IEEC
Institut d'Estudis Espacials de Catalunya

ILIADA (In-Orbit LISA Diagnostics Demonstrator)

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Generalitat de Catalunya · Universitat de Barcelona · UAB Universitat Autònoma de Barcelona · Universitat Politècnica de Catalunya BarcelonaTech · CSIC Consejo Superior de Investigaciones Científicas · Centre de: CERCA Centres de Recerca de Catalunya

Outline



1. ILIADA Background & Motivation
2. Differents elements of ILIADA
3. Quicklook and TVAC test
4. Data Processing

Catalan New Space Strategy



The Generalitat de Catalunya (Catalan government) started in 2020 the Catalan New Space strategy to boost the local ecosystem related to space missions and services with two missions:

- **2021** → Launch of GENIOT (Enxaneta): 3U telecommunications satellite to provide IoT service. Included an IOD.
- **2022** → Launch of GENEO (Menut): 6U Earth observation satellite to provide high-frequency multispectral images (Sentinel, Copernicus)
- **2023** → published a tender for an Earth Observation mission (GENEO-02). **Includes an In-Orbit Demonstrator**

Catalan New Space Strategy

GENEO-02 will be a Sun-Synchronous Orbit with a high above 590 km and have communications both at S (TT&C and IOD data) and X (EO data) band. IOD requirements:

- Maximum volume of 2U, maximum mass of 2.66 kg
- Nominal power consumption below 6 W, 8 W peak.
- CubeSat Space Protocol interface with OBC over CAN or serial port.
- IOD shall not interfere with the main payload.
- FM IOD delivery ~~Q1 2025~~ Q4 2026.

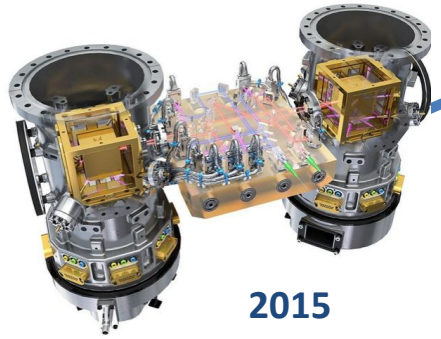


GENEO-02 Satellite

The path towards LISA

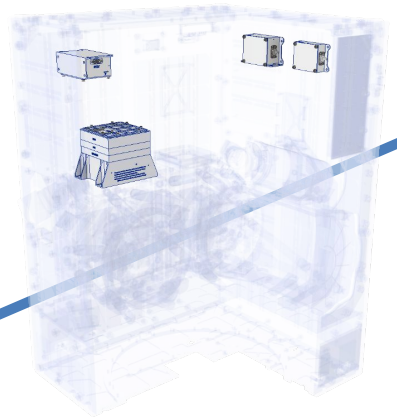
The ICE-IEEC group led the Spanish contribution to **LISA Pathfinder Diagnostics Subsystem (DDS)**

- Data Management Unit (DMU)
- 24 NTC temperature sensors
- 4 Fluxgate magnetometers
- 1 Radiation monitor (Si PIN)
- 16 Heaters
- 2 Coils



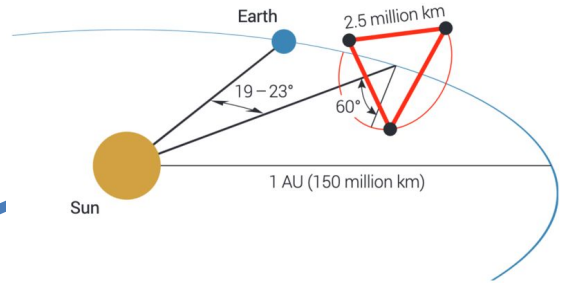
2015

2027



ILIADA is an in-orbit demonstrator for the LISA Science Diagnostics Subsystem (SDS).

2035

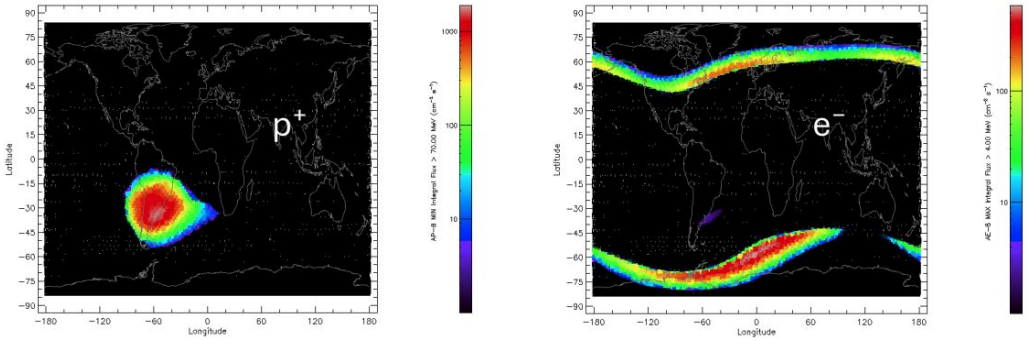


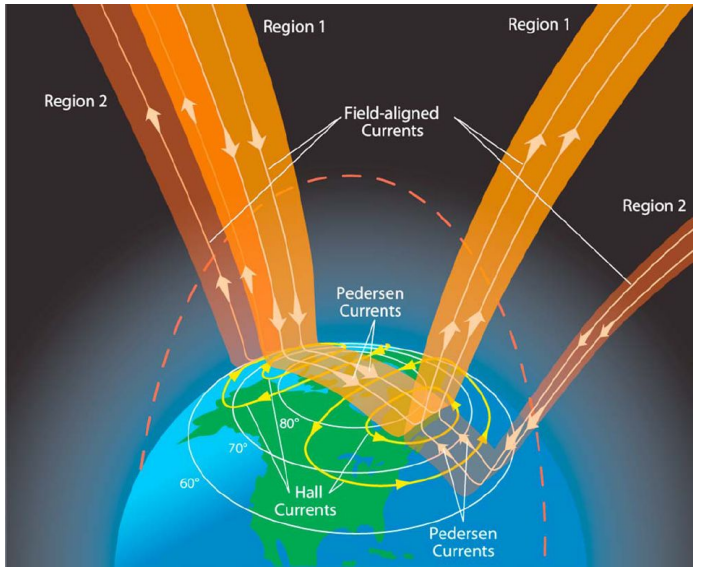
We are currently leading the **LISA Scientific Diagnostics Subsytem (SDS)**

