ANSV AGENZIA NAZIONALE PER LA SICUREZZA DEL VOLO

Our ref. ANSV 1147/19

To EASA

Cc FAA

Deputy Director
Accident Investigation and Prevention
Washington, DC

Subject: serious incident occurred on the 10th of August 2019, at Rome Fiumicino airport (Italy), to B787-8 registration marks LN-LND. ANSV safety recommendations.

1. Foreword.

On the 10th of August 2019 the B787-8 registration marks LN-LND (picture 1), flight DY7115, planned FCO-LAX, took off from runway 16R at 14.45.35 UTC.
At 14.46.11 UTC, after 36" being airborne, at a height of about 1200 ft and 200 kts groundspeed (figure 1), over the city of Fiumicino, the flight data recorder provided information the "Eng1_Vib_Warn" (left engine vibration warning) discrete parameter activated, followed shortly by several other fault messages. These are in line with the crew declaration about receiving "EEC MODE L", "LOSS OF TPR L", "ENG L EGT RED" (UTC 14.46.14), "ENG LIMIT EXCEED L" (UTC 14.46.16) and "OVERHEAT ENG L" (UTC 14.46.20) messages. The crew commanded the In-Flight Shut Down (IFSD) of the left engine and elected to turn back to departure airport (ground track in figure 2). An overweight one engine inoperative (OEI) landing took place at 15.10.10 UTC.
About 4 kg of debris (mainly fragments of turbine blades, picture 2) coming from the left engine were recovered from the streets of Fiumicino (the city nearby the airport, detail in the red rectangle in figure 3), along the direction of the runway, where several damages to buildings and cars were reported by the population. No debris were found within the airport area.
The B787-8 LN-LND was equipped with two Rolls Royce Trent 1000 G/01A. After the event, the left engine (the one that failed) did not show externally any particular sign of damage, except for the last turbine stage that was heavily damaged and blade fragments were found in the tailpipe (picture 3). The aircraft showed multiple holes and impact marks underneath the n° 2 flaps, flap fairing and on the horizontal stabilizer (pictures 4/8). Some minor dents were also found on the fuselage (picture 9). The left main landing gear tires deflated due to the hot-braking as a consequence of the overweight landing (picture 10). Complete assessment of the damage level of the aircraft is still on-going at the date this ANSV document is issued.
The Italian Civil Aviation Safety Investigation Authority (ANSV) classified the event as serious incident and launched a safety investigation. The event was notified to the States of the aircraft manufacturer (US, NTSB), of the engine design (Germany, BFU), of the engine manufacturer (UK, AAIB) and to the State of the operator (Norway, AIB). All the above

appointed an accredited representative. The NTSB appointed Boeing as technical adviser, the UK AAIB and the BFU appointed Rolls Royce as technical adviser, Norway AIB appointed the operator Norwegian as technical adviser. EASA also appointed a technical adviser to the Italian investigator-in-charge, in accordance with Regulation (EU) 996/2010.

Picture 1: Fiumicino airport, B787-8 LN-LND.

Figure 1: selection of EAFR data, red line 14.46.11 UTC.

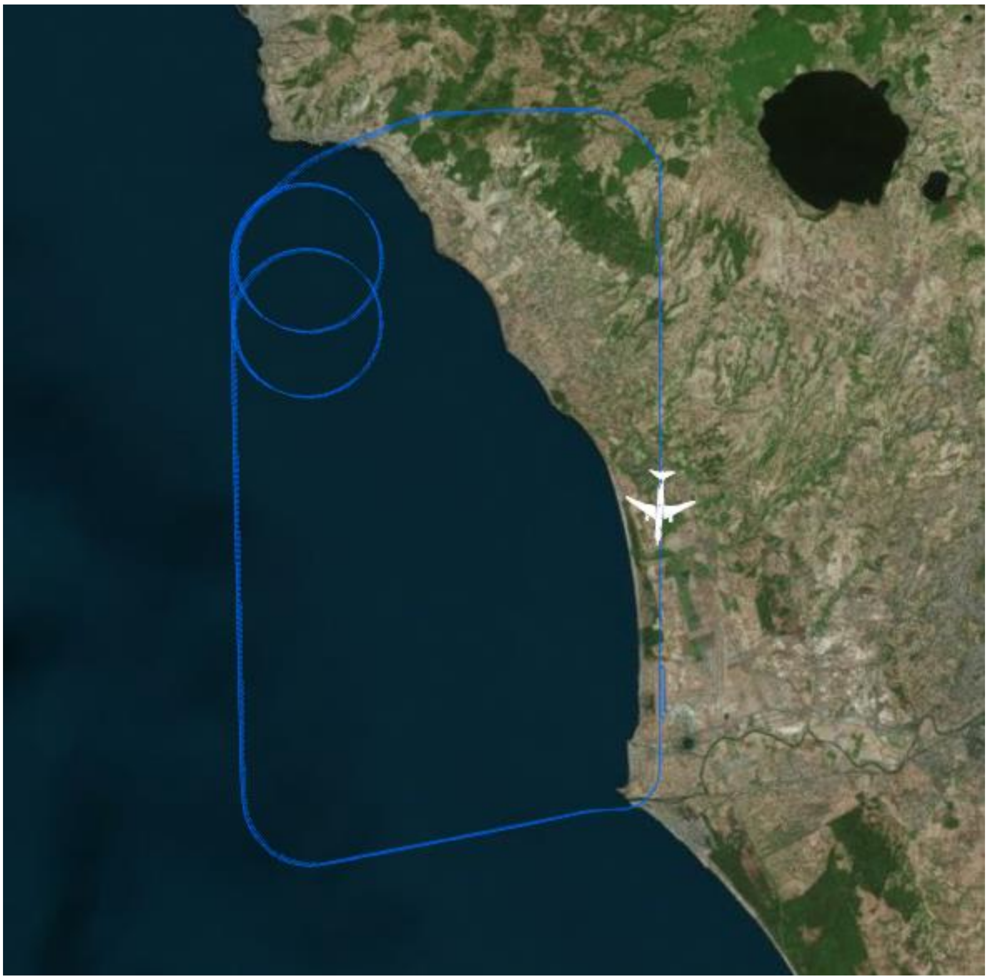


Figure 2: ground track (EAFR data).

