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	Engine Type: E4	Subject: Accident 40.NC055

Doc. No. IR-E4-19-2021






Aircraft Registration: **N853L**
 Aircraft S/N: **40.NC055**
 Engine s/n: **E4-A-00588** having **~1337fh**
 Date: **06.06.2021**
 Time: **~10.20**

Aircraft:

Aircraft Type: Diamond Aircraft DA 40 NG
 Serial No.: 40.NC055
 Flight hours: >1337 hours (acc. to information provided by operator)

Engine:


Engine Serial Number: E4-A-00588
 EECU Serial Number: 2786
 EECU HW Revision: AD
 Design data: EECU Software VC33_1_06_24

	Name / Position	Date:	Signature / Stamp:
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	Werner Dietmueller CVE Hardware & Software	04.10.21	

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Background

Austro Engine has been notified of a fatal crash involving a DA40 with the registration N853L and s/n 40.NC055. The aircraft sustained severe damages, as well as the engine and the engine EECU. After the initial investigation, no engine problems were reported.

The engine and engine parts were subject of inspection/assessment by the competent authority (NTSB, National Transportation Safety Board). The EECU was subject to a strip inspection, while the authority experts attempted to recover engine data from the EECU to enable a better assessment of the cause of the event.

The EECU status prior to disassembly was documented by the NTSB, here reported pictures provided by the authority (refer to the subsequent paragraph). Data recovery was unsuccessful as the connectors and board have been damaged. Also, a CPU was not on the mainboard anymore due to the crash.

Austro Engine has been contacted by the Authority to assist in the data recovery: following analysis of the provided pictures, it was determined that data recovery may be possible as the memory on the mainboard did not appear to be externally damaged. For this reason, the mainboard of the EECU was removed (the external connectors have been cut off from the main board at the flex cable), packed and shipped to Austro Engine.

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Pictures of the EECU status provided by NTSB:




Figure 1 - EECU Upper side



Figure 2 - EECU Bottom side

Data from EECU A could not be obtained initially due to the damage caused by the accident.

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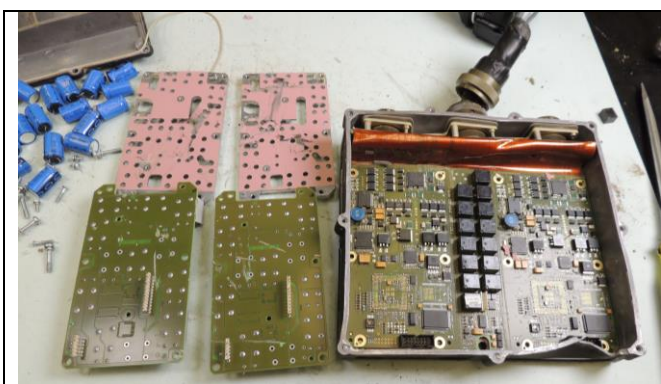


Figure 3 - EECU opened

The memory chips of ECU A and ECU B were found in good condition, except for some superficial scratches (refer to Figure 6, yellow highlighted area). These chips will be transferred together to a substitute EECU for readout.

