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MINISTÉRIO DAS OBRAS PÚBLICAS, TRANSPORTES E COMUNICAÇÕES

GABINETE DE PREVENÇÃO E INVESTIGAÇÃO DE ACIDENTES COM AERONAVES

GPIAA

FINAL INCIDENT INVESTIGATION REPORT

Societé AIR FRANCE

BOEING 777-328 ER

F-GSQT

In-flight engine failure

CRZ FL320 NYC FIR

29TH MARCH 2008

ESTÁ CONFORME O ORIGINAL

03 / 09 / 2009

GPIAA

Homologo nos termos do n.º 3 do
art.º 26º do D.L. 318/99, de 11/08

03 / 09 / 2009

O Director

Fernando Ferreira dos Reis

REPORT NR 04/INCID/2008

FOREWORD

This report expresses the technical conclusions determined by G.P.I.A.A. Investigator-in-Charge about facts and causes involved in this occurrence.

According to Annex 13 to the International Civil Aviation Organization Convention (Chicago 1944), to the Council Directive nr. 94/56/EC (21st November 1994) and to nr. 3, 11th article of Decree-Law 318/99 (11th August), it is not the object of this report to determine blame or liability but solely to identify causes and deficiencies capable of undermining flight safety and to gather information for preventing further occurrences of similar circumstances.

The original report of this incident has been issued in Portuguese language which is the official version and takes precedence as report of reference. This English translation was published for international readers' information purpose.



SYNOPSIS

On March 29, 2008, a Boeing 777-328 ER aircraft, registered F-GSQT, was operating an international passenger flight from Paris/Orly (France) to Pointe-à-Pitre/Le Raizet (French Antilles) with 448 people on board.

While cruising at FL 320, in New York FIR, the flight crew heard several low bangs and the engine #2 EGT indicator showed swift variations.

The appropriate checklist was performed and, when the right engine power was reduced, the stalls and indicator variations disappeared. Trying to increase thrust brought again the abnormal affected engine behaviour.

Then, the commander has decided to divert the aircraft to Lajes/Azores where it landed at 18:09 UTC hours.



1. FACTUAL INFORMATION

1.1 History of the flight

On March 29, 2008, a Boeing 777-328 ER aircraft, registered F-GSQT, was operating international passenger flight nr. AF620 from Paris/Orly (France) to Pointe-à-Pitre/Le Raizet (French Antilles) with 15 crew members and 433 passengers on board. Fort de France/Lamentin (Martinique) was the alternate airport.

About five hours after takeoff, roughly, at FL320 and already within New York FIR, with CPDLC link active, the pilots observed a N2 engine vibration increase prior to several low bangs coupled with some light perturbations around the yaw axis.

After looking at the other engine indicators, the crew also noticed that the #2 engine EGT evidenced rapid variations (drops).

The crew performed the “μ ENG LIM/SURGE/STALL L, R” checklist. The thrust lever was retarded until the idle position and the affected engine indications remained within appropriate limits. Advancing the throttle, the engine #2 indications became unstable again, returning vibrations and loud bangs when reaching about 60%N1.

The crew decided to divert to Lajes International Airport at Terceira Island (Azores – Portugal), where the pilot performed an uneventful landing on RWY 33, with the engine #2 thrust lever in idle position, at 18:08 hours¹.

1.2 Injuries to persons

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	-	-	-
SERIOUS	-	-	-
MINOR	-	-	-
NONE	3+12	433	

1.3 Damage to aircraft

The damage was confined to the engine #2 internal components.

1.4 Other damage

There was no damage to third parties.

¹ The time in this report refers to UTC hours.



1.5 Personnel information

INFORMATION		COMMANDER	COPILOT
Identification	Sex	Male	Male
	Age	53 years	47 years
	Nationality	French	French
Licence Details	License held	ATPL	CPL
	Nr.	3048.86	6699.99
	Date of issue	23-06-1986	29-03-1999
	Validity	31-12-2008	30-09-2008
	Authority	DGAC	DGAC
Medical Certificate	Class	1	1
	Date	30-07-2008	06-12-2007
	Limitations	None	None
Flight Experience	Total flying hours	16 434:00	13 458:00
	Total hours on type	4 876:00	3 222:00
	Hours in last 90 days	109:00	210:00
	Hours in last 30 days	31:00	79:00
	Hours in last 7 days	7:30	21:00
	Last 24 hours	7:30	7:30
Duty Time	Last 90 days	132:00	251:00
	Last 30 days	37:00	93:00
	Last 7 days	9:00	25:00
	Last 24 hours	9:00	9:00

