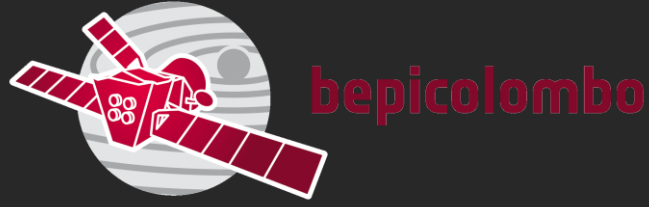


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1 BELA on BepiColombo



BELA is one instrument onboard the 2018 launched ESA mission BepiColombo. The mission consists of 2 orbiters, one of them the **MPO** (Mercury Planetary Orbiter) which carries BELA. Main goal is a **global topographical model of Mercury**, using laser time-of-flight measurements. Besides this, it is envisaged to determine surface roughness, slopes, albedo and Mercury's tidal deformation and rotation. BELA is developed, run and commanded by the collaborating institutes of: German Aerospace Center (DLR), University of Bern (UBE), Max-Planck-Institut für Sonnensystemforschung and the Instituto de Astrofísica de Andalucía. All operational aspects are taken care of by DLR, Institute for Planetary Research, in cooperation with ESA as well as the data processing. The scheduled start of the science operation is early 2027.

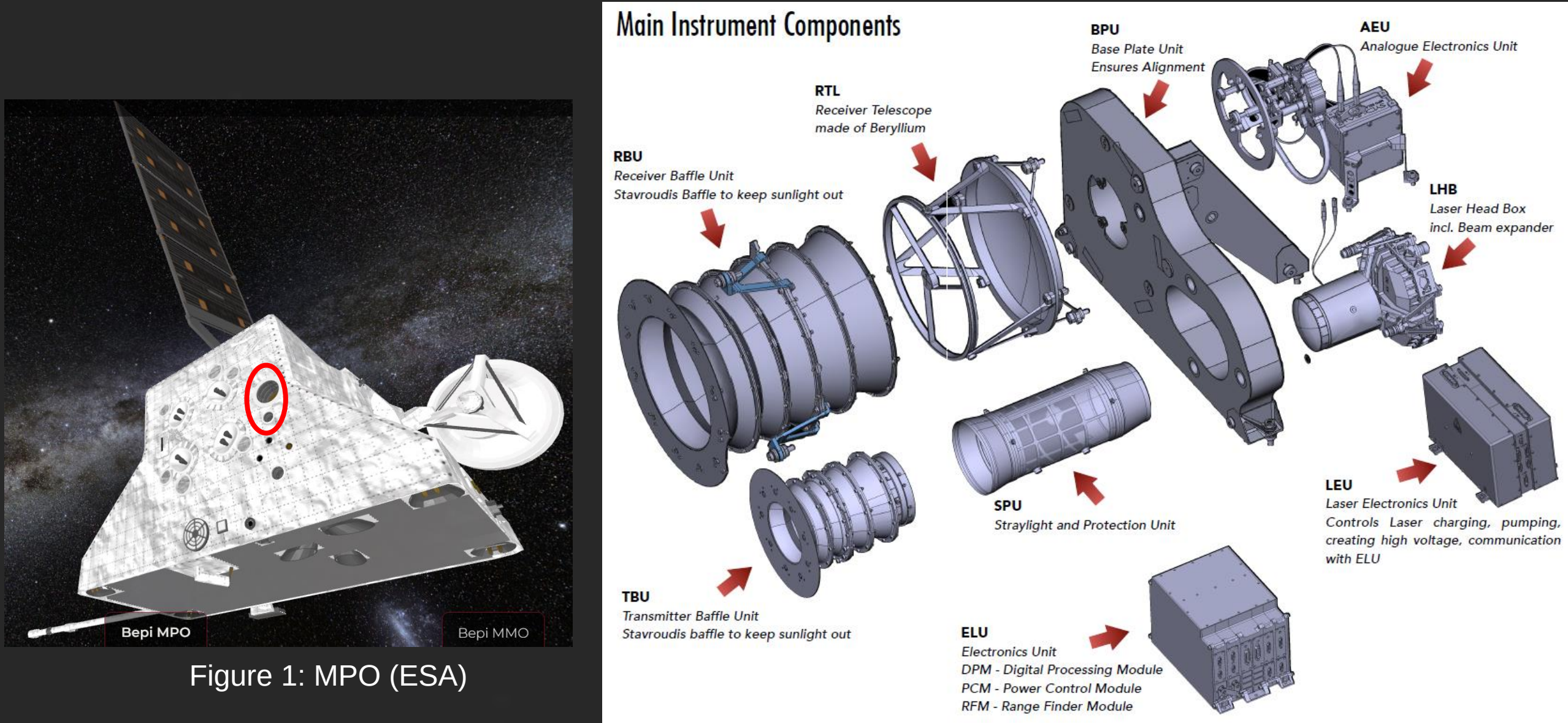


Figure 1: MPO (ESA)

