ANSV AGENZIA NAZIONALE PER LA SICUREZZA DEL VOLO

PRELIMINARY REPORT

SERIOUS INCIDENT
aircraft B787-8 registration marks LN-LND,
Rome Fiumicino International Airport (Italy),
10th of August 2019

PRELIMINARY REPORT
SERIOUS INCIDENT
Boeing B787-8 registration marks LN-LND

ANSV safety investigations are conducted in accordance with Annex 13 to the Convention on International Civil Aviation and EU Regulation No 996/2010. The sole objective of the safety investigation of an accident or incident under these Regulations is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability. Accordingly, it is inappropriate that ANSV reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

This Preliminary Report is published to provide details of the initial facts. It contains facts which have been determined up to the time of issue and contains neither conclusions nor safety recommendations. It is published to inform the aviation industry and the public of the general circumstances of the accident and should be regarded as tentative and subject to alteration or correction if additional evidence becomes available. The investigation is continuing and a final report will be published in due course.

Aircraft Type and Registration	Boeing B787-8 registration marks LN-LND (photo 1).
Date & Time (UTC)[1]	10th of August 2019, 14.46'.
Location	Rome Fiumicino International Airport (LIRF).
Description of Occurrence	IFSD[2].
Type of Flight	CAT[3].
Persons on Board	298: 3 pilots, 9 cabin crew, 286 passengers.
Injuries	None.
Nature of Damage	Aircraft: left engine exhaust cone, left wing, left flap fairing, left horizontal stabilizer, fuselage left side, left main landing gear tires (photos 2-9). On ground (Fiumicino, city nearby the airport): damage to 28 cars (mainly broken windows), and 3 awnings (holes).
Pilot in Command	Age 49 years, male, Austrian. ATPL (A)[3]. B777, B787 Rating, Instrument Rating. Class 1 Medical Certificate. Total flight experience 12.903h; 1393h on the B787.
Relief Captain	Age 37 years, male, German. ATPL (A). B777, B787 Rating, Instrument Rating.

[1] UTC: Universal Time Coordinated. Local time, at the time of accident, was UTC+2 hour.
[2] IFSD: In-Flight Shut Down.
[3] CAT: Commercial Air Transport.
[3] ATPL (A): Airline Transport Pilot Licence (Aeroplane).

Class 1 Medical Certificate.
Total flight experience 8356h; 673h on the B787.

Co-pilot

Age 29 years, male, Danish.
ATPL (A).
B777, B787 Rating, Instrument Rating.
Class 1 Medical Certificate.
Total flight experience 2882h; 953h on the B787.

Aircraft Information

Boeing B787-8, S/N[5] 35310, MTOM[6] 227.930 kg.

Weather Conditions

Following the METAR[7] at the time of the serious incident.

101220 METAR LIRF 101220Z 27009KT CAVOK 33/20 Q1015 NOSIG=
101250 METAR LIRF 101250Z 27012KT CAVOK 31/23 Q1015 NOSIG=
101320 METAR LIRF 101320Z 27011KT CAVOK 31/22 Q1015 NOSIG=
101350 METAR LIRF 101350Z 27010KT CAVOK 32/22 Q1015 NOSIG=
101420 METAR LIRF 101420Z 28012KT CAVOK 31/20 Q1015 NOSIG=
101450 METAR LIRF 101450Z 28012KT CAVOK 30/21 Q1015 NOSIG=
101520 METAR LIRF 101520Z 29010KT CAVOK 30/21 Q1015 NOSIG=
101550 METAR LIRF 101550Z 29011KT CAVOK 30/22 Q1015 NOSIG=
101555 METAR LIRF 101550Z NIL=
101555 METAR LIRF 101550Z 29011KT CAVOK 30/22 Q1015 NOSIG=

Narrative

On the 10th of August 2019 the B787-8 registration marks LN-LND, 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 about 1200 ft ground and 200 kts groundspeed (figure 1) over the city of Fiumicino, the FDR[8] 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 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 15.10'10" UTC.
About 4 kg of debris (mainly fragments of turbine blades, photo 10) 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)

[5] S/N or SN: Serial Number.
[6] MTOM: Maximum Take Off Mass.
[7] METAR: Aviation routine weather report.
[8] FDR: Flight Data Recorder.

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 (photo 2). The aircraft showed multiple holes and impact marks underneath the n° 2 flaps, flap fairing and on the horizontal stabilizer (photos 3/7). Some minor dents were also found on the fuselage (photo 8). The left main landing gear tires deflated due to the hot-braking as a consequence of the overweight landing (photo 9). At the date this ANSV document is issued, the aircraft has not returned in service yet.

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[9]), of the engine design (Germany, BFU[10]), of the engine manufacturer (UK, AAIB[11]) and to the State of the operator (Norway, AIB[12]). 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[13] also appointed a technical adviser to the Italian investigator-in-charge, in accordance with Regulation (EU) 996/2010.