1.6 Aircraft Information

Aircraft		Manufacturer The Boeing Company Type/Model 777-328 ER Serial nr. 32846 Date of Manufacture 15-02-2007 Registered Owner Societ� AIR FRANCE Operator Societ� AIR FRANCE Certificate of Airworthiness nr. / Issued by 118 060 / DGAC Date of issue / Validity 05-02-2008 / 01-03-2009 Registry Certificate nr. / Issued by B22804 / DGAC M.T.O.W. 344 500 kg (759 600 lb) POB (Crew/Pax) 3 + 12 / 433
Engines		Manufacturer General Electric Model 2 x GE 90-115B S/N 906 383 Time Since New 5 009:00 hours Time Since Last Shop Visit N/A S/N 906 132 Time Since New 14 723:00 hours Cycles Since New 1565 cycles Time Since Last Shop Visit 597:00 hours
<u>Engine # 1</u>		
<u>Engine # 2</u>		



1.7 Meteorological information

The weather at Lajes Airport was CAVOK. The wind was 280/15, QNH 1016, temperature 16°C/-. The pilot experienced some windshear during final approach to RWY 33.

1.8 Aids to navigation

Runway 33 is equipped with an ILS and a PAPI and it was used for landing.

1.9 Communications

There were standard and undoubted communications between aircraft and ATM.