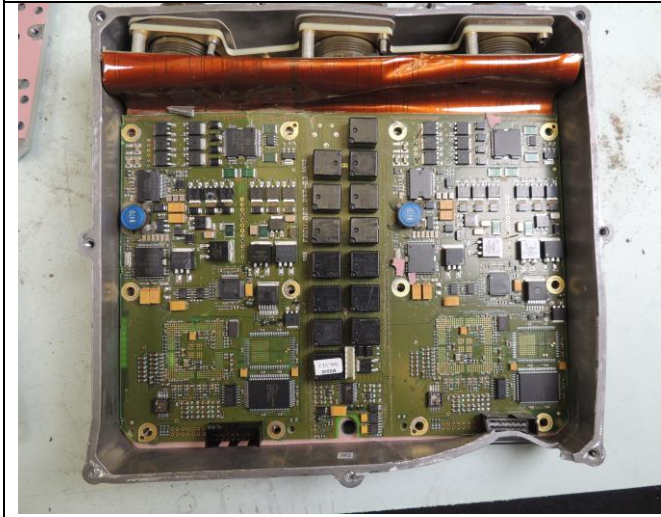


Figure 4 - EECU MB Upper side

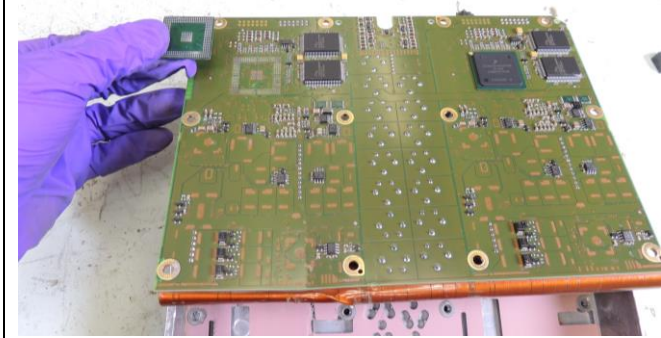

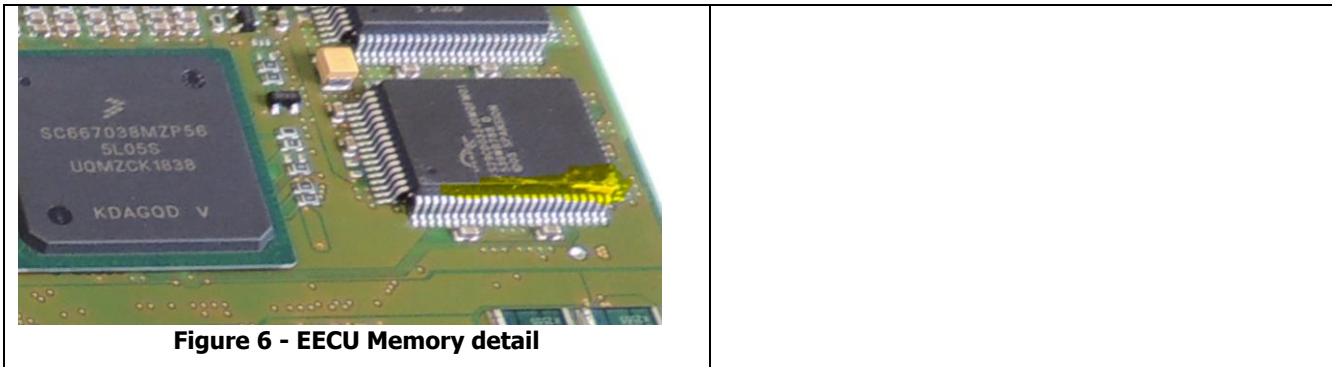




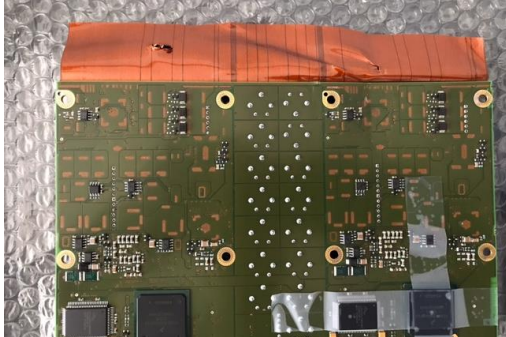



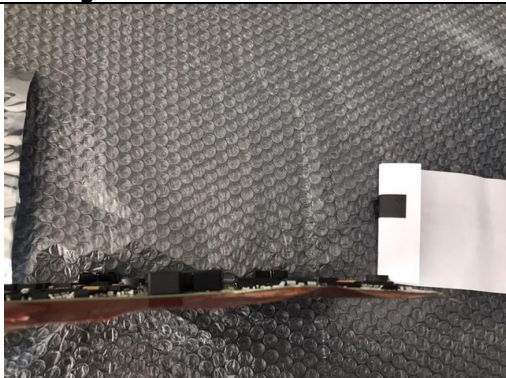

Figure 5 - EECU MB Bottom side


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Delivery condition of the EECU mainboard to Austro Engine