Preliminary Data Analysis

Following the event, data were downloaded on site from the EMU[14] and from the CPL[15]. The EAFR[16] (photo 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 "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, slightly increased left engine N2 and N3, oil temperature and pressure (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 IPT[17] 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

[9] NTSB: National Transportation Safety Board.
[10] BFU: Bundesstelle für Flugunfalluntersuchung.
[11] UK AAIB: UK Air Accident Investigation Branch.
[12] AIB: Accident Investigation Board.
[13]EASA: European Union Aviation Safety Agency.
[14] EMU: Engine Monitoring Unit.
[15] CPL: Continuous Parameter Log.
[16] EAFR: Enhanced Airborne Flight Recorders.
[17] IPT: Intermediate Pressure Turbine.

increase;
- IPT blade release causes downstream damage to the Low Pressure (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.

Left engine borescope inspection

Borescope inspection of the left engine revealed as main evidence the failure of two adjacent blades (photo 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 (photo 12 right). The trailing blade, also fractured, appears to be an overload failure.

Right engine borescope inspection

Borescope inspection of the right engine did not highlight any damage. Some erosion signs were found in the High Pressure Turbine blades within the acceptable limits for serviceability[18].

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. The appearance of the fracture surface from the IPT blade of the Trent 1000 G/01A S/N 10166 (photo 12 right), 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. Including the LN-LND event, there have been 11 cases in total (table 1).
Investigation of the 7th event engine found damage to the LPT[19] drive arm, which could, if ruptured, cause an LPT stage 1 overspeed, burst and uncontained high energy debris.
The Trent 1000 Series SB[20] 72-H818 introduces a modified IPT blade which uses a different parent material and coating composition. At the moment this ANSV report 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[21] TRENT1000 72-AK186, mandated by EASA AD[22] 2018-0257 (later superseded by AD 2019-0135), in order to manage the in-service engines with pre-mod SB 72-

[18] Reference: *Aircraft Maintenance Manual B787-A-R72-00-00-20B-280C-A.*
[19] LPT: Low Pressure Turbine.
[20] SB: Service Bulletin.
[21] NMSB: Non-Modification Service Bulletin.
[22] AD: Airworthiness Directive.

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 in force at the time of the event are listed in the following paragraph.

Engines log data

ESN[23] *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.

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

[23] ESN: Engine Serial Number.

DIFSD[24]. 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.

Safety Recommendations

Based on the information listed above, on August the 29th 2019 the ANSV considered as necessary to issue the following safety recommendations.

Type of safety recommendations: SRGC[25]/SRUR.[26]

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,

[24] DIFSD: Dual In-Flight Shut Down.
[25] SRGC: Safety Recommendation of Global Concern.
[26] SRUR: Safety Recommendation of Union-wide Relevance.

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 engine of the same pre-mod status being installed on the same aircraft, thus further lessening the

possibility of a double IFSD.

Safety Actions

In accordance with Regulation (EU) 996/2010 article 18 para 1 and ICAO Annex 13 prevision 6.10, the addressee of a safety recommendation shall inform the safety investigation authority which issued the recommendation within 90 days of the actions taken or under consideration, and where appropriate, of the time necessary for their completion and where no action is taken, the reasons therefor.
At the time this ANSV report is issued, 90 days have not passed yet; however, on September the 19th 2019, the engine manufacturer issued the revision 3 to NMSB TRENT1000-72-AK186, that reduces the IPTB life limits for specified Engine Serial Numbers and limits the terminating action to embodiment of SB 72-H818 or SB 72-J559 only.
The above NMSB was endorsed by EASA by means of AD 2019-0261 "ATA 72 − Engine – Intermediate Pressure Turbine Blades – Replacement", issued on October the 18th 2019.

Further Investigation

The ANSV safety investigation continues exploring:

- ESN 10166 tear down;
- ESN 10140 IPT blades tear down;
- failure analysis of a selection of IPT blades from ESN 10166 and 10140, including the one showing progressive characteristics from the ESN 10166;
- failure analysis other engine parts from ESN 10166, possibly related to the cause of the event;
- emergency management (crew, ATC[27], airport operator);
- certification and continuous airworthiness criteria.

[27] ATC: Air Traffic Control.

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

Photo 2: external evidence of left engine damage.

Photo 3: aircraft damage.

Photo 4: aircraft damage.

Photo 5: aircraft damage.