Figure 2: BELA subsystems (UBE)

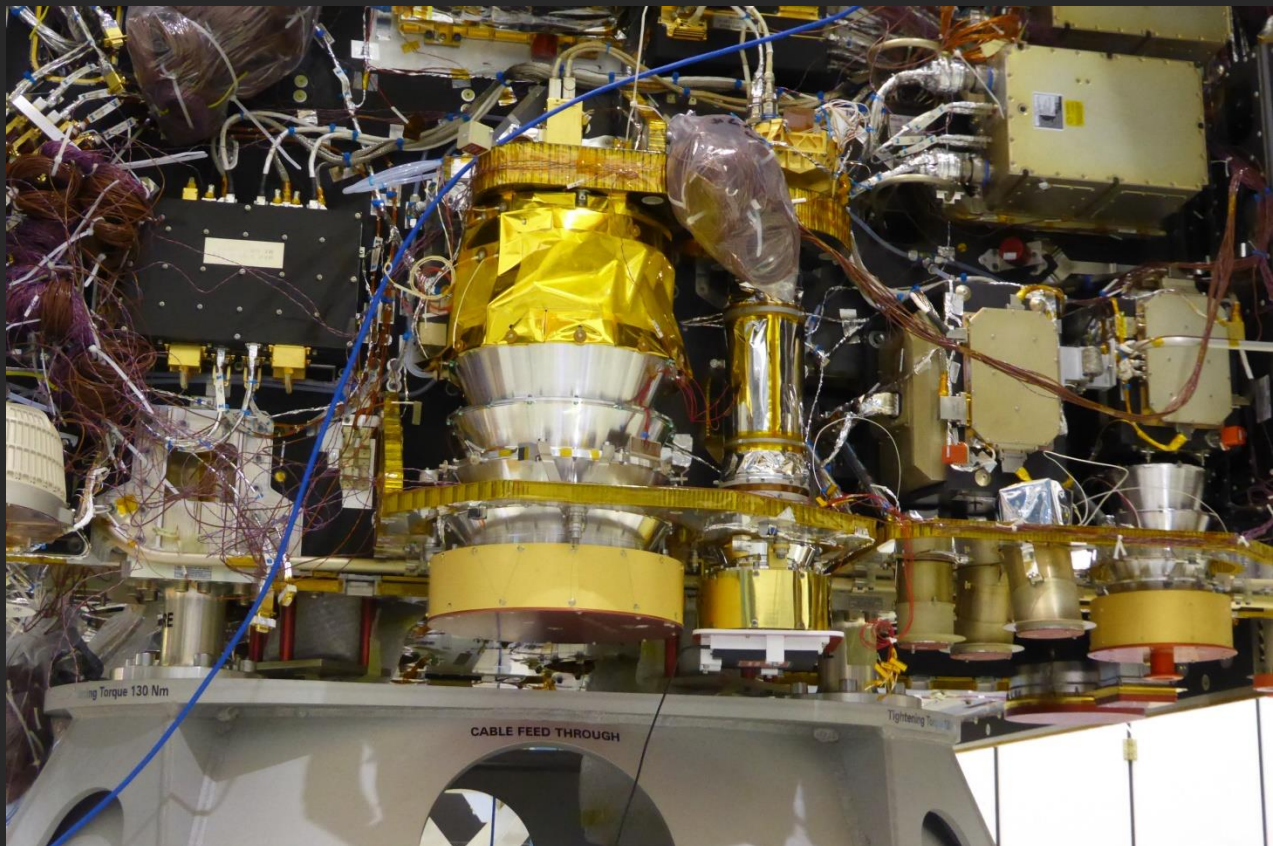


Figure 3: BELA integrated on Bepi (ESA)