- 6 Data and Acquisition Control Unit (DACU)
- 144 NTC/Pt temperature sensors
- 12 Fluxgate magnetometers
- 3 Radiation monitor (Si PM)
- 12 Heaters
- 6 Coils (audio band EM sensors)

ILIADA Science Case

1. **Rise LISA diagnostics related TRL:** temperature sensing, magnetometer (AMR), magnetometer (MEMs based), radiation monitor.
2. **Studies Earth magnetosphere**
   - **Monitoring radiation environment**
     - The radiation monitor has a 6mm Cu shielding that blocks **p < 70 MeV** (LISA design)
     - The detection rate will be driven mainly by trapped radiation and galactic cosmic rays
   - **Detection of Birkeland currents**
     - *Birkeland currents (Field Aligned Currents)*, a set of electrical currents flowing along the geomagnetic field lines.
     - These currents are detected as a transient signal in the magnetic field





ILIADA Science Case

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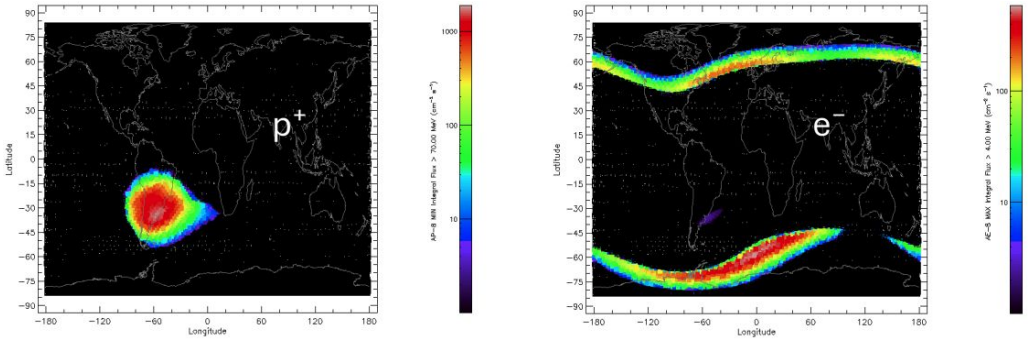
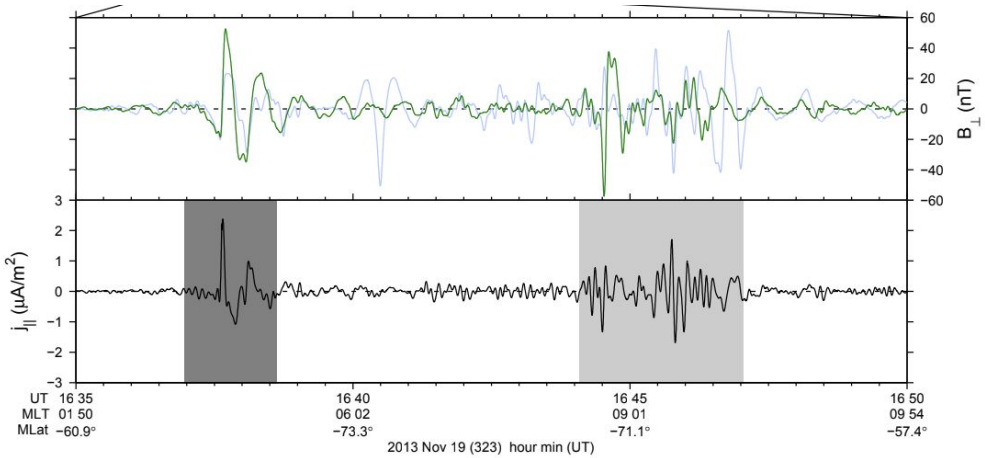
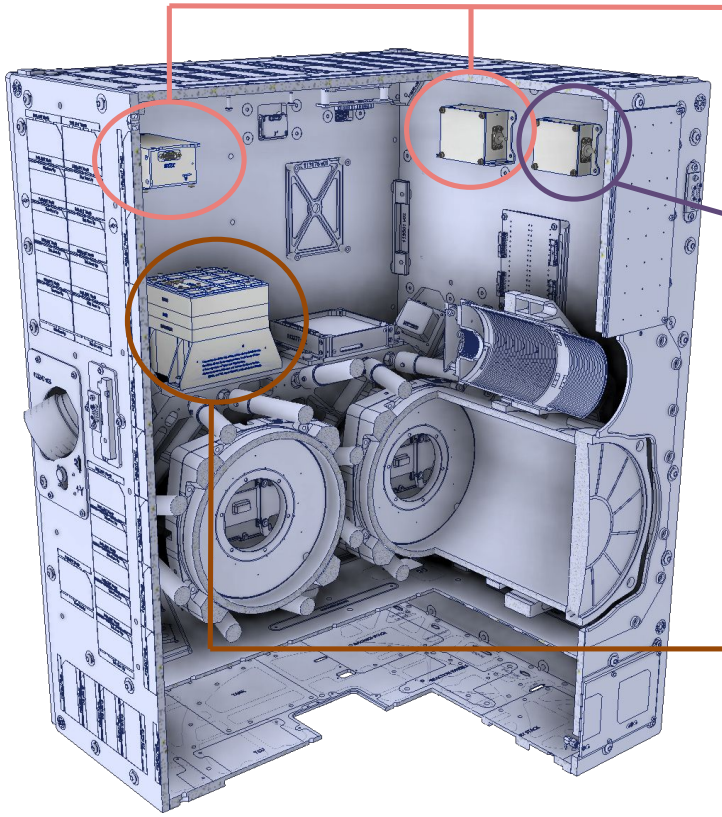




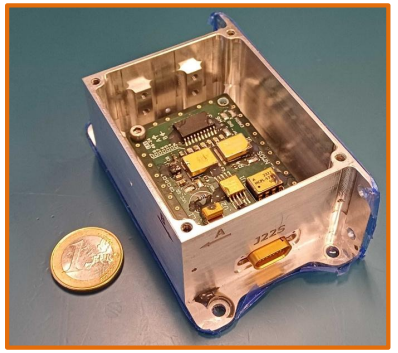
MAGIC (2015) Archer et al.[3] and RadCube (2025) Eastwood et al.[4]

ILIADA Elements



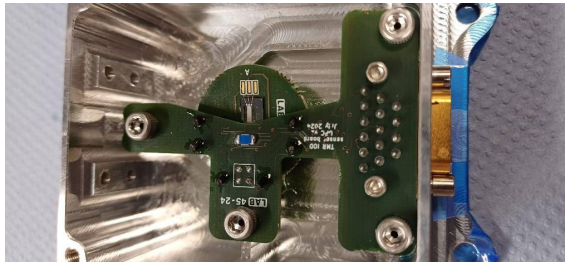
PARIS and HELENA

Magnetometer based on **Anisotropic Magnetoresistive sensors** (AMR). Reaching 30 nT/$\sqrt{Hz}$@ 0.1 mHz.