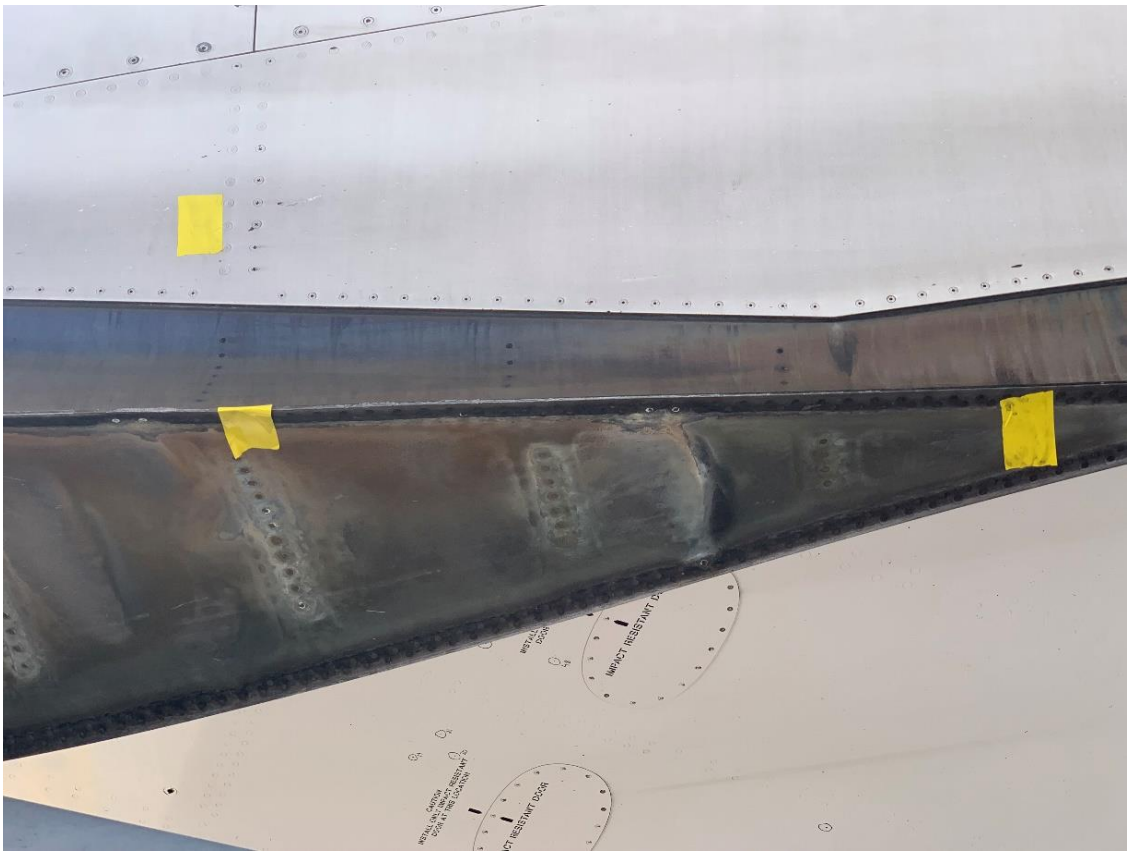
Photo 6: aircraft damage.