1.10 Aerodrome Information

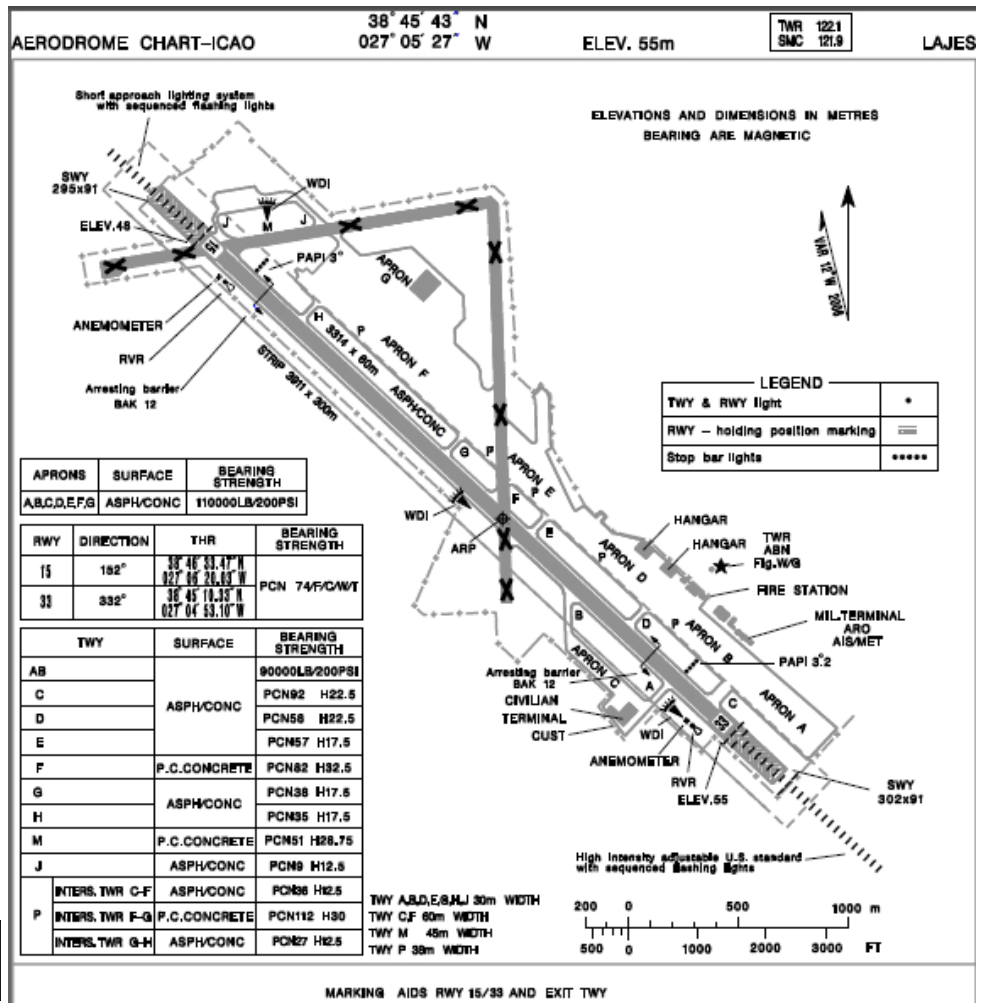
Lajes Airport – LPLA

- *ARP coordinates and site:* LAT: 38° 45' 43"N LONG: 027° 05' 27"W (Intersection of Runway 15/33 with Taxiway "F").
- *Altimeter Checkpoint location and elevation:* 180ft/55m (THR RWY 33).
- *MAG VAR /Annual change:* 11,550° W (2006) - 0.1667°
- *AD Administration:* Air Base nr. 4 Commander (Portuguese Military Air Force)
- *Operational Hours:* 24H.
- *Local traffic regulations*
 - *Limitations on use of aerodrome* – Military Aerodrome to be used in emergency or on PPR under very exceptional circumstances².
- *Repair facilities for visiting aircraft:* Minor repairs only
- *Passenger's (medical) facilities:* First Aid Treatment, Medical Assistance, Ambulance and Hospital in *Angra do Heroísmo* (15 Km from Aerodrome).
- *Rescue and fire fighting services:*
 - *AD category for fire fighting* – 9
 - *Capability for removal of disabled aircraft* - B707 or similar

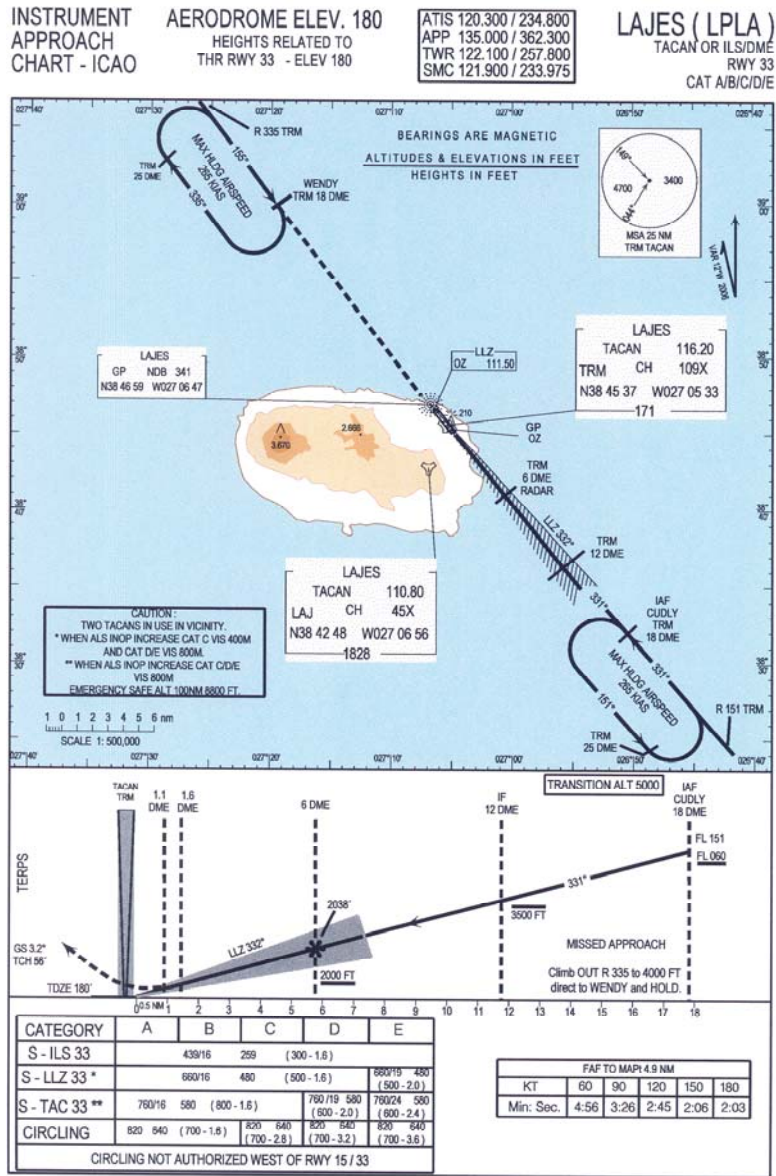
² Portuguese Military Aerodromes are normally restricted to military aircraft only. Providing that a civil airport is not available in the proximity and that intentions are clearly stated, the use of Military Aerodromes by civilian aircraft requires a 03 days prior permission request (PPR), sent by the owner or the operator. (LPLA AD 2.20 LOCAL TRAFFIC REGULATIONS)