MENELAU

Magnetometer based **on Tunnel Magnetoresistive sensors (TMR)** modulated by a **MEMS cantilever**. Reaching 20 nT/$\sqrt{Hz}$@ 0.1 mHz.

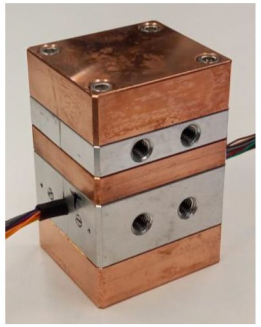


HOMER: Main unit, including

ICU: IEEC heritage from GENEO mission. Based in the **C3SatP** computer.

TEMP: Implementing LISA baseline temperature. Reaching 1μK/$\sqrt{Hz}$ at the mHz

HECTOR: radiation monitor based on plastic scintillators and silicon photomultipliers



PARIS and HELENA

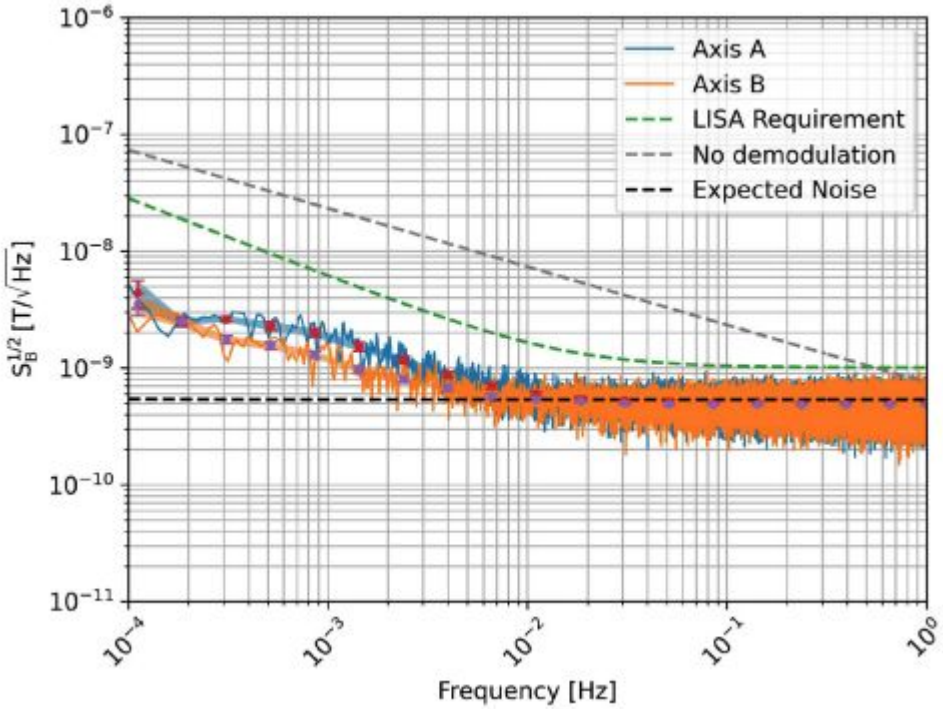
2-axis magnetometer based on Anisotropic Magnetoresistive sensors (AMR) in a full Wheatstone bridge disposition with a sensitivity ~60-20 V/T.

- Own design developed to reach LISA requirements (LIMAG internal IEEC project)
- Includes flipping electronics to modulate the output signals and overcome 1/f noise.
- **Low power consumption (~20 mW).**
- Mass below 140 g.
- Noise below 30 nT/ Hz @ 0.1 mHz

Underwent a full magnetic characterization at ESTEC MCF facility determining a ~ 30 μAm2 (populated PCB)





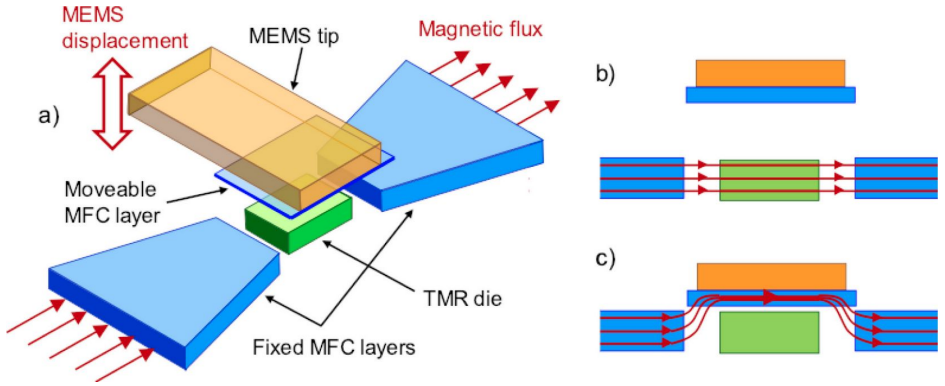


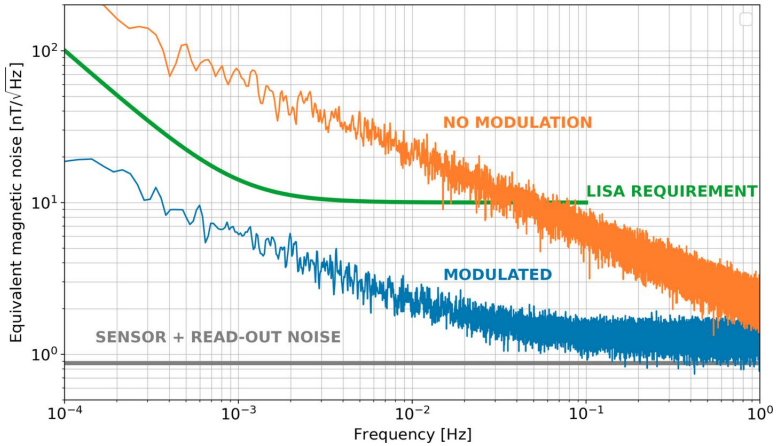
MENELAU

1-axis magnetometer based on Tunnel Magnetoresistive sensors (TMR) modulated by a MEMS cantilever with a flux concentrator material at the tip. Placed in a Wheatstone bridge disposition with a high-sensitivity (~70 V/T).