Picture 2: debris collected in the streets of the city nearby the airport, Fiumicino.

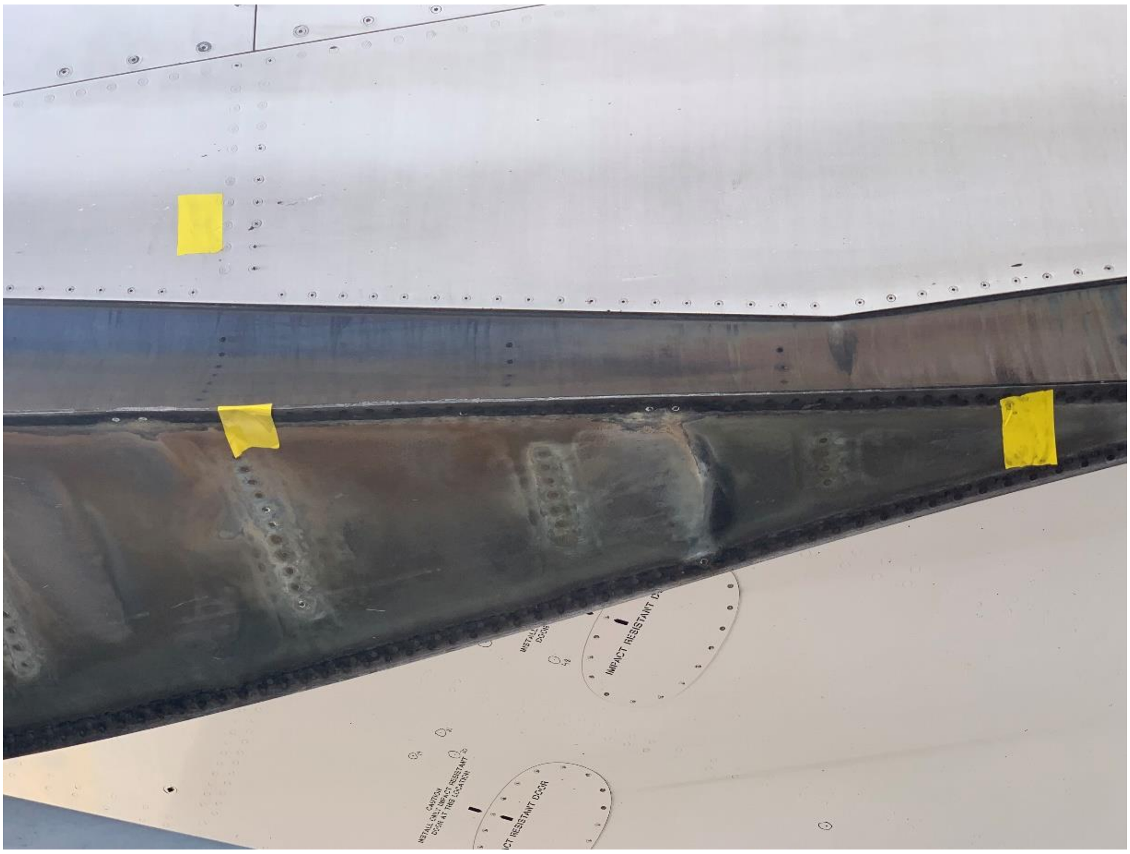
Figure 3: position of the aircraft at the activation of the FDR discrete parameter "Eng1_Vib_Warn"; details of the streets around that area, where debris from the left engine were collected.

Picture 3: external evidence of left engine damage.