 <p>Figure 7 – EECU packed</p>	 <p>Figure 8 – EECU MB upper side</p>
 <p>Figure 9 - EECU packed</p>	 <p>Figure 10 - EECU MB bottom side</p>
 <p>Figure 11 - EECU packed label</p>	 <p>Figure 12 – EECU MB Side view with bending</p>
 <p>Figure 13 - EECU MB upper Side</p>	<p>Based on the visual inspection, Austro Engine confirms that there is the possibility to recover the data. Mechanical damage had been detected on two sides of the mainboard so that the board is bent, but the location of flash memory and EEPROM do not seem to be affected.</p>

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EECU Data logging function

The E4 engine EECU consists of two autonomous, redundant channels: ECU A and ECU B. Each E4-ECU channel contains non-volatile flash-memory storage (called RecMng-Flash), which is used to store 16 channels of signals. These signals are sampled at an interval of 1 second as long as the ECU is powered on. Both ECUs perform this task independently of each other and have their own RecMng-Flash. The size of non-volatile memory is sufficient to store data for about 90 flight hours.

Currently the following signal-channels are defined:

- Boost pressure [hPa]
- Barometric air pressure (measured inside the EECU enclosure) [hPa]
- Engine oil pressure [hPa]
- Rail pressure [bar]
- Power lever position [%]
- Coolant temperature [°C]
- Intake air temperature [°C]
- Battery voltage [V]
- Fuel pressure (measured after the electric fuel pump) [hPa]
- Gearbox oil temperature [°C]
- Engine oil temperature [°C]
- Duty cycle of propeller actuator (combined d.c., ranging from -100% to +100%) [%]
- Combined engine status [hex]
- Engine oil level (not calibrated, use only for trend analysis) [mm]

The RecMng-Flash provides space for the 16 channels at a sampling rate of 1s for about 90 hours of flight time, depending on the number and duration of flights. It is organized as a “ring-buffer” holding always the most recent flight hours.

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The E4 ECU SW maintains many internal status signals. The Data Logger combines a few important ones into an 8-bit "combined engine status" bit-mask signal, which is stored as a hex value (00 – FF). To de-code the Data Logger signal, this hex value must be converted into its binary representation, where each bit indicates a particular status information:

Bit	Description
0	1 = engine status "after run"
1	1 = engine status "start"
2	1 = engine status "normal"
3	1 = rail pressure governing via metering unit
4	1 = squat switch depressed ("weight on wheels") -> aircraft on ground
5	Proposed active ECU (0 = ECU A, 1 = ECU B)
6	Voter decision (0 = ECU A, 1 = ECU B)
7	1 = ECU is passive 0 = ECU is active

Notes:

- 1) bit 0 is the least significant bit or the right most position of the bit mask
- 2) if bit 5 and 6 do not agree (e.g. bit 5 = 1, bit 6 = 0), the pilot has overruled the voter and manually selected ECU-A to become active.
- 3) bit 3 indicates whether the Metering Unit (MeUn) or the Pressure Control Valve (PCV) is being used to control the rail pressure in the two-actuator common rail system of the E4 engine
- 4) bit 5 indicates which channel should be active, as suggested by the ECU-SW, based on current error counters within the ECU diagnostic management system.

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Further actions

Data from ECU A and B could not be obtained due to the damage caused by the accident. Nevertheless, the memory chips were found in good condition to attempt a memory transfer to a substitute EECU for readout.

Substitute EECU serial number: #1657

The damaged mainboard with s/n 2786 and the new mainboard with s/n 1657 will be transferred to ELPRO Elektronische Geräte Produktions GesmbH laboratory. In presence of the Austro Engine HW and SW CVE, the memory chips from the EECU mainboard with s/n 2786 will be unsoldered, then soldered on the EECU mainboard s/n 1657. The process will be documented with pictures.



