

Technical document

VEMD and ECU examination Final report

Document ID: **BEA2017-0116_tec04**
 Date of occurrence: 21st February 2017
 Place of occurrence: San Juan airport (Puerto Rico)
 Aircraft type: AEROSPATIALE - AS350 B3
 Registration number: **N413LP**
 Equipment examined:

VEMD Thales P/N: B19030MD05 S/N: 3067	ECU Thales P/N: 70BMB01030 S/N: 520
	

Work performed:

The examination process was described in the *BEA2017-0116_tec03* preliminary report.

Data analysis:

- **VEMD**

The data relative to the last recorded flight were associated to the flight numbered 1602 which lasted 1 hour 14 minutes. This flight was associated to the flight of the event.

Ten failures and four overlimits were recorded.

Note : the VEMD flight duration (computed in minutes) starts when the NG¹ increases over 10% or the NR² increases over 70 rpm and ends when the NG decreases under 10% and NR decreases under 70 rpm ("START" and "FLIGHT" engine state). Failures are only recorded in the FLIGHT engine phase.

Flight duration is rounded, so that the flight time could have lasted between 1 hour 13 minutes 30 seconds and 1 hour 14 minutes 29 seconds.

- **Failures**

The recorded failures were summarized in the following table. Some failures were associated to recorded parameters.

¹ gas generator rotation speed – N1

² main rotor rotation speed

Label	Time	NG (%)	NG FADEC* (%)	TRQ (%)	TRQ FADEC* (%)	T4 (°C)	T4 FADEC* (°C)	NF (rpm)	NR (rpm)
NG A	1h13m18s	98.7	101.2	-	75.3	748	775	513	-
INVALID NF A	1h13m20s	105.3	-	87.5	-	856	-	545	0
NF B	1h13m20s	105.4	105.8	-	87.8	861	868	545	-
NF A	1h13m20s	105.5	105.8	-	87.8	863	871	545	-
INVAL TRQ A	1h13m21s	105.9	-	83.3	-	897	-	544	0
TRQ FADEC (126)	1h13m21s	105.6	104.7	-	55.7	900	903	544	-
TRQ FADEC (128)	1h13m21s	105.5	104.7	-	47.7	901	908	544	-
FADEC SELECTOR	1h13m33s	72.3	69.2	-	1.4	673	630	544	-
OUT OF RNG T4 (R & L)	1h13m31s	0	-	0	-	0	-	0	0

**When the parameter is noted FADEC (or ECU), the value of the parameter is sent by the FADEC (or ECU) to the VEMD.*

- NG is the gas generator rotation speed (N1).
- TRQ is the torque value.
- T4 is the temperature measured at the exit of the gas generator chamber.
- NF is the free turbine rotation speed (N2/NTL), converted as a rotor rotation speed.
- NR is the main rotor rotation speed

○ **Overlimits**

T4 overlimit was detected: - Greater than 941°C for 9 seconds (T4 HI) The maximum T4 value reached 987°C.
NG overlimit was detected: - Greater than 102.3% for 11 seconds (NG TRA) The maximum NG value reached 106.1%.
NF overlimit was detected: - Between 120 and 150% for 4 seconds (NF TRA) The maximum NF value reached 543 rpm (around 140%).
Two NR overlimits were also recorded at 445 rpm.

○ **Engine Power check (EPC)**

The 8 EPC were displayed. They are not dated. The two last EPC didn't show any discrepancy. Three EPC showed that the *TRQ MARGIN* value was considered as "bad". The 3 *TRQ MARGIN* measured values were -0.5%, -0.1% and -0.4%.

In case of "bad" engine power check result, the Safran Helicopter Engines troubleshooting manual recommends to perform an engine cleaning and then another engine power check. If the second result is still "bad", dedicated maintenance card of Safran Helicopter Engines has to be applied.

● **ECU**

The recorded power-up number used to associate recorded failures to a particular flight was faulty. All the failures were recorded with the same power-up number. This failure is known by the manufacturer and doesn't impact the airworthiness of the computer.

The recorded failures were associated to the flight of the event according to the flight duration (around 1 hour 14 minutes according to the VEMD).

Four failure blocks and 8 failure contexts were recorded.

Note: the ECU computed flight time starts when the computer is powered up and stops when powered down.

- **Failure blocks**

The recorded failures were summarized in the following table.

Time	Label
1h13min27s	T1 measurement N1 measurement alternator
1h13min29s	N1 measurement alternator N2 measurement sensor 1 N2 measurement sensor 2
1h13min31s	Raw torque measurement Torque slope measurement N1 measurement alternator N2 measurement sensor 1 N2 measurement sensor 2
1h13min40s	Raw torque measurement Torque slope measurement E/L ARR E/L RAL E/L VOL N1 measurement alternator N2 measurement sensor 1 N2 measurement sensor 2

- **Failure contexts**

The parameter values of N1, TRQ and N2 of the 8 failure contexts were equal to 0.