- Own design developed to reach LISA requirements (MELISA internal IEEC project)
- Very low power consumption (~1 mW)
- Mass below 140 g
- Noise below 20 nT/ Hz @ 0.1 mHz







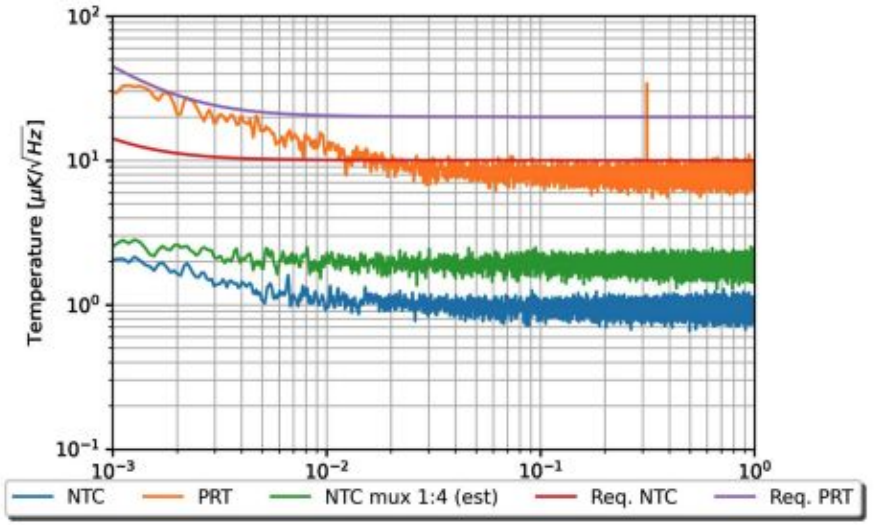
Manyosa, X. et al. MEMS miniaturized low-noise magnetic field sensor for the observation of sub-millihertz magnetic fluctuations in space exploration. Measurement 230, 114489 (2024)

LETS (LISA Enhanced Temperature Subsystem)

- LETS was developed under an ESA ITT as a technological demonstrator to achieve the future LISA mission requirements



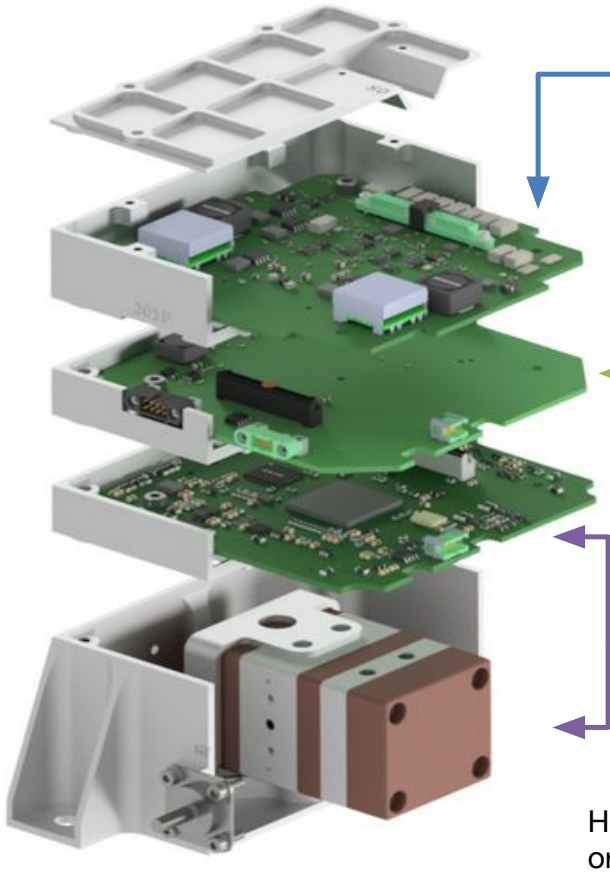
- Is able to acquire up to 16 resistive sensors (NTCs as baseline) placed in an AC biased Wheatstone bridge disposition with a high accuracy and a stability of ~2 μK/ Hz at the mHz.



Roma-Dollase, D. et al. Resistive-Based Micro-Kelvin Temperature Resolution for Ultra-Stable Space Experiments. Sensors, 23(1), 145. (2023)

- ILIADA temperature subsystem implements a compact version.

HOMER



Digital Acquisition Unit

Based on LETS module. Generates modulation signals, bias signals and converts analog output to digital values.

Instrument Control Unit Flight heritage from the previous GENEO mission (IEEC heritage).

- Based on a **SAMv71 microcontroller**.
- Running a FreeRTOS with CSP libraries.
- Communicates with the OBC via UART/CAN, packing the RM data and modulating/demodulating temperature/magnetic sensors.