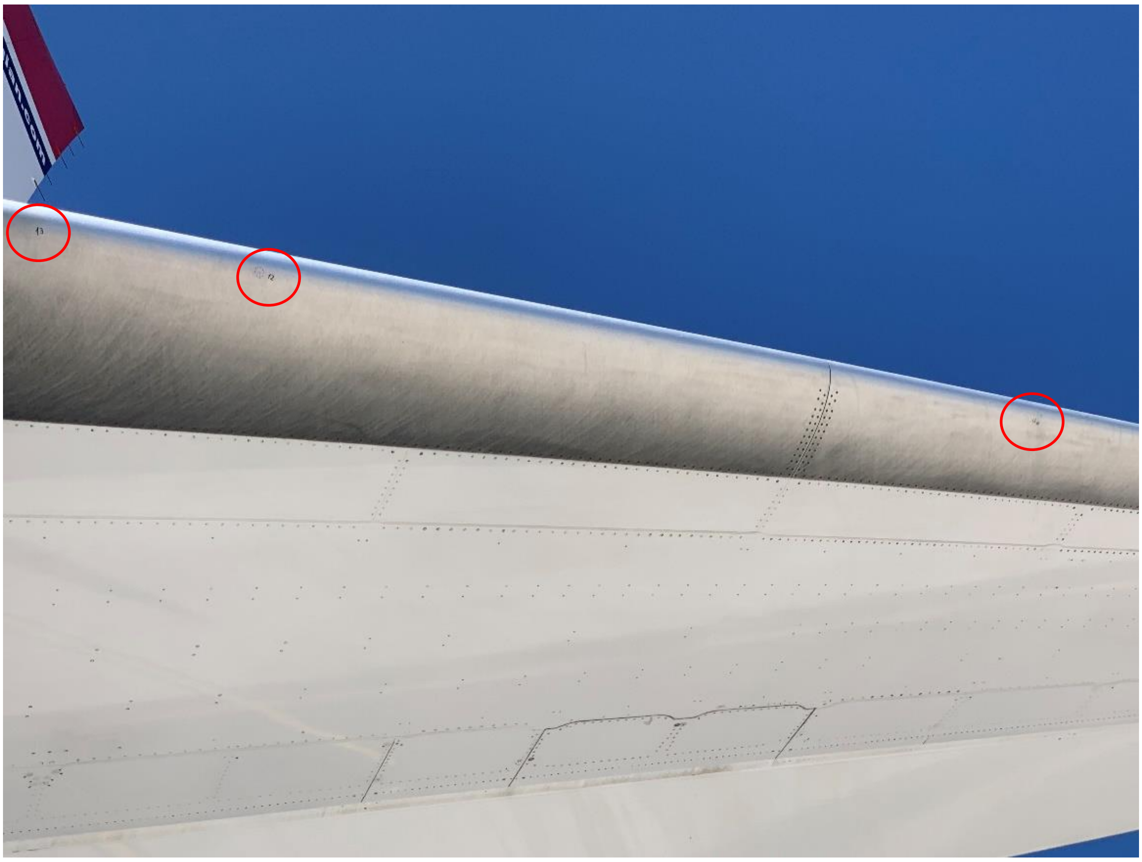
Picture 4: aircraft damage.

Picture 5: aircraft damage.

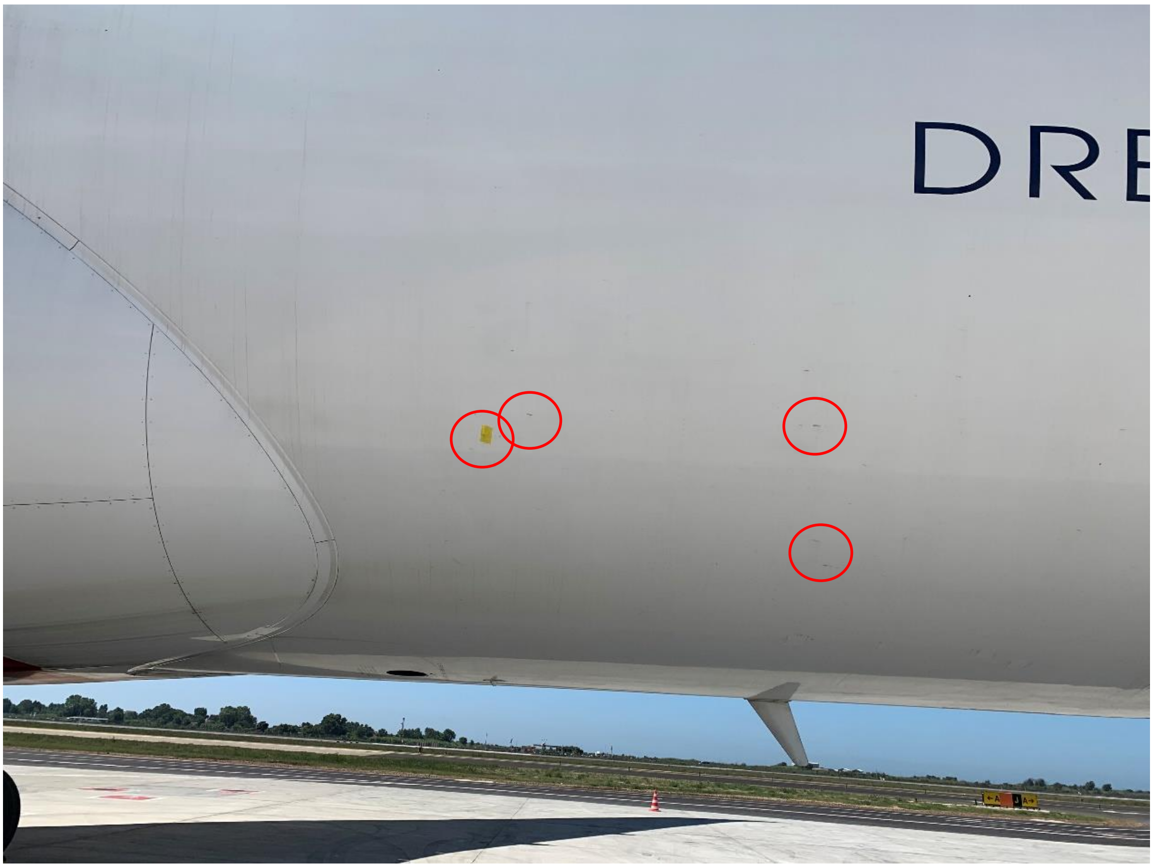
Picture 6: aircraft damage.