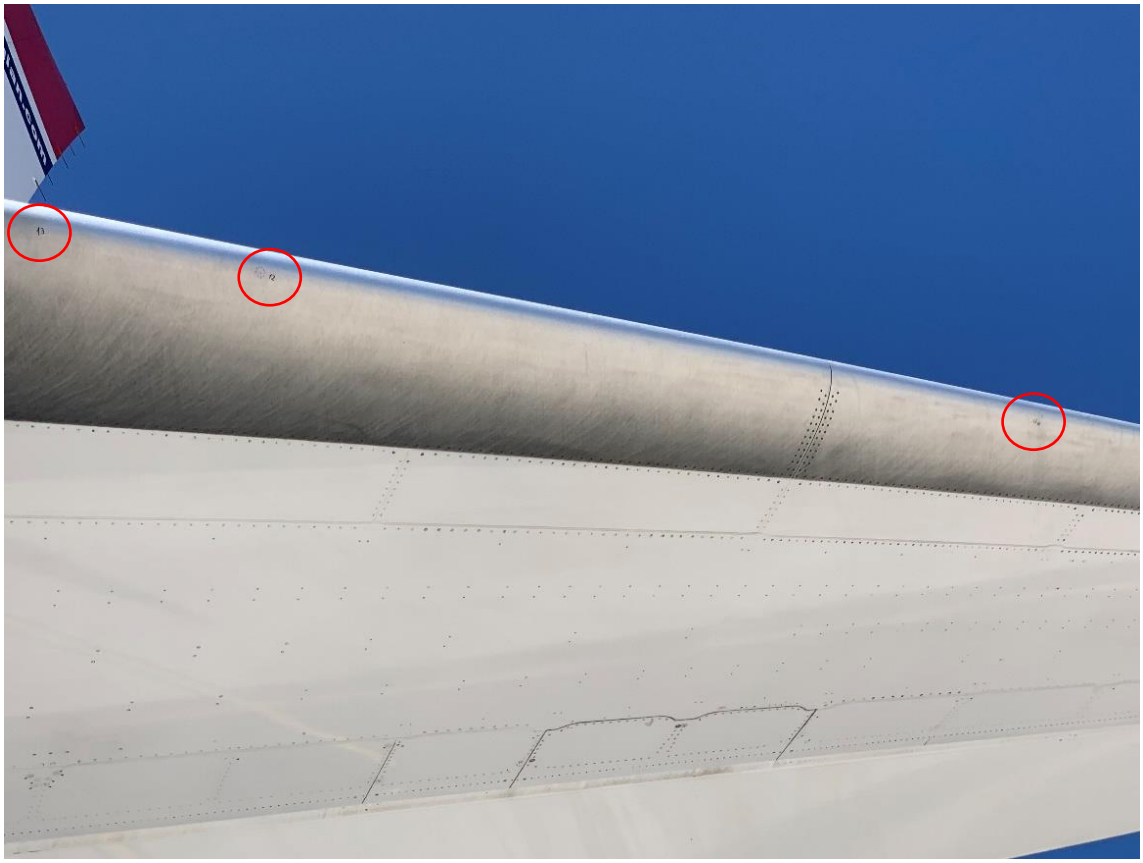

Photo 7: aircraft damage, horizontal stabilizer.

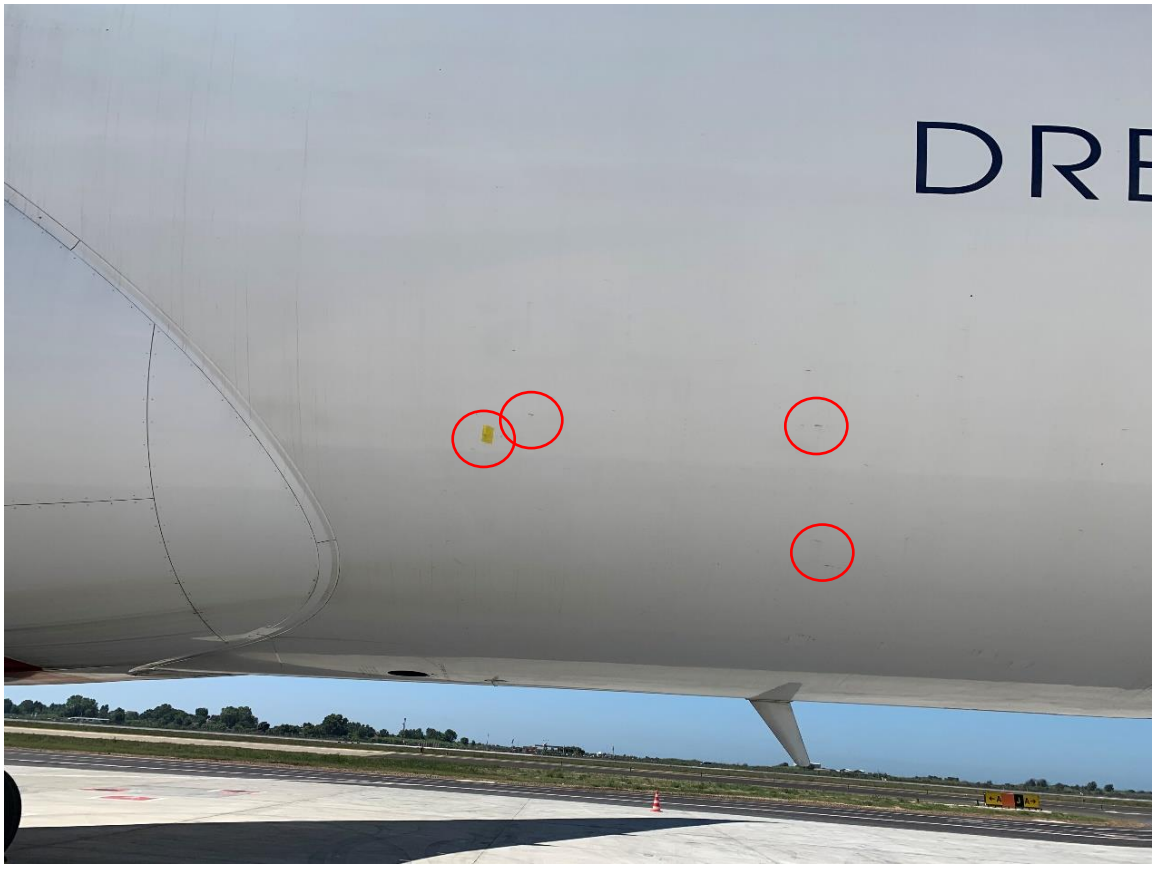

Photo 8: aircraft damage, fuselage.

Photo 9: deflated left landing gear tires.

Figure 1: selection of EAFR data, red line 14.46’11” UTC.