- **Remarks:**
 - Due to high terrain to the west, all turns and traffic circuit are made to the east.
 - Caution - RWY may not be visible during portions of downwind leg on circling approach.
 - Due to terrain visual traffic circuit should not be flown less than three miles from island.
- **Runway 33 physical characteristics:**
 - QTE - 320.71°
 - QFU – 332°
 - **Dimensions (m) and Declared Distances:**
 - RWY and SWY – 3314 x 60 and 295 x 60
 - TORA / TODA / ASDA / LDA – 3314 / 3609 / 3609 / 3314
 - Strength (PCN) / surface of RWY and SWY – 74/F/C/W/T / Asph., Concr.
 - THR elevation and highest elevation of TDZ of precision APP RWY – 180 ft THR
 - Slope - 0%



Lajes Aerodrome Chart



Lajes Instrument Approach Chart

1.11 Flight recorders

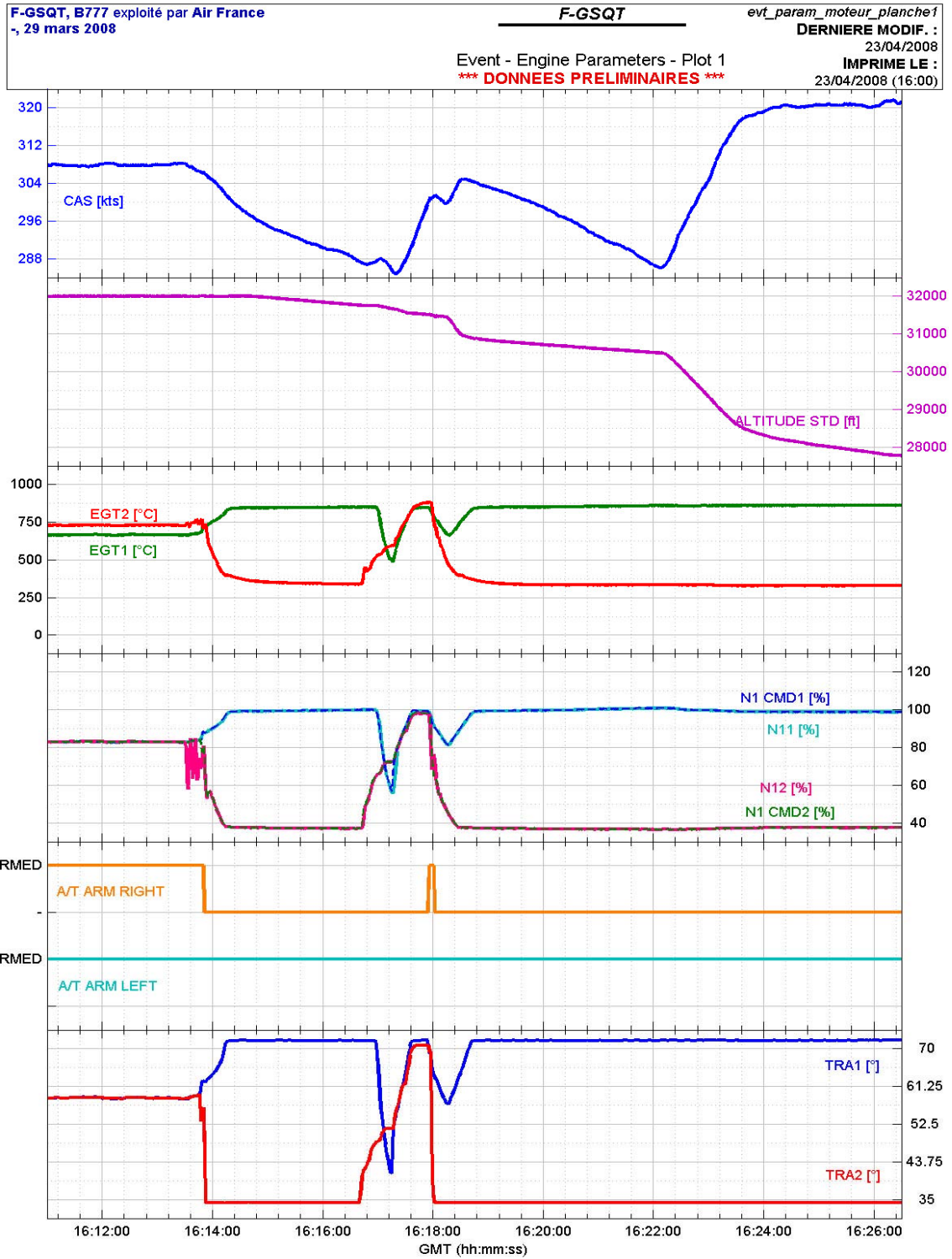
The aircraft was equipped with a CVR and a DFDR.