3 Data Processing

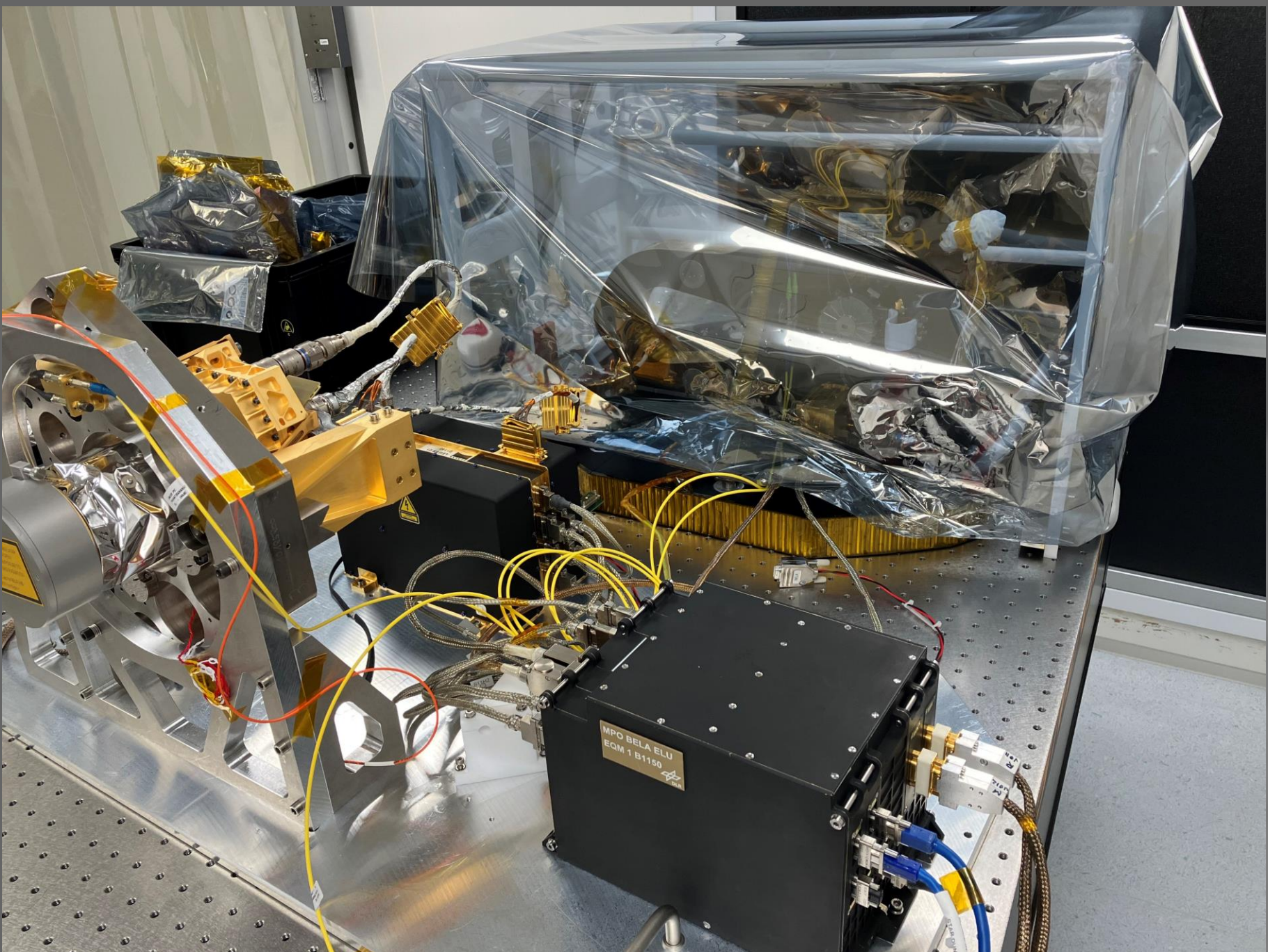
The software tools (**data pipeline**) to process the raw data, included in the downlinked TM (telemetry) packets, will be provided by the Institute of Planetary Research at DLR. The data includes all science relevant data, in the case of BELA, the time-of-flight measurements and shape information of the outgoing and incoming laser pulses. After reception and storage of the raw data the software tools are used to process the data into a format, which can be used by the scientific community, in this case into **PDS4** format.

The final products include the calibrated and in some cases calculated values, also the physical units and a description of each single data type.

One aspect of the operation is to check if the commanding was executed correctly from the instrument. For those checks it is vital to have a working data pipeline and check the science data. For this also house-keeping (HK) data is included.

HK data on the other hand will be processed and analyzed immediately by the OGS (Operation Ground Segment, ESOC).