Radiation Monitor (HECTOR) Front-end electronics and sensor

Reduced version with commercial components of the RM for LISA

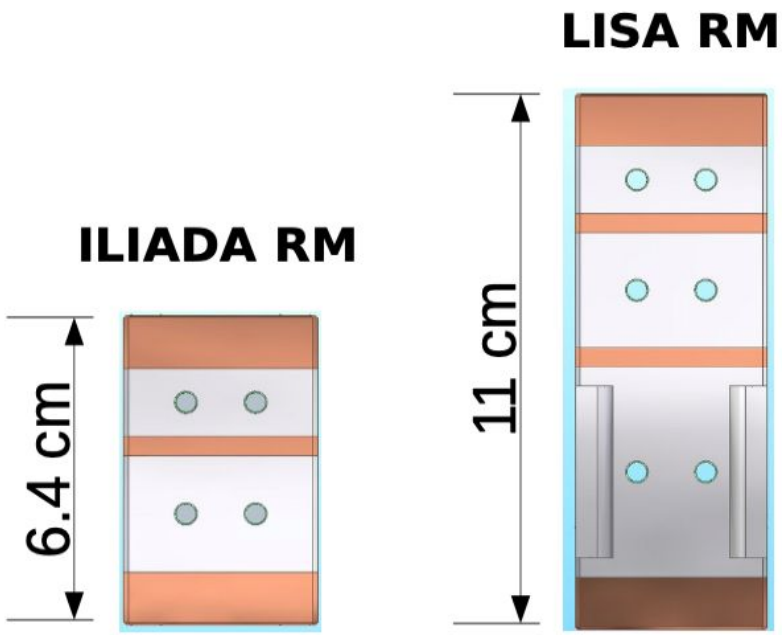
HOMER will include an engraving of the Iliad poem in original **Greek** and recent **Catalan**, as part of an agreement with Casa dels Clàssics to promote classical culture.

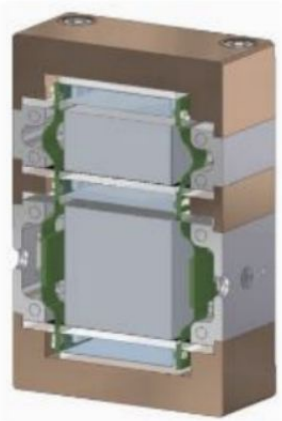


HECTOR

HECTOR is a reduced version of the LISA baseline radiation monitor, based on

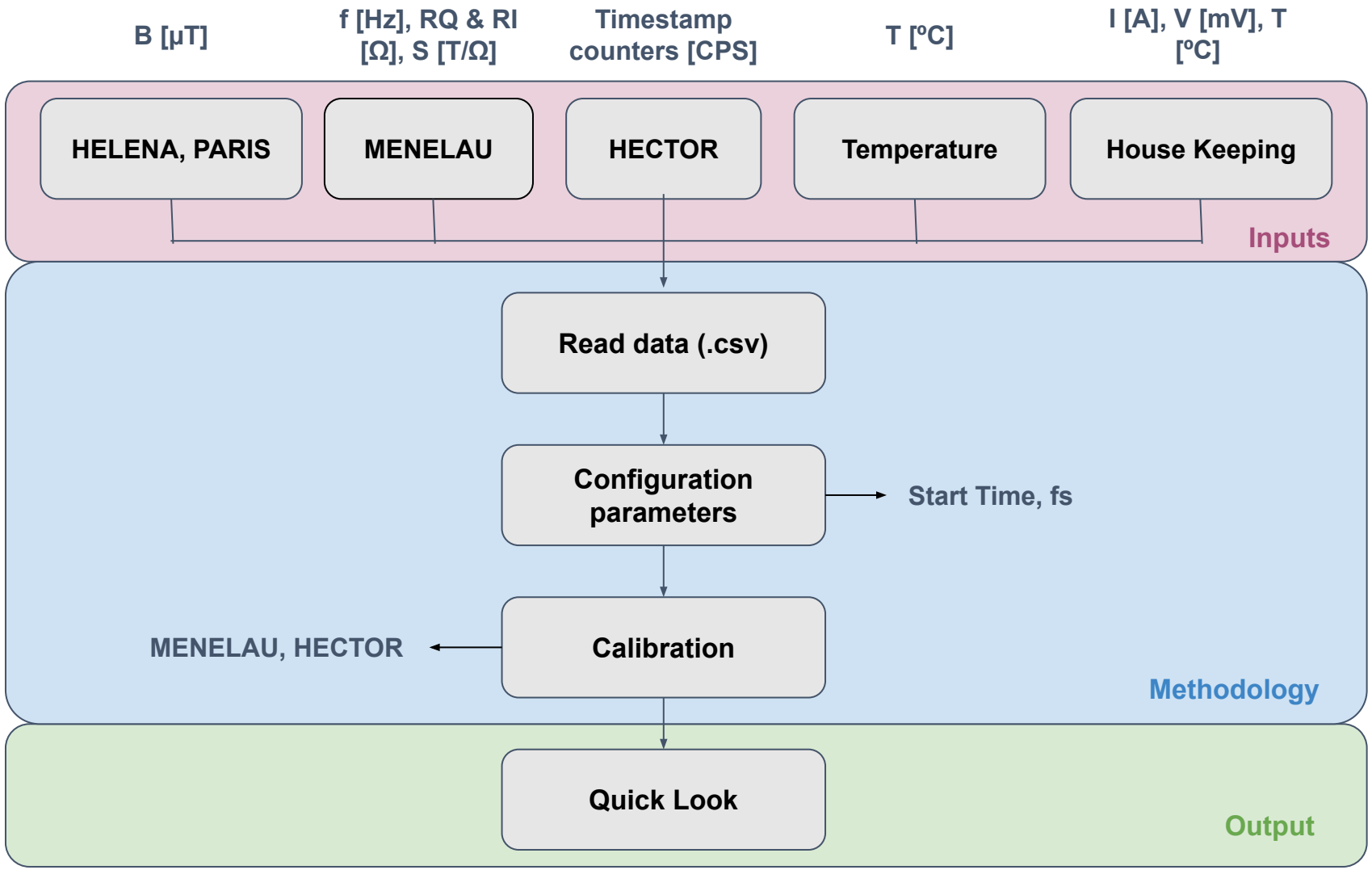
- Three plastic scintillators and Silicon photomultipliers separated by two absorbers (W) of different size.
- The BETA ASIC can amplify, shape and digitize up to 64 photodiodes output.
- An FPGA will interface with the BETA ASIC to provide coincidence event and/or individual trigger rates in form of histograms.