- 1- The CVR has been analyzed but the event itself wasn't registered. The recording began with a crew message of the F-GSQT requesting to Santa Maria ATC, on HF frequency, a lower flight level, already on the route diversion to Lajes Airport. The CVR had no information about what the crew experienced and the way the pilots handled the incident. These had established communication with Air France Maintenance service, via SATCOM and, during the flight, both engine parameters profiles have been downloaded via ACARS.

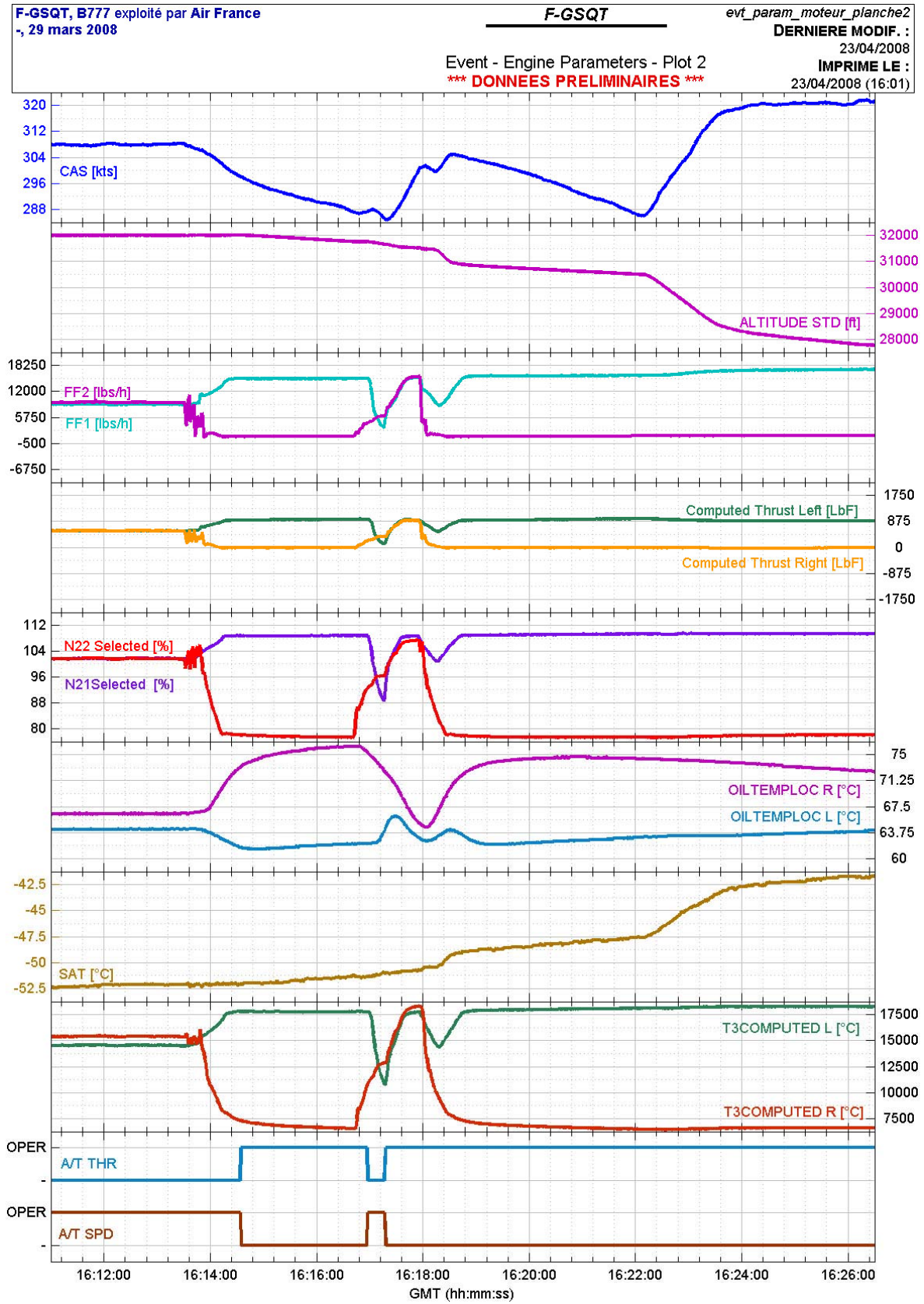
The communication established between the Maintenance and the Captain revealed that he was already aware that the engine #2 had some problems before.



2- When engine #2 vibrations and loud bangs were noticed, the crew retarded the thrust lever to the idle position for a while. Once advanced beyond 60%N1, the engine #2 indications became unstable again, returning to vibrations and loud bangs. Information from the DFDR showed that there was no significant change in other engine parameters.