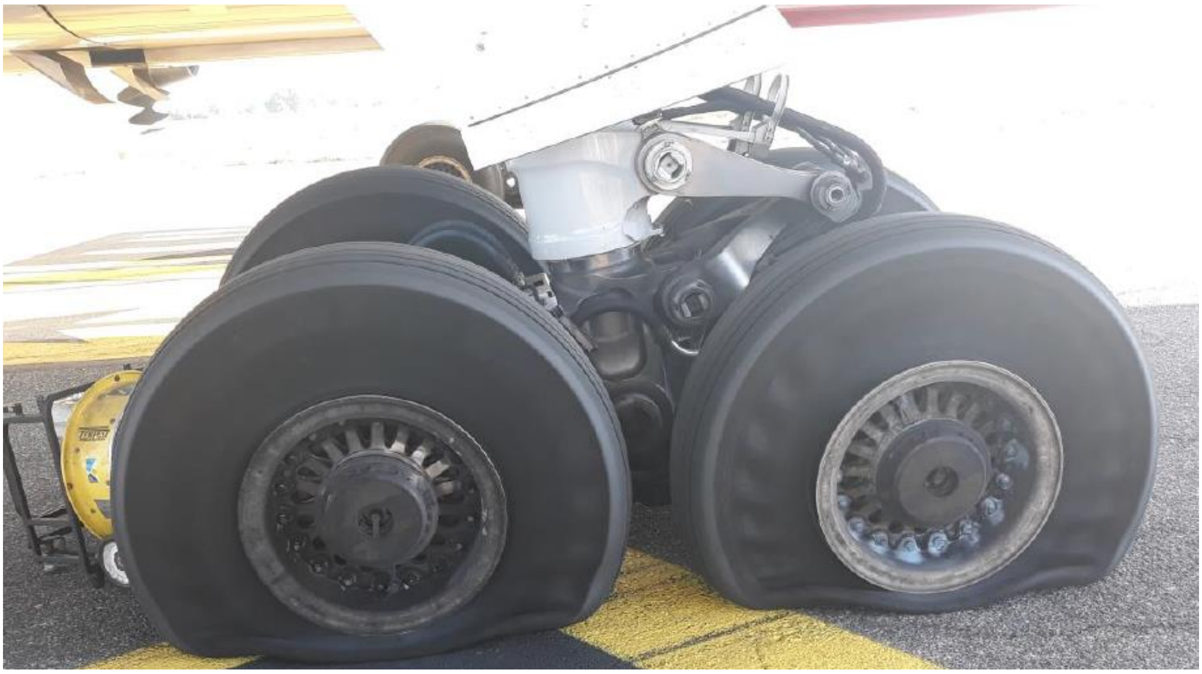
Picture 7: aircraft damage.



Picture 8: aircraft damage, horizontal stabilizer.



Picture 9: aircraft damage, fuselage.



Picture 10: deflated left landing gear tires.

2. Preliminary Data Analysis.

Following the event, data were downloaded on site from the Engine Monitoring Unit (EMU) and from the Continuous Parameter Log (CPL). The Enhanced Airborne Flight Recorders (EAFR, picture 11) were downloaded at the ANSV laboratories.

The preliminary analysis of the EAFR data shows that at 14.46.05 UTC (about 6 s before the "Eng1_Vib_Warn" discrete parameter activation) an abrupt decrease of left engine N1 (from 90% to less than 60%, figure 4). At the same time, left engine N2 and N3, oil temperature and pressure slightly increased (figure 5). From the point onward the overall vibration level of the left engine increased (figure 6/7). The left engine IFSD was commanded by the crew at 14.48.06 UTC. The engine manufacturer reviewed the EMU (5 Hz sampling rate) data, confirming the above evidence as well as highlighting, in addition, that the behavior of the engine was compatible with an Intermediate Pressure Turbine (IPT) blade damage. In more detail, the EMU data shows that the drop in N1 happened after IP tracked order vibration increased (as a result of the IPT blade release). Therefore, the most likely sequence of events is (figure 8):

- IPT blade release resulting in IP tracked order vibration increase;
- IPT blade release causes downstream damage to the LP turbine and a reduction in LP shaft speed and increase in LP tracked order vibration;
- the engine control system then attempts to restore power before the pilot shuts down the engine.

No significant variations in the vibration level or other engine related parameters were recorded from the left engine prior to the event.

Picture 11: EAFRs from the B787-8 marks LN-LND.