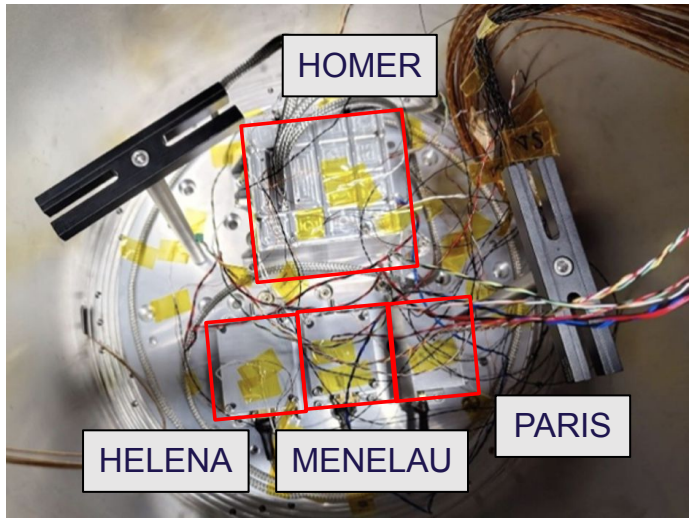
Quicklook and TVAC tests

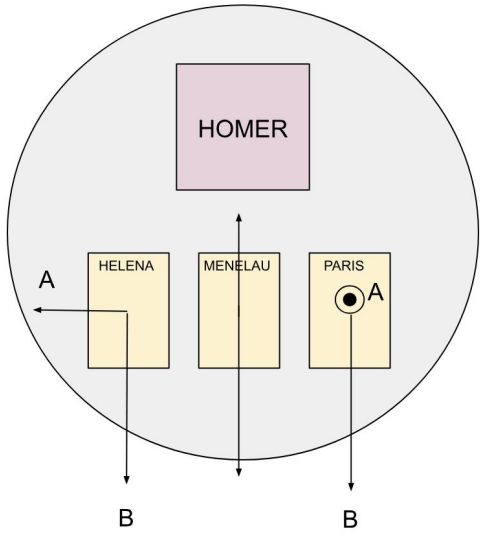
- All ILIADA data in one place.
- **Objective:** Provide a quick overview to verify that all data are being received correctly and that the system is operating as expected.