Engines' parameters – Plot 1



Engines' parameters – Plot 2

GPIAA hasn't been supplied with the relevant vibrations registry graphs.



1.12 Information on the incident site

Not applied.

1.13 Medical and pathological information

No-one was injured.

1.14 Fire

No fire broke out as a result of the incident.

1.15 Survival aspects

Not applied.

1.16 Tests and research

1.16.1 Prior engine #2 maintenance occurrence

On December 20, 2007, the engine was removed from another Air France's aircraft for a maintenance intervention due to the LPT stage 6 blade interlock being worn beyond limits. On January 25, 2008 the engine was installed on F-GSQT #2 position.

1.16.2 Flight AF 620 engine #2 activity history

On March 29, 2008, around two hours after the takeoff, an automatic ACARS message appeared on the Orly Maintenance Centre telex, delivered by the F-GSQT, for a N2 HIGH VIBRATION RIGHT alert, indicating vibrations about 2.03/2.04. The information surprised the technicians because the Maintenance Manual indicates a maximum of 4.0 allowed value. So the Maintenance contacted the crew and asked the pilots to check the engine #2 N2 vibration level and to send a manual snapshot each hour. Five hours after the departure, at FL320, the engine #2 experienced a self recovering stall, causing diversion to Lajes Airport, where a safe landing was performed with the right engine set to idle position.

A maintenance team was sent by Air France to replace engine #2 (Engine s/n 906132 was later on replaced by engine s/n 906131).

GPIAA's Investigation Team, also present at Azores, was informed of the following technicians' tests results:



Engine #2 replacement



1.16.3 In site inspection (at Lajes Airport)

1. External investigation –

- Little amount of light colored metal chips inside the right engine exhaust nozzle;
- No stabiliser, aircraft/engine body or wing damage found;
- No DMS (*Data Management System*) message found in CMCF (*Central Maintenance Computer Function*). DMS chip count indicated zero on the last ACMS (*Airplane Condition Monitoring System*) engine stable report.

2. Internal investigation - The first exam with borescope revealed:

- HPC (High Pressure Compressor) - stages 1, 2 and 3 with no damage observed;
- HPC4 rotor – one blade with half missing and damage on other blades (cracks, missing material, dents, notches);
- HPC - Stages 5 to 8 with damage similar to stage 4 (except that no blades were missing);
- Most of the blade damage was out of AMM limits.

3. Engine parameters registration – Five ACMF exceeding reports for N2 vibration have been generated.

1.16.4 Further inspection (Shop & Laboratory investigation)

Air France maintenance sent the engine to GE. Meanwhile GPIAA was expecting the engine #2 report issued by the suitable manufacture.

The following information is taken from the report provided by GE:

➤ **Engine GE90-115B s/n 906132 (Aircraft F-GSQT, position #2)**

• **Shop Investigation findings:**

- Stage 4 HPC blade set found heavily damaged (some blades found with airfoils missing, - #44 blade with airfoil missing just above the platform - some others with tip corner loss on trailing edge and on leading edge);
- One stage 4 Vane found with missing airfoil;
- Stage 5 HPC blade set found heavily damaged on leading edge (all blades found with nicks, tears and missing material, consistent with secondary impact distress);
- Stages 6 to 9 blade set found with nicks and tears, also consistent with secondary impact distress.



Engine #2 HPC Stage 4



Stage 4 HPC #44 blade with airfoil missing, (separated just above the platform).



Stage 4 HPC:

- Four of the blades (#12 shown) were found with tip corner loss on trailing edge (left hand photo);
- Blade #10 found with tip corner loss on leading edge (right hand photo).



- Laboratory Investigation findings:

All stage 4 HPC damaged components have been examined. Presumably the origin of the problem was on the stage 4 HPC #44 blade airfoil separation, although the root cause of the crack couldn't be identified. The detached fragment came into contact with Stage 4 Vane Segment, releasing one airfoil and bending another one impacting on the remaining blades and starting other components distress.

Regarding to the Lab Investigations findings:

- Stage 4 HPC blade #44:
 - Correct microstructure;
 - No evidence of metallurgical defect, FOD or any material distress;
 - Typical light manufacturing marks similar to other non-distressed blades (with less than 0.007 mm deep);
 - Shot peening found effective on the surface close to fracture origin;
 - No blade dimensional deviation noticed.

An investigation on other blades didn't disclose any crack on their root area.

- Stage 4 HPC vane:
 - Airfoils damage consistent with the blade #44 airfoil fragment going through stage 4 HPC vane sector.