Figure 14 - EECU s/n 1657



Figure 15 - EECU s/n 1657 bottom side



Figure 16 - EECU s/n 1657 MB upper side

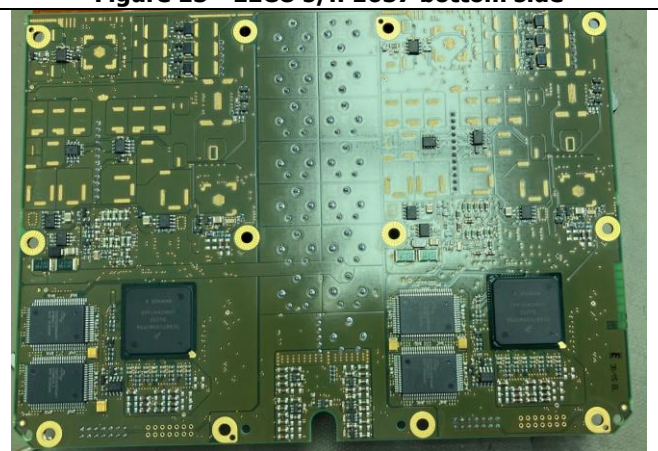



Figure 17 - EECU s/n 1657 MB lower side

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After this operation, the substitute mainboard will be returned to Austro Engine, where the EECU will be assembled and the data download will be tried in presence of the Austrian Authority.

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EECU memory replacement

The following pictures provide evidence of flash memories uninstallation/installation from s/n 2786 to s/n 1657

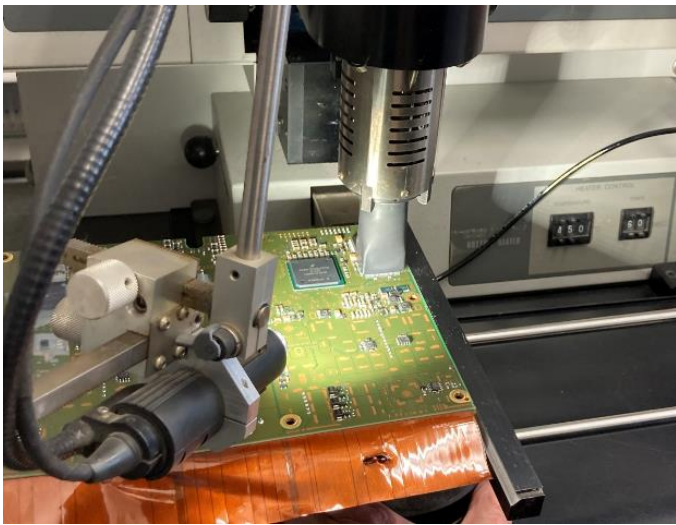


Figure 18 - EECU s/n 2786 MB memory removal



Figure 19 - EECU s/n 2786 MB memory removal



Figure 20 - EECU s/n 1657 MB memory installation

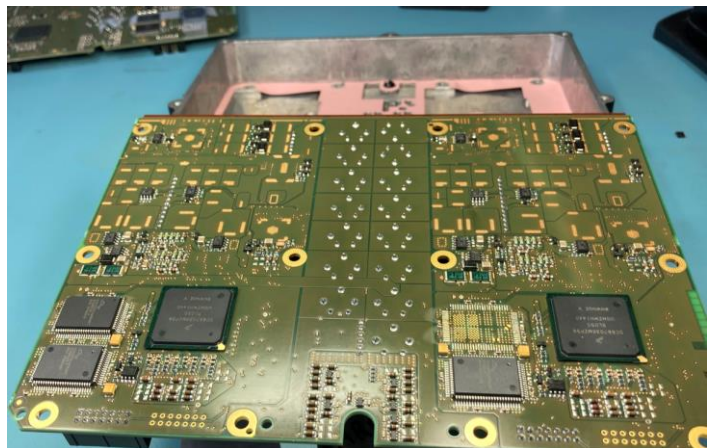



Figure 21 - EECU s/n 1657 MB memory installation

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The following pictures provide the functional test after memory installation, no data was read or downloaded. The test aimed to check the EECU s/n 1657 correct operation after the memory swap.