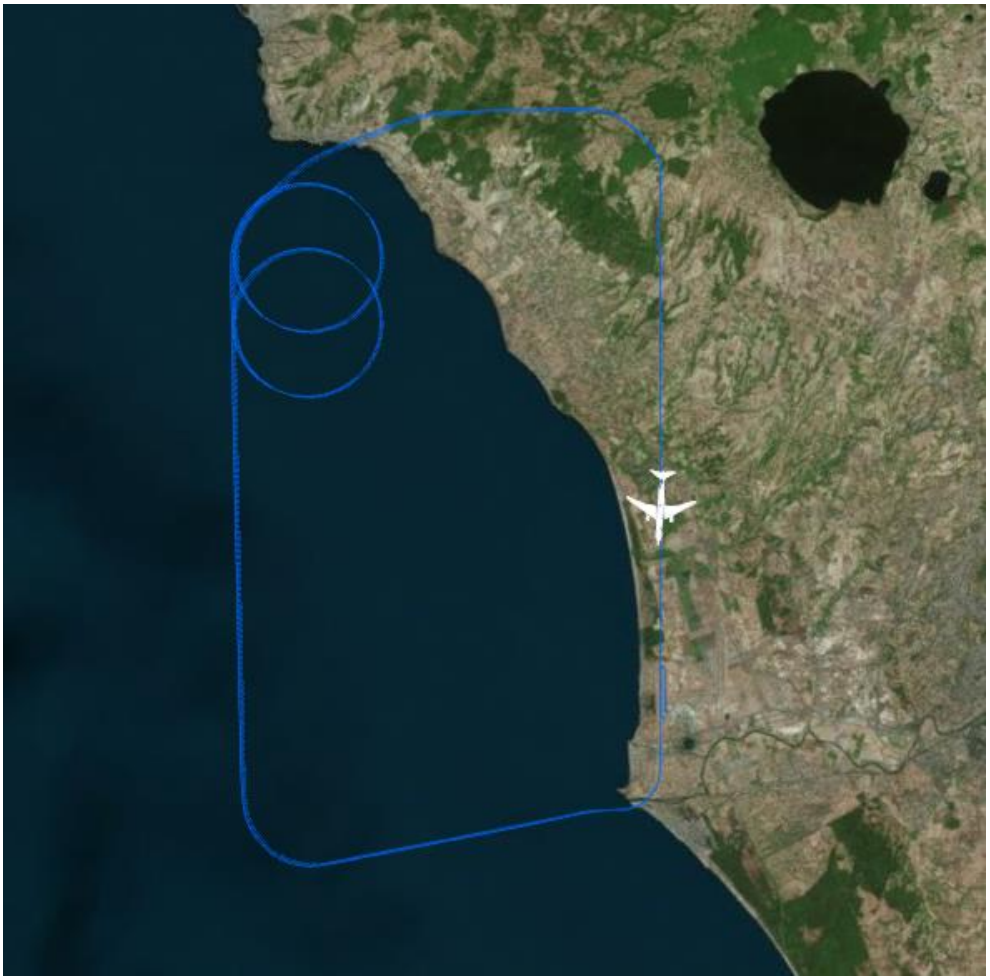

Figure 2: ground track (EAFR data).

Photo 10: debris collected in the streets of the city nearby the airport (Fiumicino).

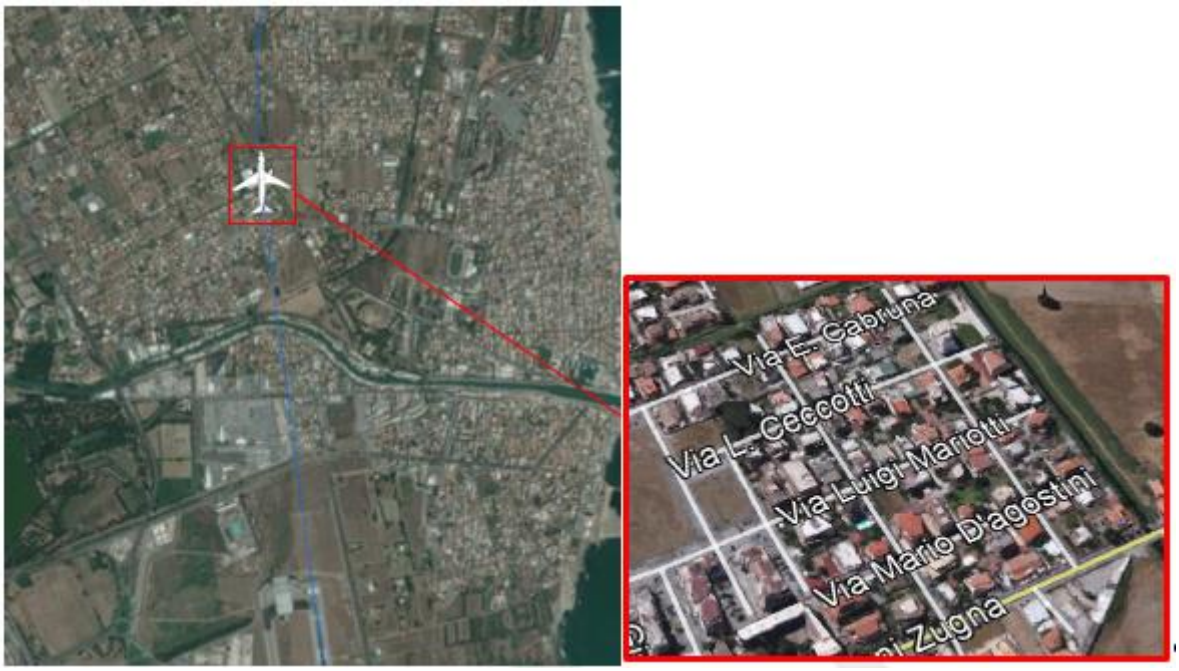

Figure 3: position of the aircraft at the activation of the FDR discrete parameter "Eng1_Vib_Warn"; details of the streets around that area, where debris from the left engine were collected.