- **VEMD and ECU synchronization**

The VEMD failures were synchronized with the ECU ones based on the first NG/N1 failure recorded by both computers. A time difference of 9 seconds was determined.

Conclusion:

The event flight was identified in the recorded data of both computers. The recorded data were found to be consistent.

The last VEMD failure of both channels (*R* and *L*) was associated to parameter values equal to 0. Similarly, in the ECU, the parameter values of N1, TRQ and N2 of the 8 failure contexts were equal to 0. It indicates that these failures were recorded on ground, while the engine was not running. They were probably recorded during power-ups after the accident.

The NR value associated to some VEMD failures remained at 0. It most probably indicates that the VEMD received NR value greater than 525 RPM which was considered as invalid and the received value was replaced by 0 to indicate the invalidity.

The *T1 measurement* failure recorded by the ECU during the accident flight was also found during previous flights. This failure was not confirmed and was recorded only when another confirmed failure was detected by the ECU. Thus this failure, even if recorded at 1 h 13 min 27 s during the accident flight was probably detected just after power-up.

➤ **The first failure recorded by both computers was the NG/N1 failure:**

- *NG A* in the VEMD
- *N1 measurement alternator* in the ECU

This NG/N1 failure indicates that the N1 (gas generator rotation speed) measurement reached an out-of-limit value (maxi, gradient or sensors' difference). The control system

would then trigger a flashing amber “GOV” signal at the end of the flight. The control system would remain in automatic mode (loss of redundancy).

This failure was probably triggered by the acceleration of the engine.

The ECU logical words recorded in the VEMD showed that fuel regulation was in mixed mode. That means that the fuel metering unit was out of the neutral position (the twist grip was out of the flight notch). Fuel regulation was still ensured by the ECU through the stepper motor to match the ECU target. The pilot's demands are compensated to maintain the ECU target until the stepper motor reaches its stop. When the stepper motor reaches its stop, the fuel flow is only controlled by the pilot's demands.

➤ **The second failure recording, recorded 2 seconds after the NG/N1 failure, was the NTL/NF/N2 failure:**

- *INVALID NF A, NF A and NF B* in the VEMD
- *N2 measurement sensor 1 and 2* in the ECU

This N2/NTL/NF failure indicates that the N2 (free turbine rotation speed) measurement reached an out-of-limit value (maxi, gradient or sensors' difference). These two N2/NTL/NF failures lead to a total failure of the control system (declared by the ECU). In these conditions, the ECU triggered a red “GOV” signal and was no longer managing the fuel regulation. The pilot had to take manual control of the fuel regulation.

This failure was triggered by the maximum value recorded at 545 RPM (equivalent NR of 140%).

This total failure was not recorded in the VEMD, in the associated data (logical words) of this failure. The logical words seemed to be not consistent. No explanation was found. Nevertheless, the total failure information was recorded in the logical words of the next failure (TRQ).

➤ **The third failure recording, recorded 1 second after the NTL/NF/N2 failure, was the TRQ failure:**

- *INVALID TRQ A, TRQ FADEC (126) and TRQ FADEC (128)* in the VEMD
- *Raw torque measurement and Torque slope measurement* in the ECU

This message indicated that the torque (or slope) measurement has reached an out-of-limit value (mini, maxi or gradient). The control system would then trigger an amber “GOV” signal that indicates a “degraded” automatic operation of the control system. In this case, the aircraft flight manual indicates to avoid abrupt power changes.

➤ **The fourth failure recording, recorded around 10 seconds after the TRQ failure, was the FADEC SELECTOR failure:**

- *FADEC SELECTOR* in the VEMD
- *E/L ARR/RAL/VOL* in the ECU

Those messages were related to a discrepancy of the “Stop/Idle/Flight” position of the selector, located on the instrument control panel. A combination which was different from 1/0/0, 0/1/0 or 0/0/1 led to the discrepancy detection. The control system would then trigger an amber “GOV” signal that indicates a “degraded” automatic operation of the control system. In this case, the control system allows shutting-down the engine but does not allow selecting “idle”.

Scenario based on the ECU and VEMD data:

The analysis based on the sole failure messages recorded by VEMD and ECU showed that N1 (gas generator rotation speed) and N2 (free turbine rotation speed) reached values that exceeded values encountered during normal operations.

It is highly probable that the NG/N1 failure was triggered following an excessive opening of the fuel metering unit leading to an overspeed of the free turbine (N2).

The subsequent NTL/NF/N2 and the TRQ failures were probably a consequence of the free turbine overspeed.

The FADEC SELECTOR failure might be the consequence of the impact with the ground as it appeared 10 seconds after the previous failures.

The overlimits recorded were consistent with this sequence.

Attached document:

- *TEA_RIs2017-033*, Safran Engine Helicopters report about the ECU examination
- *EAI 51_2017*, Airbus Helicopters report about the VEMD examination