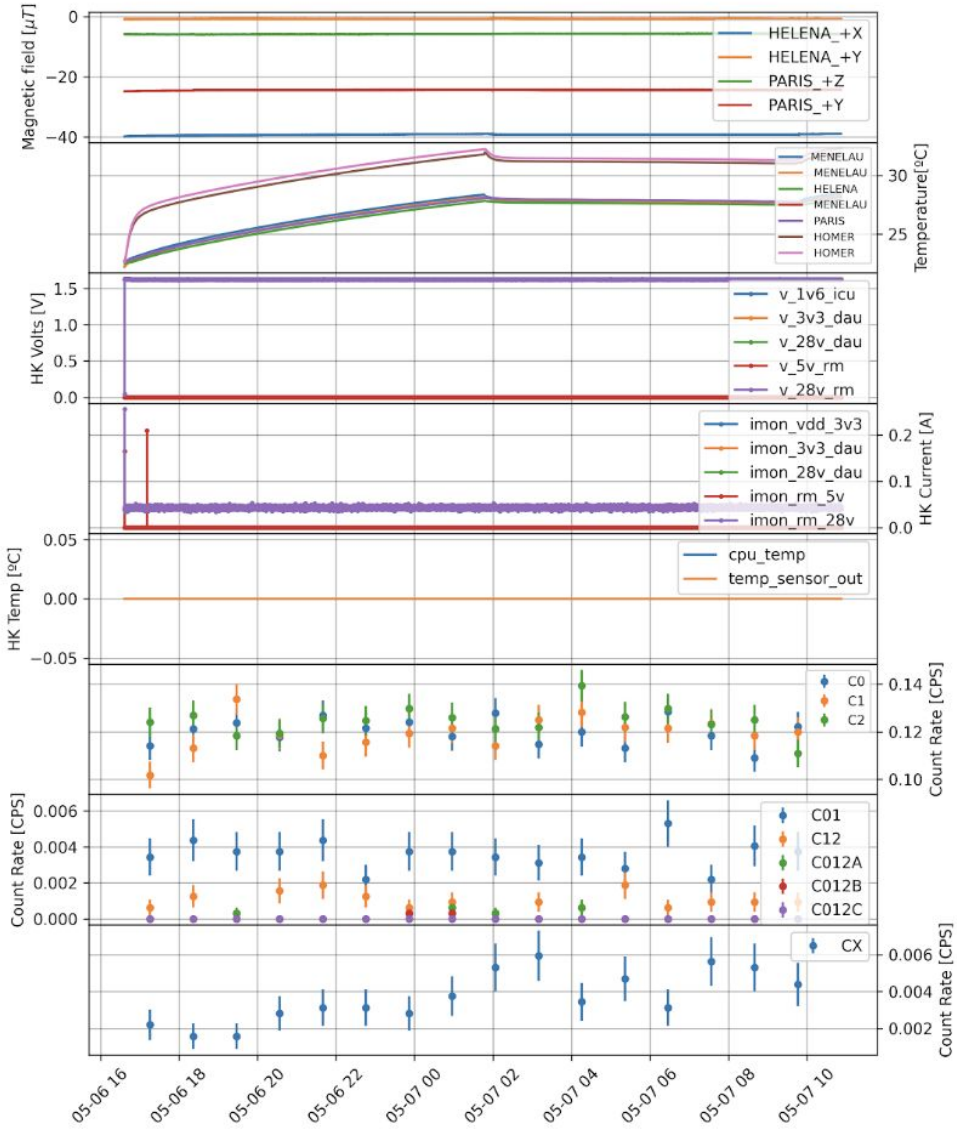


Quicklook and TVAC tests

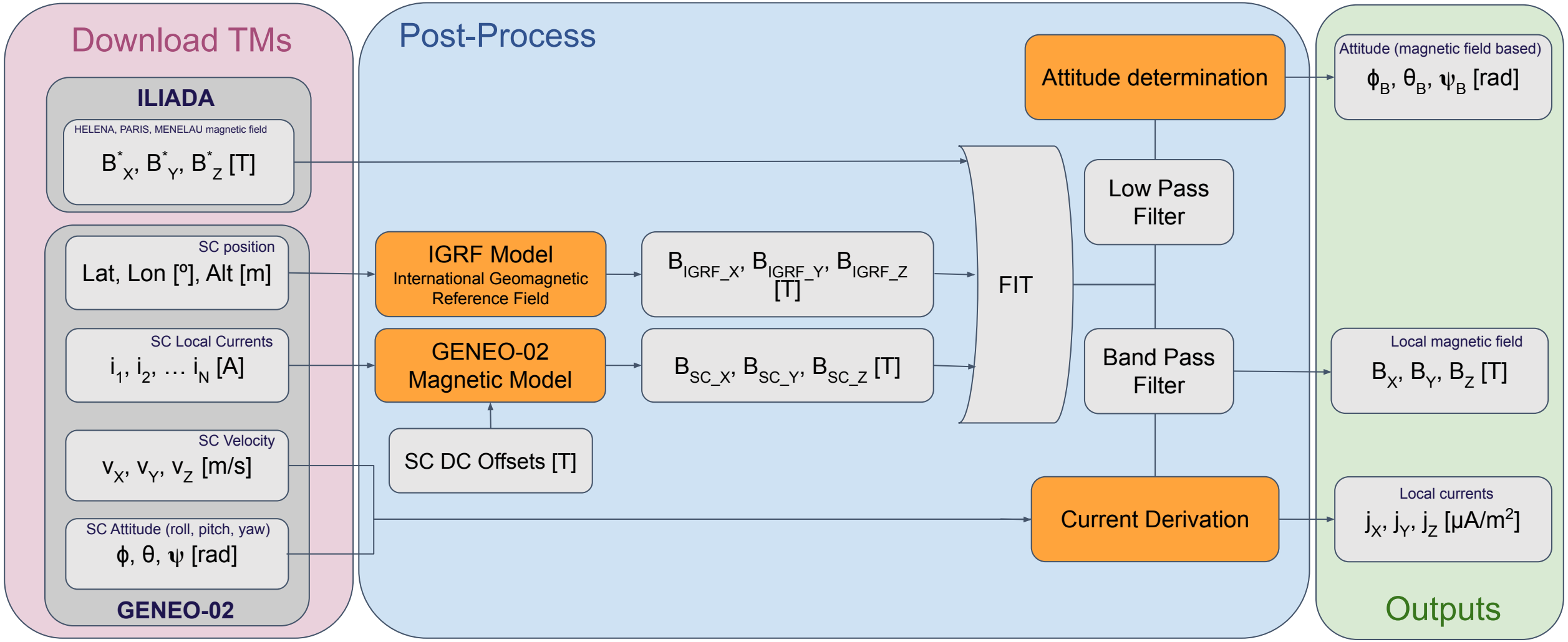
- **May 6th** Validation test of ILIADA FM
- The test was performed under vacuum conditions at a pressure between **$2 \cdot 10^{-5}$ and $3 \cdot 10^{-5}$ mbar** and a temperature of **23 °C.**