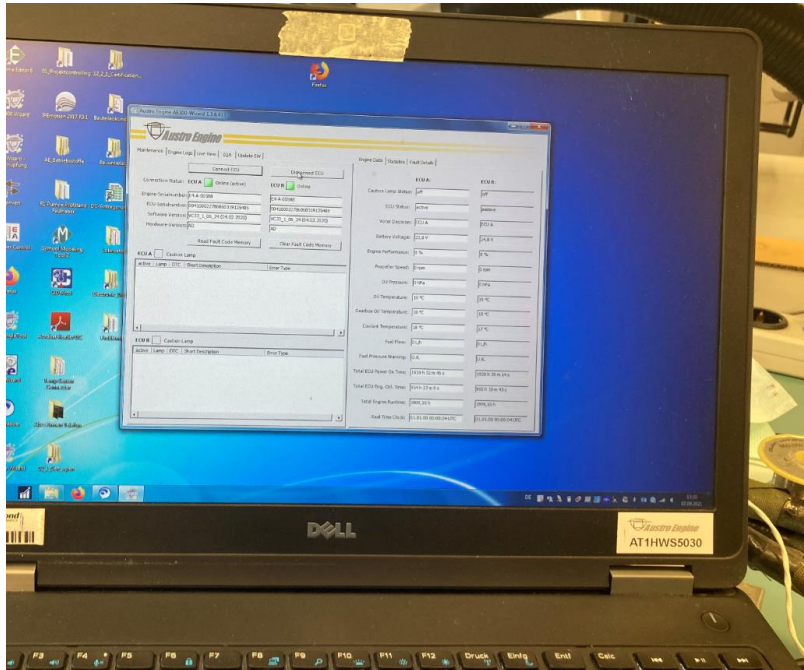
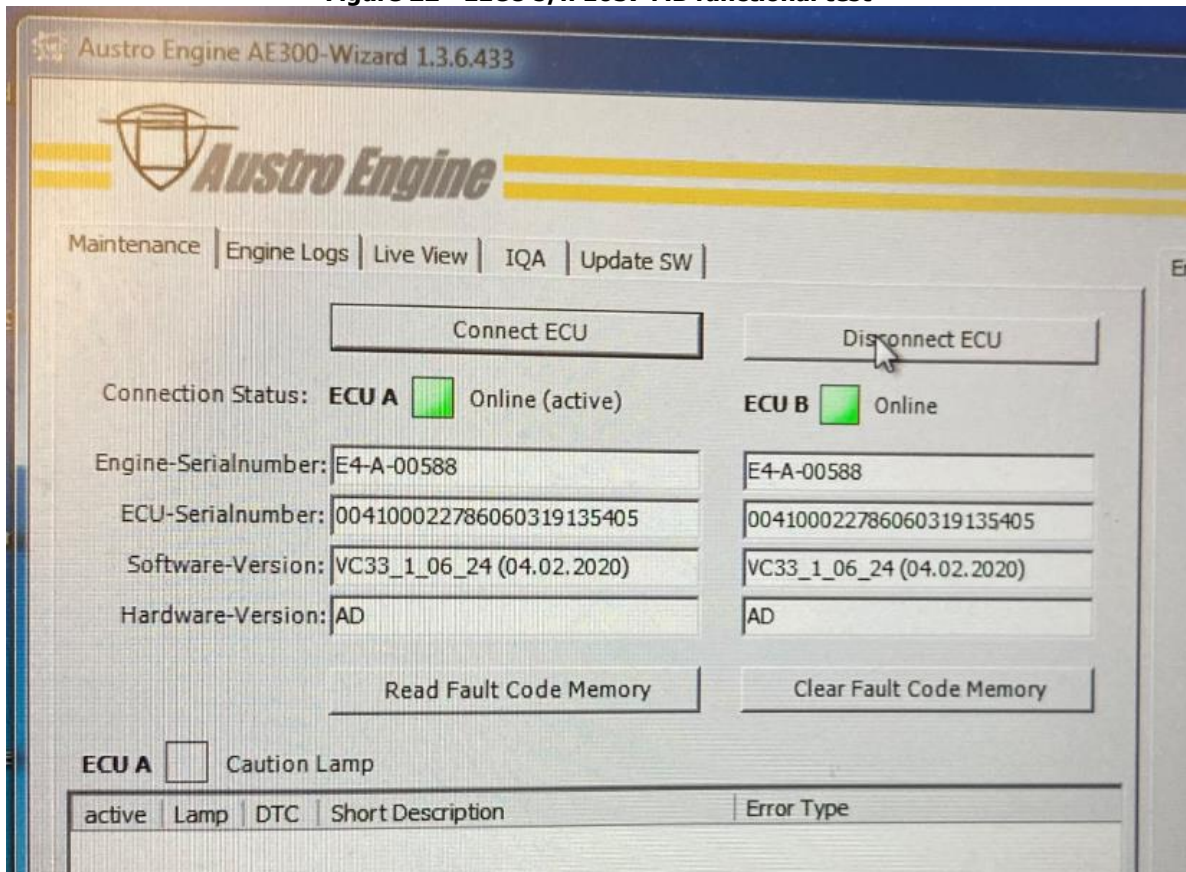