Accordingly, the Laboratory investigations concluded that the Stage 4 blade #44 airfoil separation resulted from High Cycle Fatigue, having the crack initiated at mid-chord on pressure side close to airfoil-to-platform radius. SNECMA suspects that this blade already lost Tip Corners that changed its vibratory response mode. HPC stage 3 or 4 tip corner loss due to rubs has also occurred in 45 other engines to date.

In the sequence of this incident GE established a relevant Control Program and a SB (# 72-0270) was issued in July, 2008, which recommends that Operators carry out a periodic inspection of stage 3 and 4 HPC blades for tip corner loss.

As closing action, GE and SNECMA decided to increase the HPC stage 3 and 4 blade tip clearance to reduce the potential for rubs which lead to tip corner loss. This is to be



incorporated in each shop visit when the rotors are exposed and is to be introduced into production the 2nd quarter of 2009. Also a new applicable SB (#72-0322) will be issued in the 3rd quarter 2009.

1.17 Organizational and management information

The operator had fully complied with crew training and the pilots were qualified to undertake the flight.

1.18 Additional information

On April 14, 2008, the Air France Maintenance supplied to IR the outcome of the preliminary technical investigations submitted to #2 of F-GSQT, followed by the message (quoting) *“More important investigation will be performed after engine return to facilities.”*

The IR has included in the present report technical data supplied by Air France Maintenance. The event engine was initially delivered on another Air France Boeing 777 (F-GSQH). However, it was removed for LPT blade replacement and then installed on F-GSQT, on January 25, 2008.

Meanwhile, the IR has done a wider evaluation in order to determine any other similar occurrences involving Boeing 777 airplanes powered by GE engines. A few incidents involving the same type of engine were found such as in-flight engine shutdowns, engine failures and engine loss of thrust.

1.19 Useful or effective investigation techniques

None.



2. ANALYSIS

In a given part of the communication, via SATCOM between the Maintenance technicians and the Captain, it was possible to deduce that the pilot already knew that the engine #2 had some problems. Actually, about two hours after takeoff, and in the sequence of an automatic ACARS delivered by the airplane to the Orly Maintenance Centre telex, the crew was asked by Air France Maintenance to survey the engine #2 N2 vibration level and to send a manual snapshot each hour.

However, five hours after departure engine #2 experienced a self recovering stall and forced the crew to divert the flight to Lajes Airport. Air France maintenance personal verified that the HPC stages 4, 5 and 8 showed damage, some of which was out of AMM limits and that the HPC stage 4 rotor had one half blade missing. The HPC stages 1, 2 and 3 were observed with no damage.

The engine was sent to the manufacturer. SNECMA submitted the engine to lab assessments and concluded that the stage 4 HPC components had the correct microstructure, having no blade dimensional deviation. Light manufacturing marks, similar to other non-distressed blades, were within limits and there was no evidence of metallurgical defect, FOD presence or any material distress.

Probably due to the stage 4 HPC blade #44 tip corners loss, the blade vibratory response mode changed, with propagation under low dynamic level, followed by airfoil separation. The detached fragment came into contact with a Stage 4 Vane Segment, releasing one airfoil and bending another one that contacted the remaining blades, leading to distress on other components. These circumstances caused HPC loss of efficiency with increasing distress resulting in stall.

Following this incident, and based on the fact that 45 other engines have experienced tip corner loss to date, SNECMA and GE decided to issue SB #72-0270 (July 2008) recommending that Operators perform a periodic inspection of stage 3 and 4 HPC blades for tip corner loss.

Closing action has been identified and is to be incorporated at each shop visit and introduced into production the 2nd quarter of 2009. The aim is to increase the HPC stage 3 and 4 blade tip clearance in order to reduce the potential for rubs, responsible for tip corner loss.

A new applicable SB (#72-0322) will be issued in the 3rd quarter of 2009 as well.



3. CONCLUSIONS

3.1 Findings

- Both pilots were properly licensed with airline transport pilot's ratings and had valid medicals issued by the appropriate authorities and indicated no restrictions on their capabilities;
- Limits concerning crew time, flying time and rest time were complied with;
- The operator had fully complied with aircraft maintenance;
- Aircraft's technical records showed previous entries on engine #2 but with no bearing on this incident (gearbox and LPT episodes);
- There were no personal injuries to any aircraft occupants;
- Stage 4 HPC blade #44 airfoil was separated just above the blade platform;
- There was no evidence of metallurgical defect, FOD presence or any material distress to the stage 4 HPC blade #44;
- Stage 4 HPC components had the correct microstructure, no blade dimensional deviation and the manufacturing marks were within limits;
- Several stage 4 HPC blades revealed tip corner loss on leading and/or on trailing edge;
- Stage 4 HPC vane exhibited heavy damage. (Damage consistent with stage 4 HPC blade airfoil fragment going thru stage 4 HPC vane sector).