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

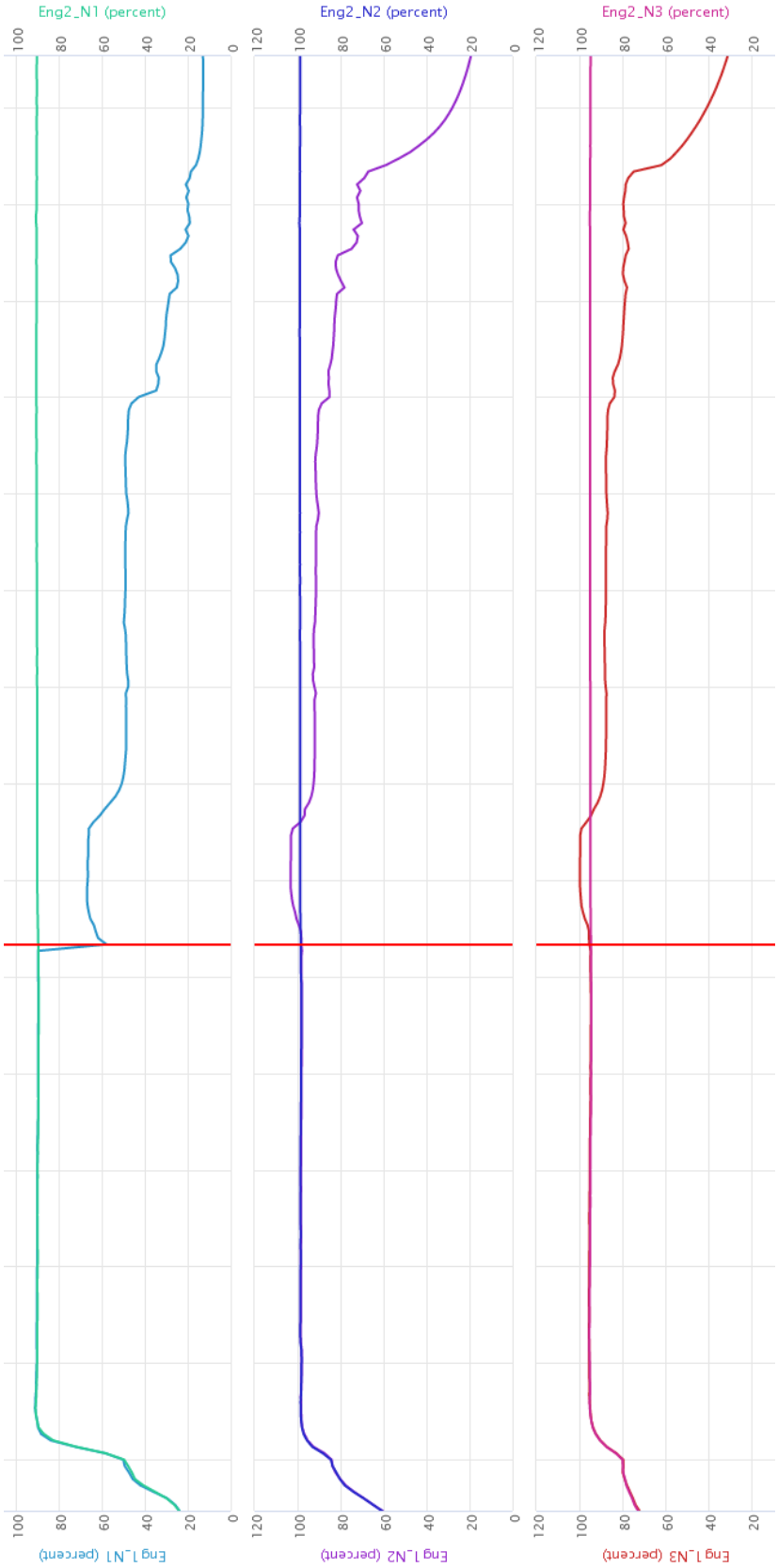

Figure 4: selection of EAFR data, red line 14.46’05” UTC, comparison of ENG1 (left) and ENG2 (right).

Figure 5: selection of EAFR data, red line 14.46’05” UTC , comparison of ENG1 (left) and ENG2 (right).