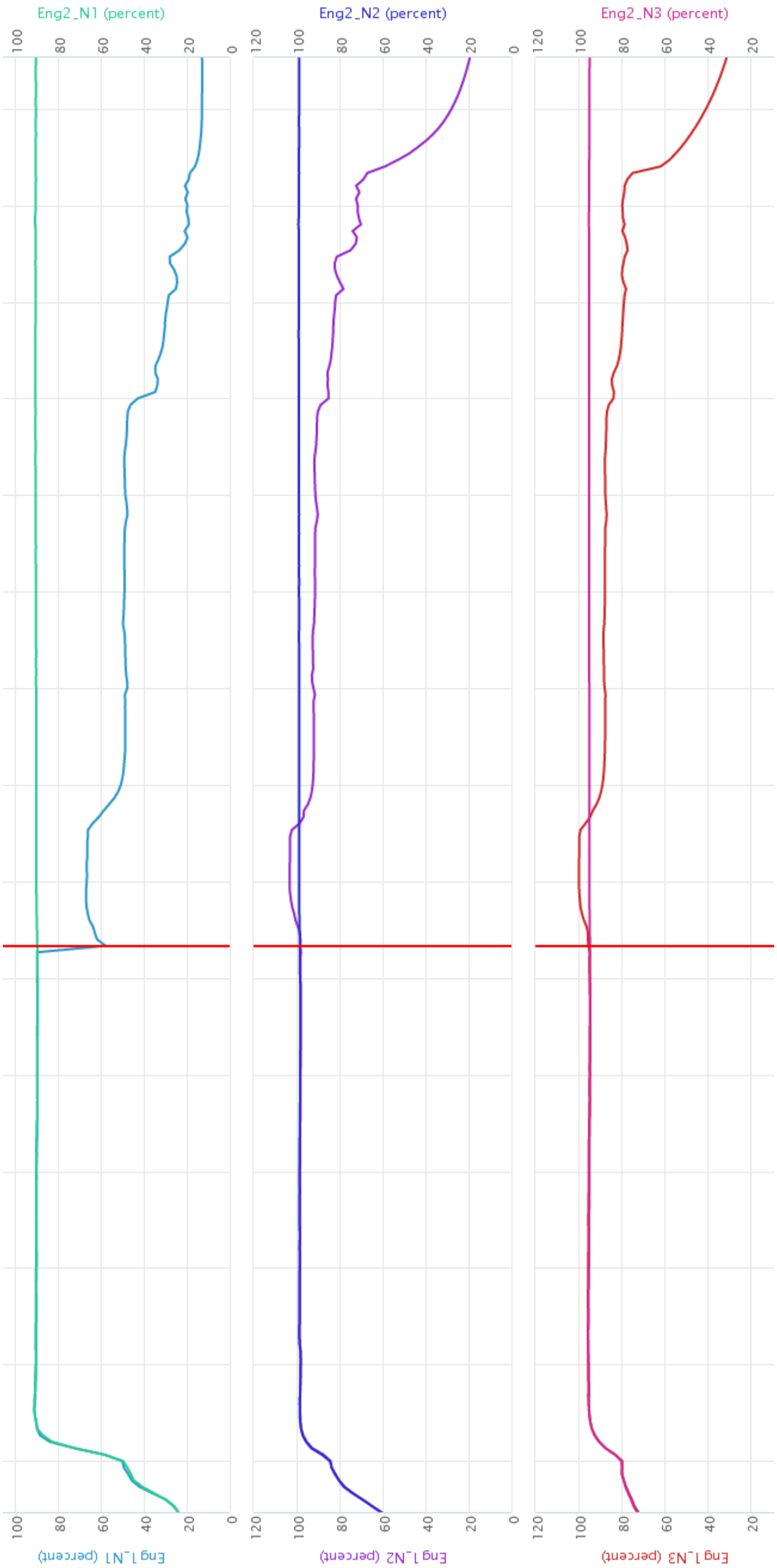


Figure 4: selection of EAFR data, red line 14.46.05 UTC, comparison of ENG1 (left) and ENG2 (right).

Figure 5: selection of EAFR data, red line 14.46.05 UTC, comparison of ENG1 (left) and ENG2 (right).