3.2 Causes

The investigation concluded that the incident on F-GSQT had its cause in the #2 engine HPC due to the stage 4 HPC blade #44 airfoil separation. The debris impacted a stage 4 vane segment causing successive damage on other HPC components. These circumstances caused HPC loss of efficiency with increasing distress resulting in a stall.



4. SAFETY RECOMMENDATIONS

Since the previously released control program (SB 72-0270) has been demonstrated to be effective in preventing HPC stage 3 and 4 separations, the IC recommends that GE:

- a. Issue SB 72-0322 as planned;
- b. Introduce the proposed increased HPC 3 and 4 blade tip clearance into production as planned.

The IC has no further safety recommendation to release.

The Investigator-in-charge

Artur A. Pereira

Lisboa, April 13, 2009.



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ACRONYMS

#	Same as “Nr”
°C	Centigrade degrees
°	Degrees
'	Minutes
”	Seconds
ABN	Aerodrome beacon
ACARS	Aircraft Communications Addressing and Reporting System
ACMS	Airplane Condition Monitoring System
AF	Air France
AIS	Aeronautical information services
ALS	Approach lighting system
AMM	Aircraft Maintenance Manual
APP	Approach
ARO	Air traffic services Reporting Office
ARP	Airport Reference Point
ASPH	Asphalt
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATPL	Airline Transport Pilot Licence
BEA	<i>Bureau d'Enquêtes et d'Analyses</i>
CAT	Category
CAVOK	Ceiling And Visibility OK
CH	Channel
CMCF	Central Maintenance Computer Function
CPDLC	Controller Pilot Data Link Communications
CONC	Concrete
CPL	Commercial Pilot License
CRZ	Cruise
CUST	Customs
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance measuring equipment
ELEV	Elevation
DGAC	<i>Direction Général de l'Aviation Civile</i> (French aviation authority)
DMS	Data Management System
ENG	Engine
FAF	Final approach fix
FT	Feet
Fig	Figure
FIR	Flight Information Region
FL	Flight Level
Flg	Flashing
FOD	Foreign Object Damage
EGT	Exhaust Gas Temperature
ER	Extended Range
G	Green
GE	General Electric
GP	Glide Path



GPIAA	<i>Gabinete de Prevenção e Investigação de Acidentes com Aeronaves</i> (Portuguese Air Accident Investigation Branch)
GS	Glide Slope
H	Hours
HF	High Frequency
HLDG	Holding
HPC	High Pressure Compressor
IAF	Initial Approach Fix
IC	Investigator in Charge
ICAO	International Civil Aviation Organization
IF	Intermediate Approach Fix
ILS	Instrument Landing System
INCID	Incident
INOP	Inoperative
INTERS	Intersection
KIAS	Knots Indicated Airspeed
Kg	Kilograms
KT	KNOT(S)
L	Left
Lb	Pounds
LIM	Limit
LPT	Low Pressure Turbine
MAPT	Missed approach point
MAX	Maximum
MCC	Maintenance Control Computer
MET	Meteorological or Meteorology
Min	Minute
MSA	Minimum Sector Altitude
N	North
N/A	Not Available
NDF	No Deficiency Found
NM	Nautical Miles
Nr	Number
NTSB	National Transportation Safety Board
NYC	New York
PAPI	Precision Approach Path Indicator
PC	Pavement Classification
PCN	Pavement Classification Number
POB	People On Board
PSI	Pound per Square Inch
QFU	Aviation Q-code for Magnetic Heading of a Runway
QTE	True line of position from a direction-finding station
QNH	Altitude above mean sea level based on local station pressure
R	Radial
R	Right (Followed by three figures)
RWY	Runway
SARP	Standard And Recommended Practices
SATCOM	Satellite Communications
SB	Service Bulletin
Sec	Second(s)
SMC	Surface Movement Control
S/n	Serial Number
SNECMA	<i>Société Nationale d'Etudes et de Construction de Moteurs d'Aviation</i>
SWY	Stopway
TACAN	UHF Tactical Air Navigation Aid



TCH	Threshold crossing height
TDZ	Touchdown zone
TERPS	Terminal Procedures
THR	Threshold
TRM	Track Magnetic
TWY	Taxiway
UTC	Universal Time Coordinated
VAR	Variation
VIS	Visibility
W	White
W	West