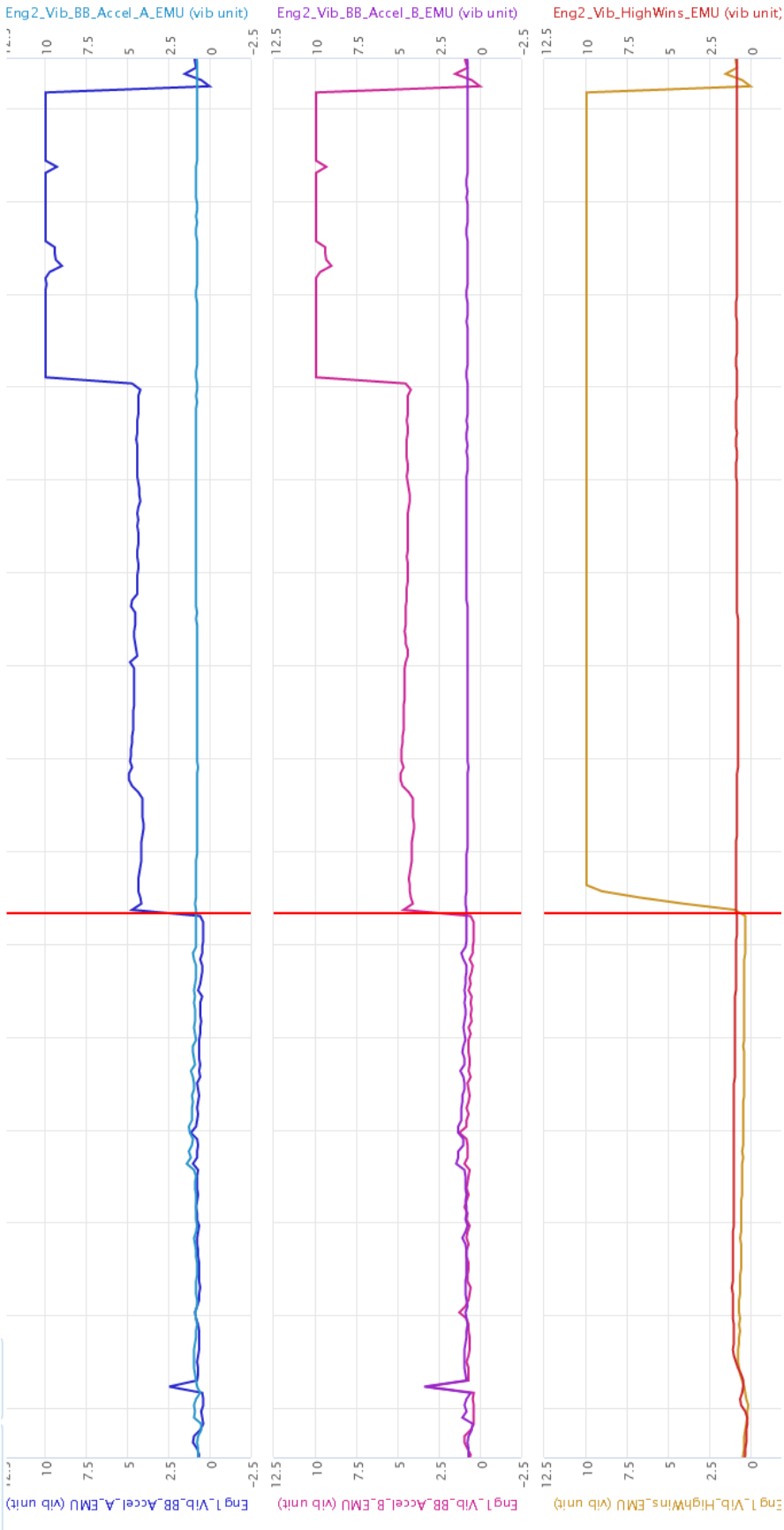

Figure 6: selection of EAFR data, red line 14.46’05” UTC, comparison of ENG1 (left) and ENG2 (right).

Figure 7: selection of EAFR data, red line 14.46’05” UTC, comparison of ENG1 (left) and ENG2 (right).