2 BELA GRM



The BELA GRM (Ground Reference Model) is a copy of the flight model. It is used to test new operating-software, all operational aspects and the overall science performance. For non-nominal operations like updating the on-board operation software on the FM the GRM is used in advance to validate the commanding. On top of these tests, all new operations are tested on the ETB (Engineering Test Bench) at ESOC.

One important aspect is the understanding of all failures or anomalies for which the GRM is a powerful tool for investigation. The nature of space mission is, that in all cases these solutions a software based.

Figure 4: BELA GRM (DLR)

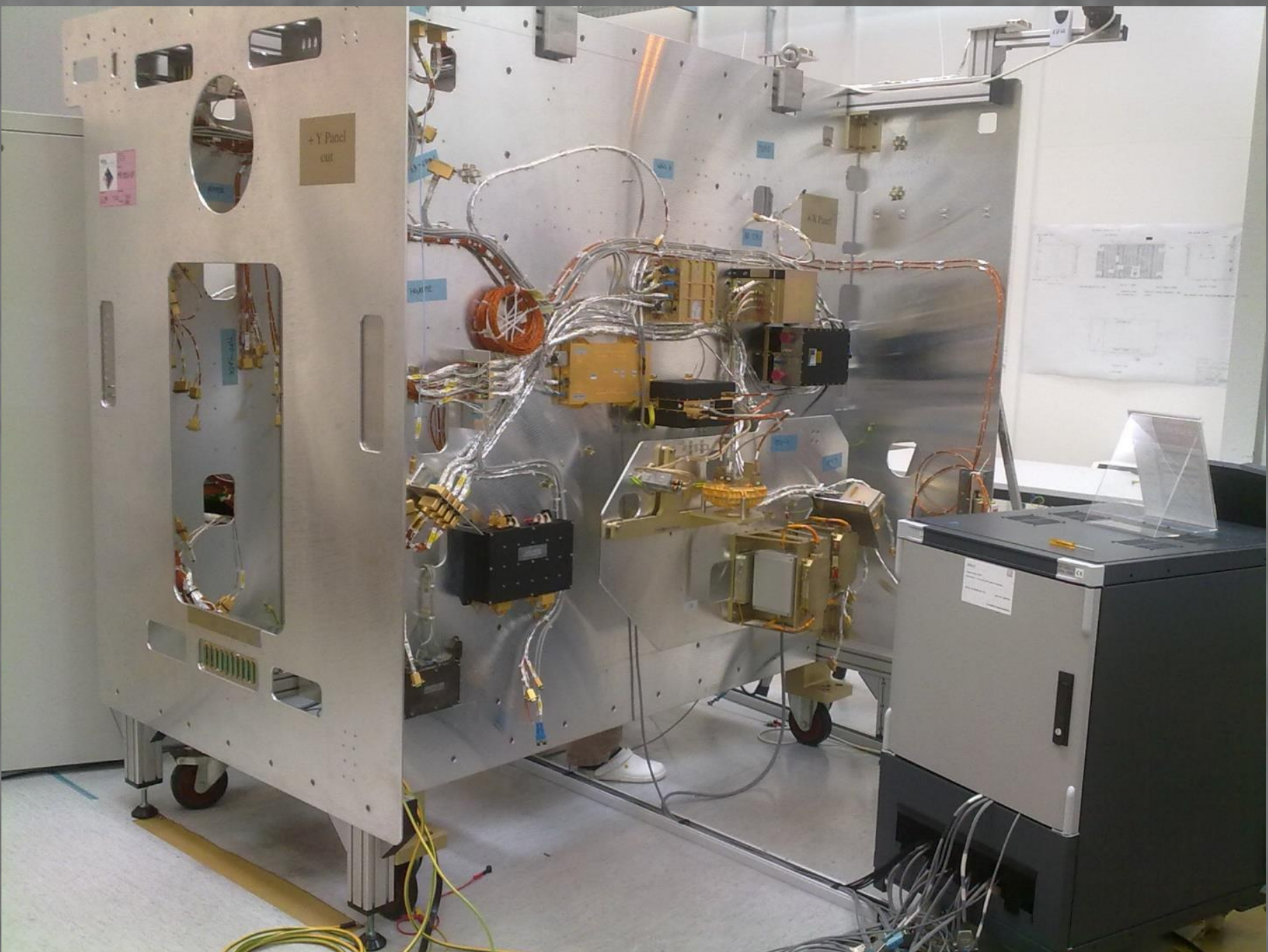


Figure 5: Bepi ETB (Airbus)

4 Operations

Telecommands (TC) are sent to instruct the instrument while **telemetry** packets (TM) are received from the instrument. **Databases** facilitate their coding and decoding.