Figure 22 - EECU s/n 1657 MB functional test



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Figure 23 - EECU s/n 1657 MB functional test

Readout and Download of the data

On September 08, 2021, under the witness of the Austrian Federal Safety Investigation Authority, the data read-out and download of the EECU s/n 1657, having installed the memories of the damaged EECU s/n 2786, was performed. The download of the data took almost 3h in total.

The data were downloaded from both channels. The following pictures were taken during the download process:



Figure 24 - EECU s/n 1657

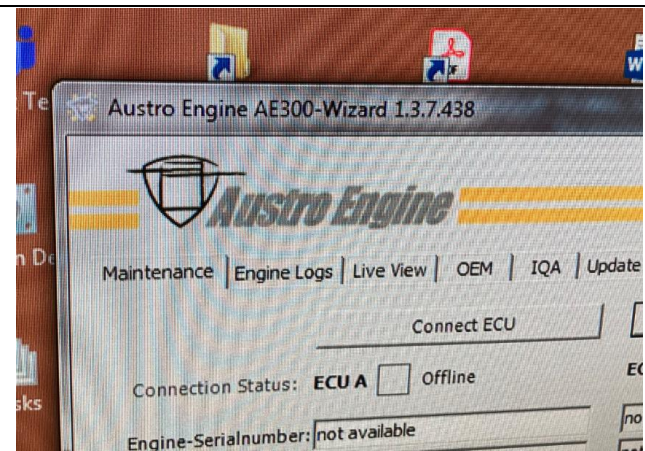


Figure 25 – AE Wizard version used



Figure 26 - EECU s/n 1657 connected

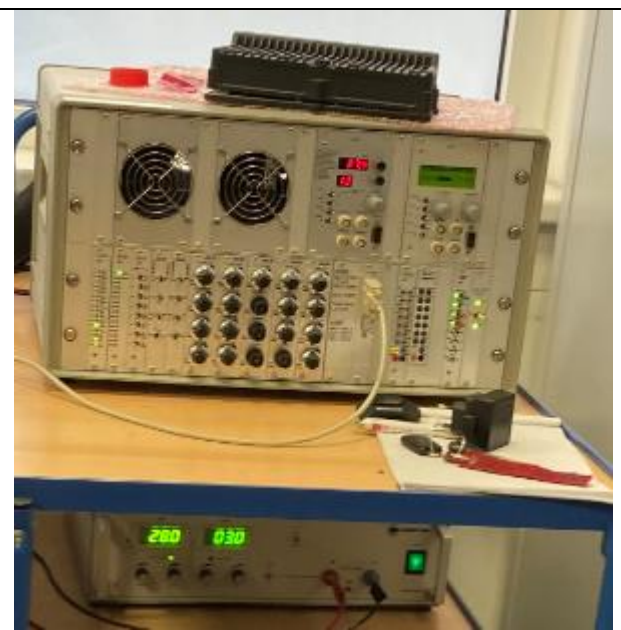



Figure 27 - EECU s/n 1657 connected, powered

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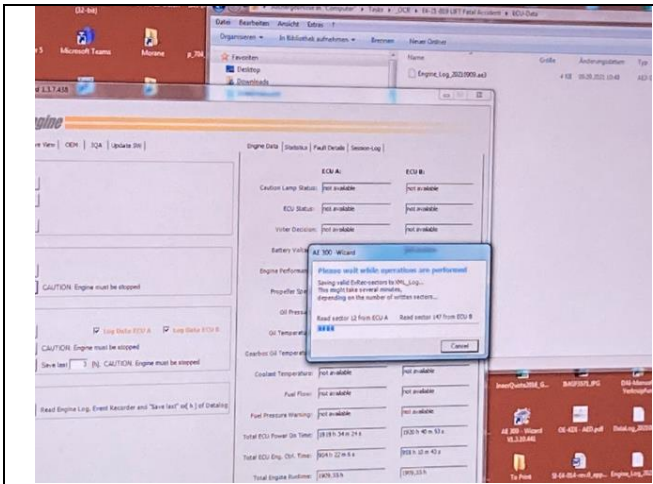


Figure 28 - EECU s/n 1657 data download

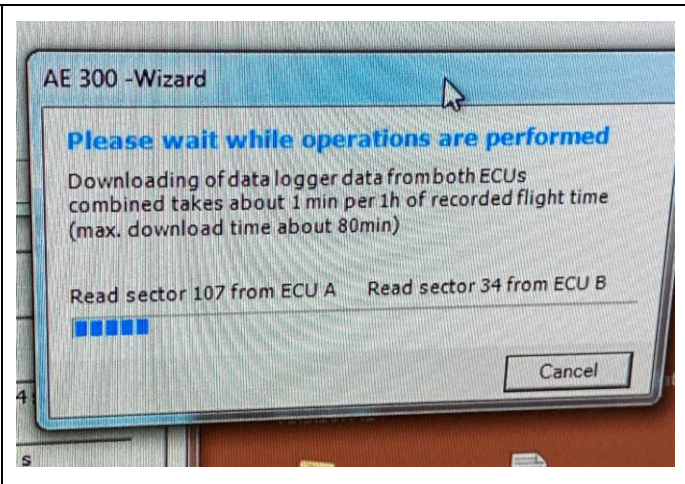


Figure 29 - EECU s/n 1657 data download

It was determined that during the last flight, ECU B was the active EECU channel while ECU A was in hot stand-by mode. It was confirmed that data related to the occurrence was recorded on ECU B, thus engine operation data prior to the occurrence is available. ECU A had a recording error (ref. to the following table), thus data recording related to last event is available only from channel B. The following errors with the relevant explanation are verified after the download:

ECU A		
Code	Error	Note
1d06	Real time clock error ⁽¹⁾	Date/Times are missing (Records starting 01.01.01)
1e01	Record manager failure	ECU A have a data recording and data log recording function problem. Last data recorded is not related to the occurrence.
1e02	Data log failure	
ECU B		
1d06	Real time clock error ⁽¹⁾	Date/Times are missing (Recordings starting at 01.01.01)
1e02	Data log failure	No valid lead-out sequence on the last session. (This was due the crash of the airplane while the engine and the EECU was still operating)
0600	External CAN bus failure	This error was recorded while, after the memory swap the EECU was turned "ON" to test its functionality without a CAN connected.