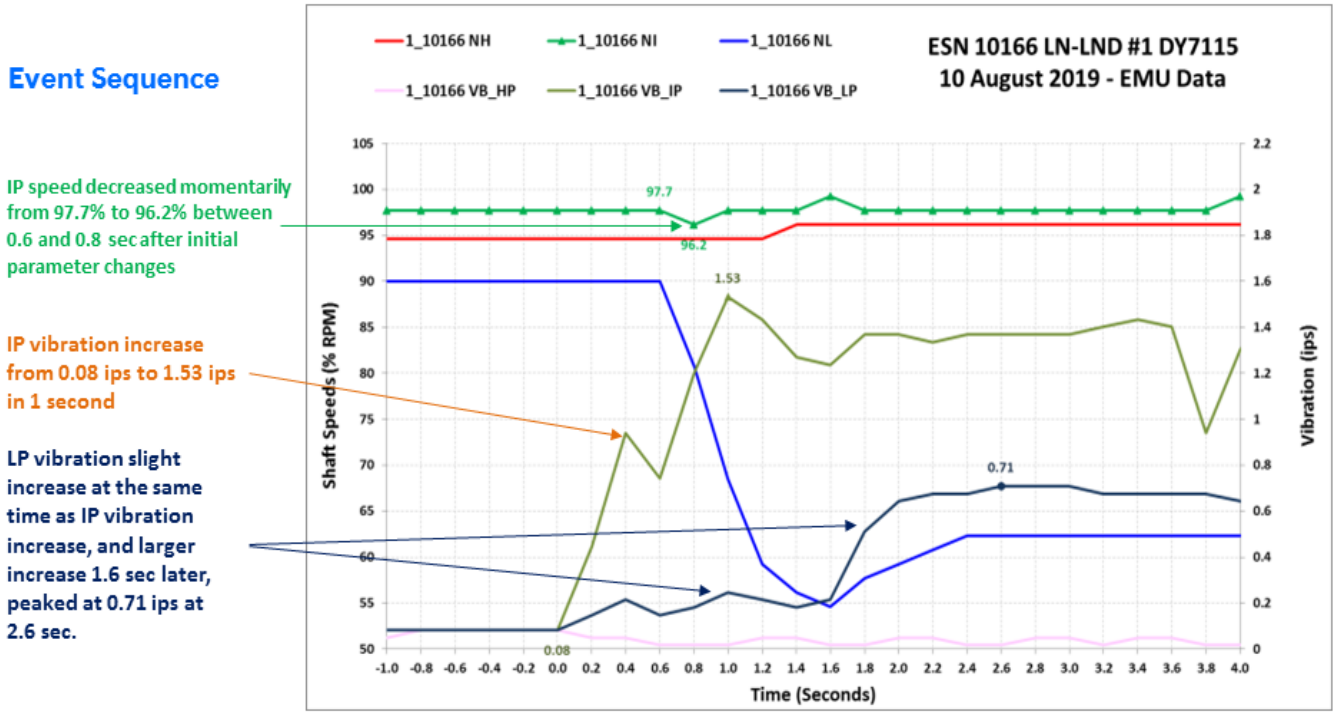

Figure 8: EMU data analysis (source Rolls-Royce).

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

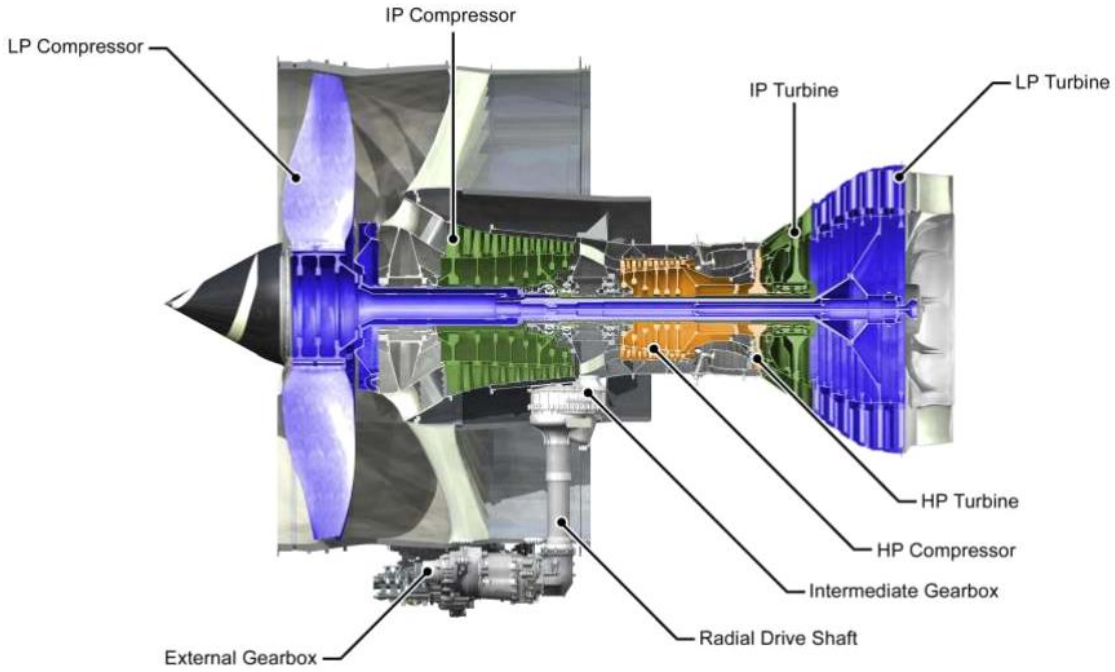

Figure 9: TRENT 1000, schematic view (source Rolls-Royce).

	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: list of the ESN that experienced IPTB release attributed to the corrosion-fatigue phenomenon (source Rolls-Royce).