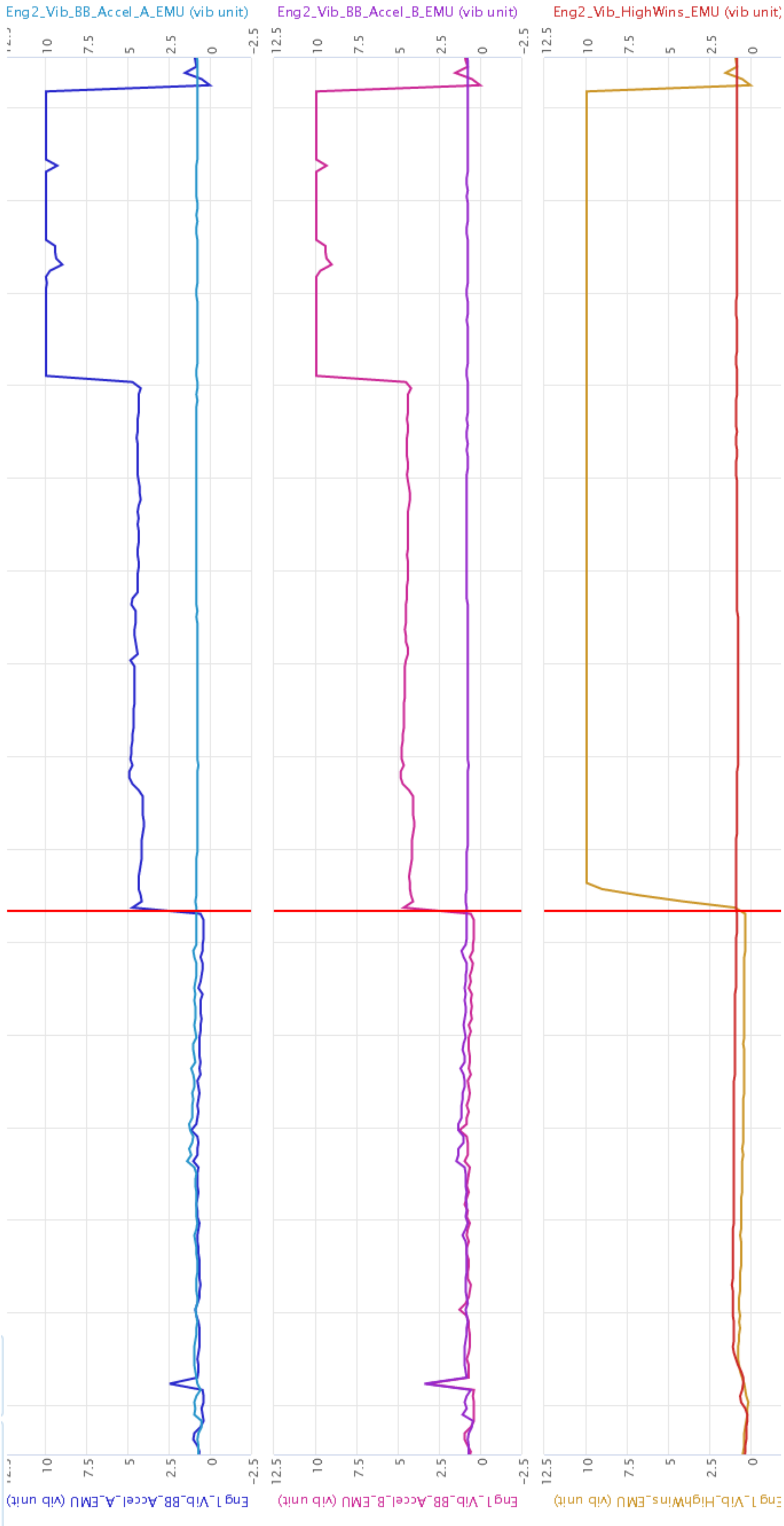


Figure 6: selection of EAFR data, red line 14.46.05 UTC, comparison of ENG1 (left) and ENG2 (right).

Figure 7: selection of EAFR data, red line 14.46.05 UTC, comparison of ENG1 (left) and ENG2 (right).

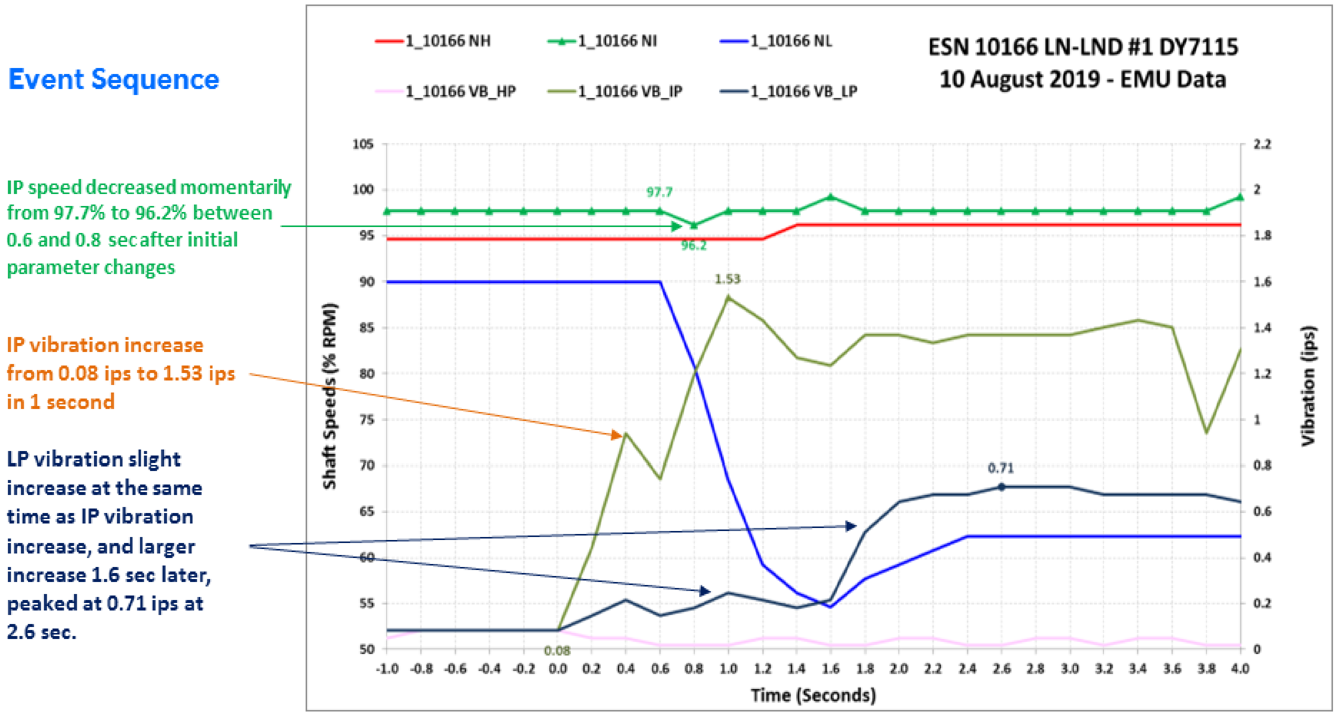


Figure 8: EMU data analysis (source Rolls-Royce).

3. Left engine borescope inspection.

Borescope inspection of the left engine revealed as main evidence the failure of two adjacent blades (picture 12 left) in the IPT stage (figure 9) and consequent damages in the following stages, confirming the preliminary data analysis. The fracture surface of one of the two IPT blades fractured appears to be a progressive failure (picture 12 right). The trailing blade, also fractured, appears to be an overload failure.

Picture 12: fracture surfaces of the IPT blades found broken.