⁽¹⁾ Real time clock error is related to the EECU s/n 1657 used to migrate the memories and do not affect the downloaded data.

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Conclusions

From the available data, it appears that the engine was operating normally until the impact with the ground. The following screenshots show the analysis from the data log named "DataLog_20210913_1hour.ae3":

On ECU B, the latest data show that the engine was running properly. All parameters are in the normal range and correspond to the power request (light blue line, power lever position):



Figure 30 – ECU B Engine Operation Data before the event graph

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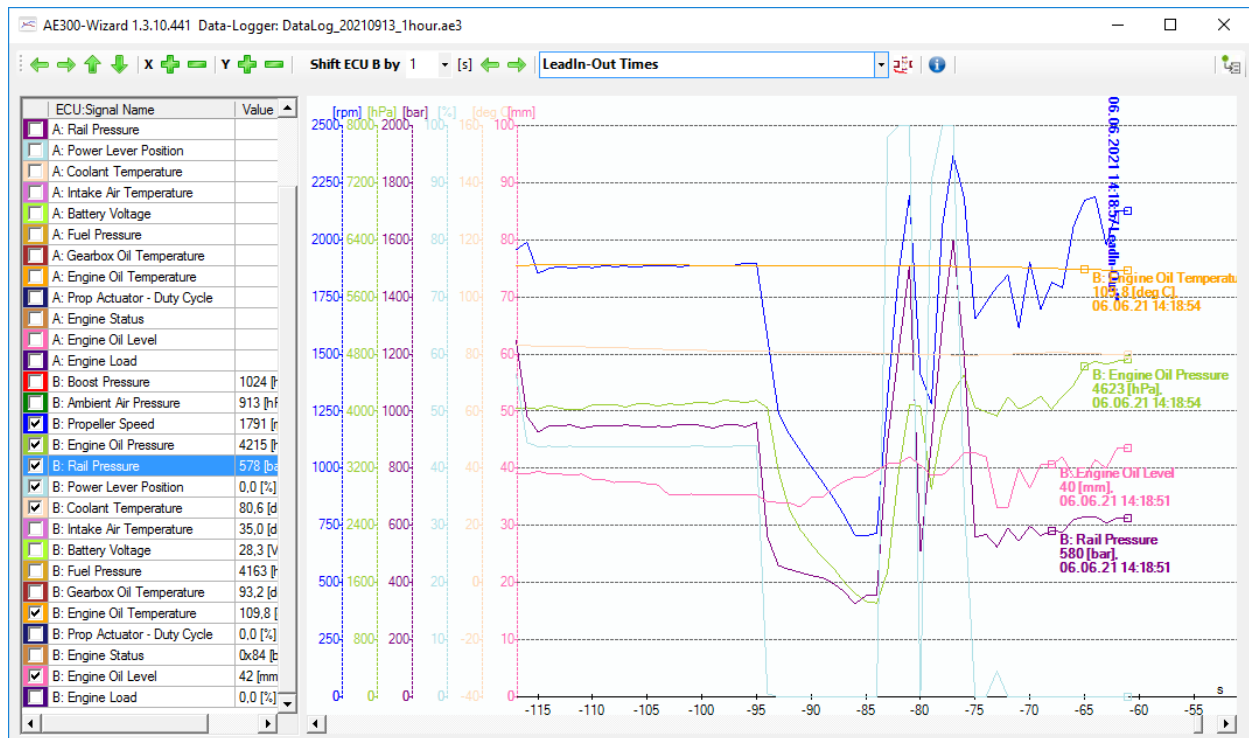



Figure 31 – ECU B Engine Operation Data before the event graph

ECU A shows a completely different flight situation at the end of the recording. Even in this situation, all parameters have normal values.



Figure 32 – ECU A Engine Operation Data log graph

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Attachments

Engine_Log_20210909
 EvRec_20210909
 DataLog_20210909_Full
 DataLog_20210913_1hour
 DataLog_20210909_3hours
 Extract E4.04.00-Occ-21-010

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