transport Canada Airworthiness Directive CF-2013-02.
- Introduced Process Compensated Resonance Testing (PCRT) inspection methodology at final blade manufacture.
- Introduced a 10,000-hour soft-time blade replacement interval for higher-power engine models.
- Included acceptance criteria in the Overhaul Manual for blade shroud contact points to ensure effective blade damping in operation.

On the other hand, the manufacturer´s engineering organization has examined the No.6 and 7 bearing oil tubes fractures as a result of the subsequent out of balance loading following a power turbine (PT) blade release. Investigations have revealed that most of the No.6 and 7 bearing oil tubes, but not all, have fractured at the fitting interface. The manufacturer is currently working on a product improvement that is changing the attachment of the end fittings from a brazed to a welded join configuration. This will improve the durability of the interface and will be aligned with it current best practice for this type of tube.

1.19. Useful or effective investigation techniques

Have not been used.

2. ANALYSIS

The aircraft took off at 07:53:11 from runway 36L at the Madrid-Barajas Airport en route to the Melilla Airport.

As they were climbing through 9,000 ft, the crew detected a slight mist in the cockpit and passenger cabin. Shortly thereafter, just seven minutes after having taken off, the no. 1 engine fire warning was received. The crew carried out the corresponding emergency procedure and the warning cleared after the second extinguisher bottle was discharged into the engine.

Once the fire was out, the crew requested priority to return to the airfield. They described the problem that had occurred and requested the presence of the airport's firefighting service. The aircraft made the approach on a single engine and landed without further incident at 08:12:00 on runway 33L at the Madrid-Barajas Airport and then taxied to parking under its own power.

As concerns the crew's actions, the crew strictly adhered to the procedures established by the operator at all times. This allowed them to work quickly and efficiently and limited the damage sustained by the engine.

As far as the engine failure is concerned, point 1.6.2 describes the damage found in the engine, the probably failure sequence and the engine manufacturer's conclusion regarding the problem detected.

We must also consider the incidence of the cause-effect relationship between the fracture of a blade and an in-flight fire, which adds a qualitative factor to the analysis of this type of incident. Bearing in mind the low rate of blade failures of this type, the low probability of a fire occurring as a result of such a failure, and the effectiveness of the applicable operating procedures, no measures in addition to those already available for preventing and dealing with this type of incident are deemed necessary.

3. CONCLUSIONS

3.1. Findings

- The aircraft crew was properly qualified, adequately experienced and physically fit, and their licenses were in good standing.
- The aircraft had been maintained according to approved maintenance program and had valid Airworthiness and Registration Certificates.
- The weight and balance of the aircraft were within the limits.
- The navigation aids were working properly, according to the findings made.
- The ground-air communications worked properly at all times.
- During the climb to cruise level, there was fire in the aircraft engine no. 1.
- A rotor blade in the first stage of the power turbine in the engine no. 1 of the aircraft was fractured by a process of fatigue.
- Piping and cable fastening components, broke due to mechanical vibrations and altered gas flow inside the engine.
- The vent line for the nos. 6 and 7 bearings broke producing oil leaks, which ignited when it contacted the outer surface of the hot part of the engine.
- The crew properly managed the emergency and the aircraft landed normally at the airport of origin with a single operating engine.

3.2. Causes

The incident was caused by the fracture, due to fatigue failure, of a rotor blade in the first stage of the power turbine in the aircraft's no. 1 engine, which led to a damage progression in the engine that resulted in a fire in said engine.

4. SAFETY RECOMMENDATIONS

There are not safety recommendations as a result of the investigation of the incident.