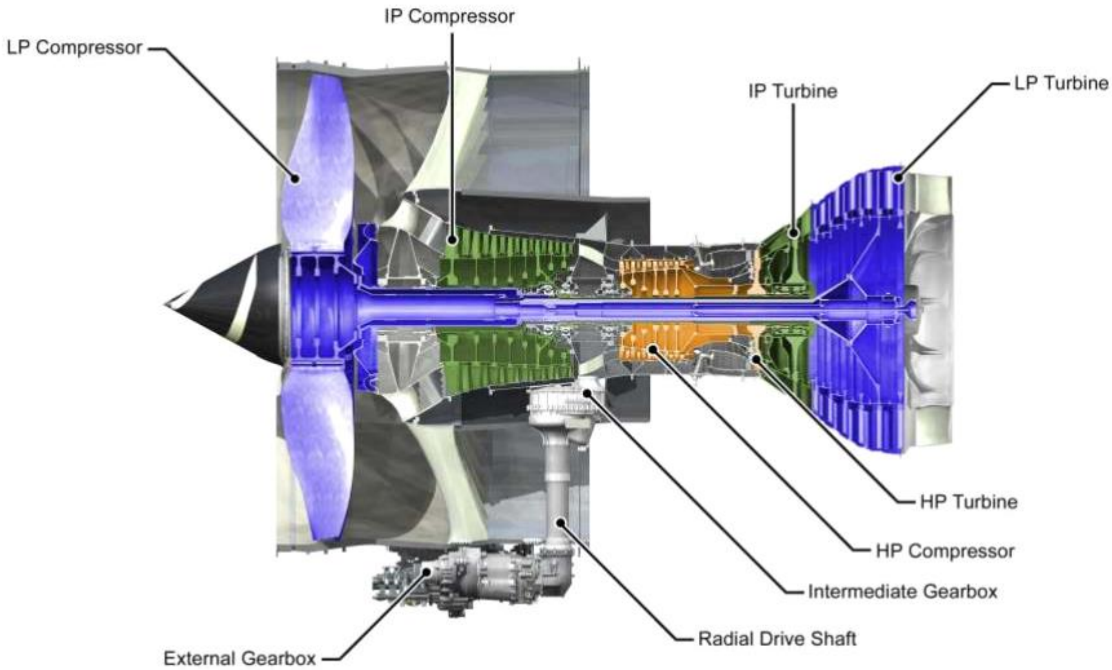


Figure 9: TRENT 1000, schematic view (source Rolls-Royce).

4. Previous known similar cases.

Since 2015 there have been 10 previous cases of IPT blade (IPTB) progressive fractures. The failure mechanism has been recognized as corrosion-fatigue due to sulphidation (picture 12 right). The appearance of the fracture surface from the IPT blade of the Trent 1000 G/01A SN 10166, left engine of the B787-8 registration marks LN-LND in the flight of the event, appears to be consistent with this kind of fracture mechanism. Following a table reporting the 11 cases in total.

	Event Date	ESN	IPTB FC	IPTB Life	IPTB Failure mechanism
1	21st Oct 2015	10159	1409	*Pre NMSB 72-AK186	Corrosion fatigue
2	22nd Feb 2016	10079	1984	*Pre NMSB 72-AK186	Corrosion fatigue
3	3rd Mar 2016	10072	2739	*Pre NMSB 72-AK186	Corrosion fatigue
4	18th Mar 2016	10179	1370	*Pre NMSB 72-AK186	Corrosion fatigue
5	20th Aug 2016	10176	4849	*Pre NMSB 72-AK186	Corrosion fatigue
6	11th Feb 2017	10209	2145	*Pre NMSB 72-AK186	Corrosion fatigue
7	5th Dec 2017	10231	1545	*Pre NMSB 72-AK186	Corrosion fatigue
8	6th Dec 2017	10227	1455	*Pre NMSB 72-AK186	Corrosion fatigue
9	6th Jul 2018	10086	3184	*Pre NMSB 72-AK186	Corrosion fatigue
10	15th May 2019	10202	1440	1455	(Fracture looks like others)
11	10th Aug 2019	10166	1210	1410	(Fracture looks like others)

***NMSB 72-AK186 introduced blade hard life in October 2018**

All failed blades are pre-modification SB 72-H818

Table 1: previous known similar cases (source Rolls-Royce).

Investigation of the 7th event engine found damage to the Low Pressure Turbine drive arm, which could, if ruptured, cause an LPT stage 1 overspeed, burst and uncontained high energy debris.

The Trent 1000 Series Service Bulletin 72-H818 introduces a modified IPT blade which uses a different parent material and coating composition. At the moment this ANSV document is issued, the tests programmed to evaluate the effectiveness of the modification have provided satisfactory results against the premature failure of the IPT blades. However, testing is a continuous process involving sampling from the in-service fleet.

A fixed blade hard life was introduced in October 2018 by means of the Alert NMSB Trent 1000 72-AK186, mandated by EASA Airworthiness Directive (AD) 2018-0257 (later superseded by AD 2019-0135), in order to manage the in-service engines with pre-mod SB 72-H818 blades until the modification could be applied to all the engines. This life limit is different for different groups of serial numbers based on statistical models – derived from extensive blade sampling and fleet data analysis – from the engine manufacturer. For the engines of the B787-8 marks LN-LND the life limits are listed in the following paragraph.

5. Engines log data.

ESN 10166 (#1 Posn, left, the one failed in the subject event)

- Time Since New: 21193:20 hrs.
- Cycles Since New: 2470 cyc.
- Time since installation: 5298:48 hrs.
- Cycles since IPT module installation: 1210 cyc.
- IPT blades life limit as per EASA AD 2019-0135: 1410 cyc.
- Remaining life at the time of the event: 200 cyc.

ESN 10140 (#2 Posn, right)

- Time Since New: 22438:17 hrs.
- Cycles Since New: 2636 cyc.
- Time since installation: 1880:18 hrs.
- Cycles since IPT module installation: 1337 cyc.
- IPT blades life limit as per EASA AD 2019-0135: 1440 cyc.
- Remaining life at the time of the event: 103 cyc.