Pre-defined sequences of TC and TM checks, so called **procedures** provide easier commanding of routine operations: e. g. instrument switch-on or nominal laser ranging. This insures that the order of the TC's is correct, that waiting times between each TC is correct, that the right TC's are used and that the according TM is checked automatically. Also in some cases, TC parameters are fixed or a range is set to have the wanted values.

ESA provides software tools to the instrument teams to have access to the mentioned procedures. They can be put together in a **POR** (Payload Operation Request). The program creates a commanding file which can be used by the operating system of the OGS (Operational Ground Segment), ESOC Darmstadt to send it via radio to the spacecraft.

So definition of the operation is done by the instrument teams, execution of it by ESA, control of the received data by both; in the case of science data, this is done by the instrument teams.

Once approved, telecommands will be scheduled in the **Mission Time Line** (MTL) and executed accordingly.

The BELA instrument team is working together with the **OGS** and **SGS (Science Ground Segment)** to have all needed resources available to operate BELA such that it will provide the desired scientific data.

Launched in 2018, BELA was operated during the **NECP** (Near Earth Commissioning Phase), 11 **CCO** (Cruise Check Out), 1 **MSB** (Mercury Swing-By) and for a test of the SSMM (Solid State Mass Memory). In August 2024 the complete operation software was successfully updated and tested. Further CCO and MSB operations are planned.

For all operations BELA behaved as expected. Some examples of TM data from the CCO9 are shown below.

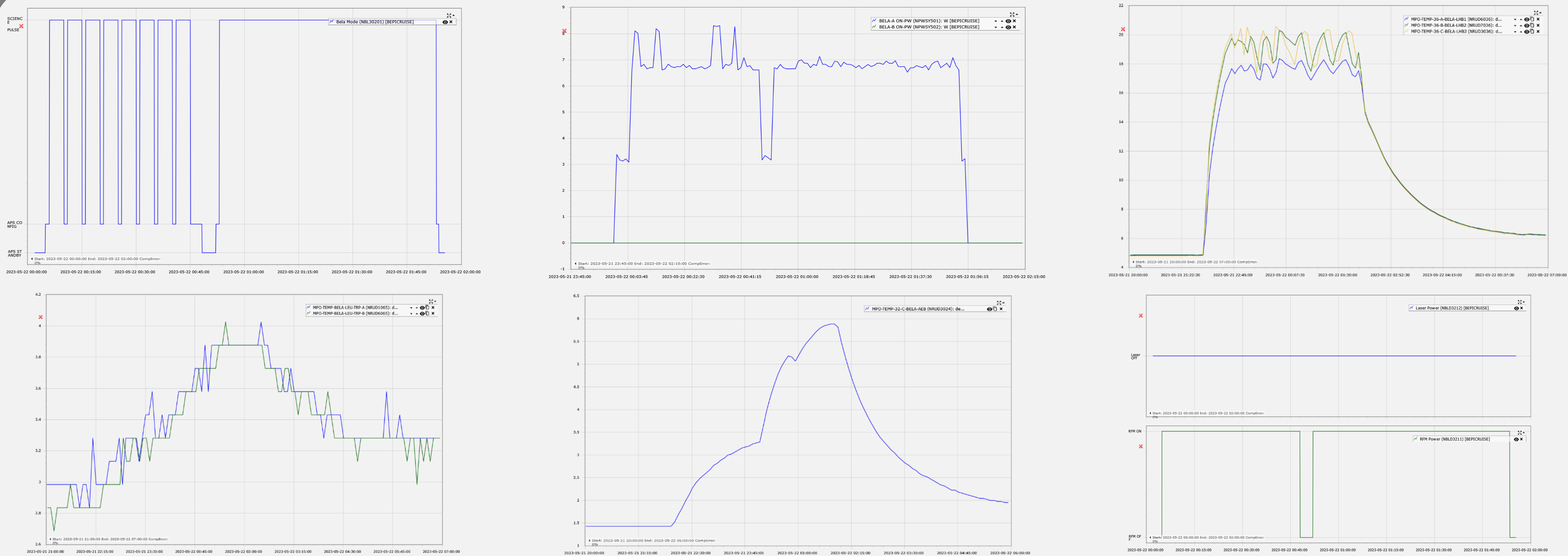


Figure 6: Technical TM data for the BELA CCO#9 (May 2023) from left to right: BELA modes, power consumption, laser temperature, Laser Electronics temperature, Analogue Electronics temperature, status laser and receiver