6. EASA Airworthiness Directives

In order to cope with the IPT blade release events, EASA issued in the last 2 years 6 Airworthiness Directives:

1. AD 2017-0056 – Engine – Intermediate Pressure Turbine Blades – Inspection / Replacement;
2. *Emergency* AD 2017-0253-E – Engine – Removal / De-Pairing;
3. AD 2018-0086 – Engine – Removal / De-Pairing;
4. AD 2018-0139 – Engine – Removal / De-Pairing;
5. AD 2018-0257 – Engine – Intermediate Pressure Turbine Blades – Replacement;
6. AD 2019-0135 (dated 11-06-2019) – Engine – Intermediate Pressure Turbine Blades – Replacement.

Three of the above reflect fleet management strategies, while ADs 2018-0086, 2018-0139 and 2019-0135 update applicability and do not result from in-service events. At the time of the B787-8 marks LN-LND event there was only the last AD applicable to these blades. The other ADs in this list have all either expired or been superseded.

Prior to the issue of NMSB 72-AK186, NMSB 72-AJ992 instructed a de-pair life in order to protect against risk of Dual In-Flight Shut Down (DIFSD). However, when 72-AK186 was introduced to mitigate the potential progression to hazard, the blade hard life required for that purpose was significantly less than the de-pair life requirement (i.e. the life at which engines would have had to be departed to mitigate a DIFSD risk). Rolls-Royce therefore agreed with EASA to remove the de-pair requirement. Hence, AD 2018-0139 was superseded by AD 2018-0257 and, following, by the AD 2019-0135.

The engines involved in the LN-LND event are both pre-mod 72-H818 standard and, at the time this ANSV document is issued, there is no requirement for de-pairing pre-mod 72-H818 engines.

7. Safety Recommendations.

Based on the information gathered up to now, the ANSV considers as necessary to issue the following safety recommendations for the immediate consideration of EASA.

Type of safety recommendations: SRGC/SRUR.

Motivation: the borescope inspection of the engine Trent 1000 G/01A SN 10166, performed after the IFSD event occurred to the B787-8 registration marks LN-LND, highlighted the fracture of two IPT blades. One of these is attributable to the same corrosion fatigue fracture mechanism that was responsible for ten previous cases of IFSD in the Trent 1000 fleet. In one of those cases, in addition to IFSD the blade release also caused damage on the LPT drive arm, proving further negative effects on safety could be possible as a consequence of a IPT blade fracture beside what happened in the B787-8 marks LN-LND event, in which damages to the aircraft and to objects on the ground were recorded. Indeed, for this matter EASA has already recognized the need to maintain fleet safety and has mandated several Rolls-Royce recommended safety actions in the last two years through 6 ADs, the latest and only live action being issued in NMSB 72-AK186, which instructs a hard life for pre-modification blades and is mandated by EASA AD 2019-0135. However, the in-flight IPT blade failure of the Trent 1000 G/01A SN 10166 happened 200 flight cycles before the hard life limit, demonstrating this not sufficient to avoid detrimental effects on safety.

Recipient: EASA.

Safety Recommendation ANSV-9/1147-19/1/I/19.
To take immediate actions to achieve an higher level of safety, also taking in consideration, but not limiting EASA initiatives to, defining different and more stringent time limits for the Trent 1000 pre-mod 72-H818 IPT blades.

Safety Recommendation ANSV-10/1147-19/2/I/19.
To re-evaluate the whole validity of the service management adopted by the manufacturer for the Trent 1000 pre-mod 72-H818 IPT blades, endorsed by the AD 2019-0135.

Type of safety recommendation: SRGC/SRUR.

Motivation: the borescope inspection of the engine Trent 1000 G/01A SN 10166, performed after the IFSD event occurred to the B787-8 registration marks LN-LND, highlighted the fracture of two IPT blades. One of these is attributable to the same corrosion fatigue fracture mechanism that was responsible for ten previous cases of IFSD in the Trent 1000 fleet. In one of those cases, in addition to IFSD the blade release also caused damage on the LPT drive arm, proving further negative effects on safety could be possible as a consequence of a IPT blade fracture beside what happened in the B787-8 marks LN-LND event, in which damages to the aircraft and to objects on the ground were recorded. Indeed, for this matter, EASA has already recognized the need to maintain fleet safety and has mandated several Rolls-Royce recommended safety actions in the last two years through 6 ADs, the latest and only live action being issued in NMSB 72-AK186, which instructs a hard life for pre-modification blades and is mandated by EASA AD 2019-0135. The in-flight IPT blade failure of the Trent 1000 G/01A SN 10166 happened 200 flight cycles

before the hard life limit, demonstrating this not sufficient to avoid detrimental effects on safety. The right engine of the B787-8 marks LN-LND Trent 1000 G/01A SN 10140, was also a pre-mod 72-H818, having less flight cycles remaining than the left engine (103 FCs remaining).
Since the life limit imposed has been proved to be not adequate to prevent the left engine Trent 1000 G/01A S/N 10166 to fail, as well as the engine S/N 10202 to fail (15th of May 2019 (see table 1) and at the time this ANSV document is issued, there is no requirement for de-pairing pre-mod 72-H818 engines, there was the possibility also that the right engine could have failed. In addition, in case of one engine inoperative the engine that remains operative undergoes overall higher solicitations. This would increase the probability of a DIFSD.

Recipient: EASA.

Safety Recommendation ANSV-11/1147-19/3/I/19.
To evaluate provisions relevant to the de-pairing of pre-mod 72-H818 engines, avoiding two engines of the same pre-mod status being installed on the same aircraft, thus further lessening the possibility of a DIFSD.