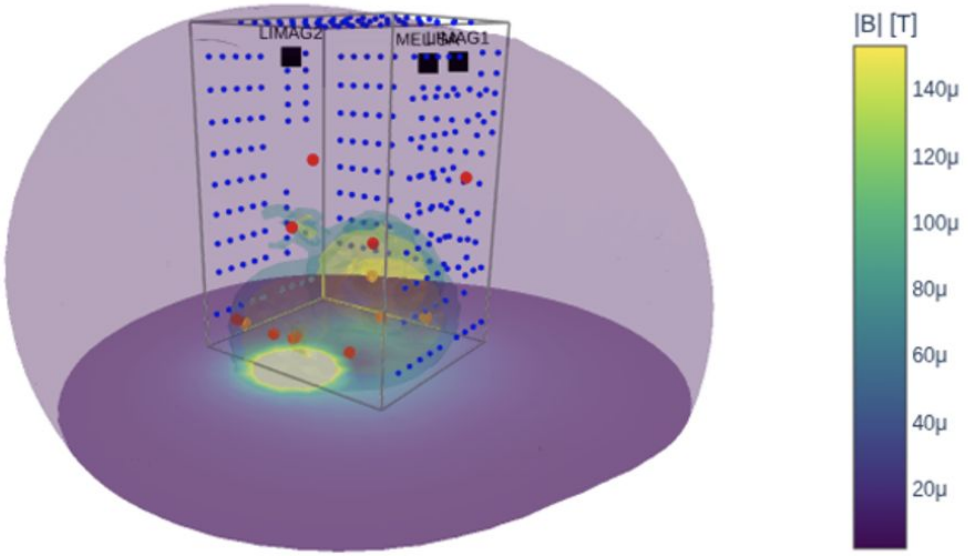


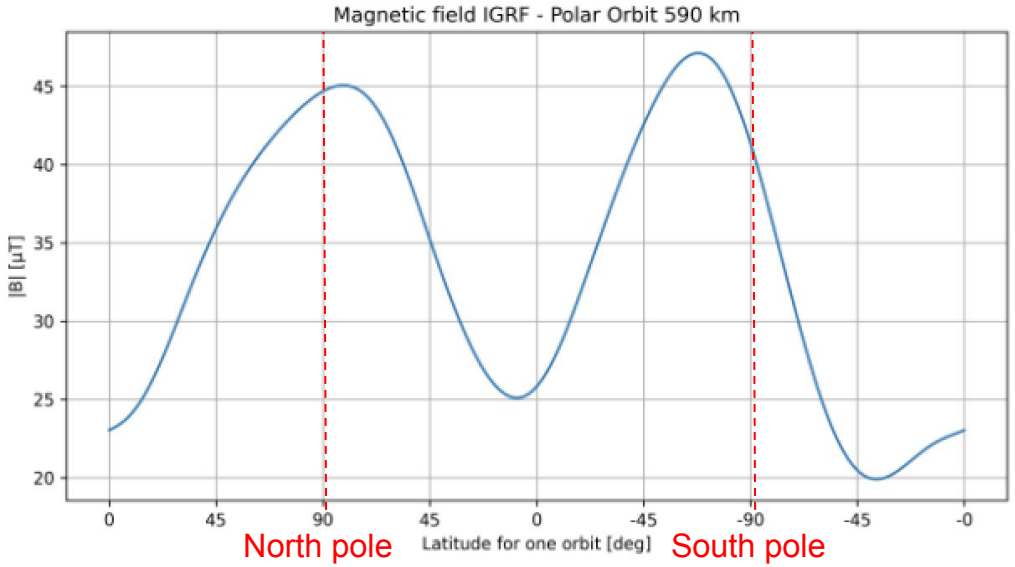
Data processing

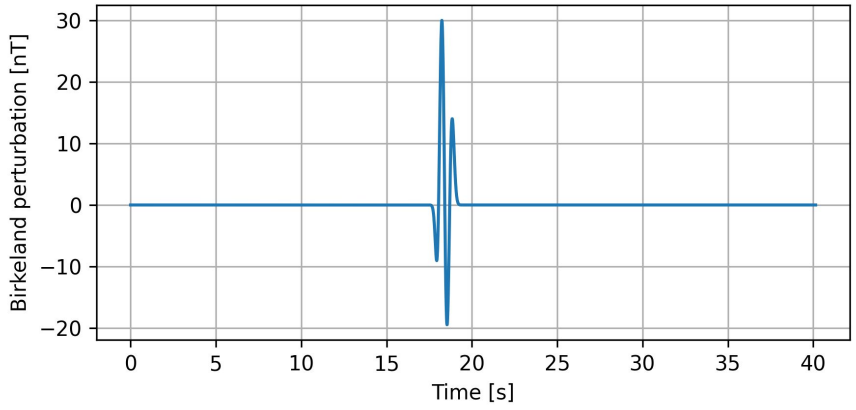


Data processing: Raw Data

Synthetic data were generated using GENEO-02's orbital characteristics and the expected magnetic field along the satellite's trajectory.



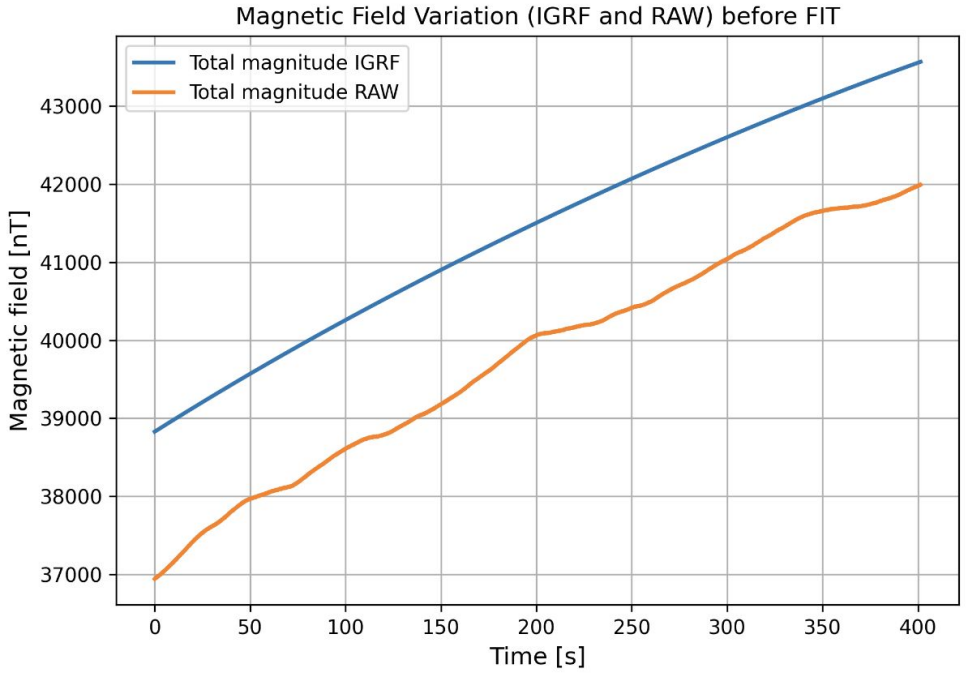


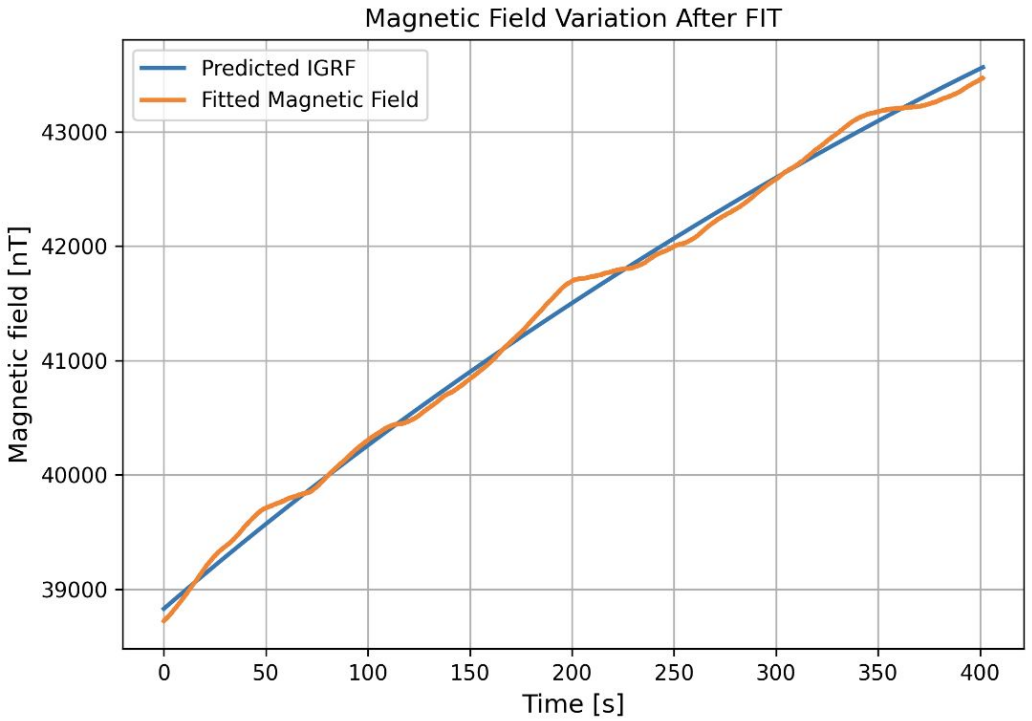


B = IGRF + GENEO-02 + Birkeland Current + Noise

Data processing: FIT

The FIT process estimates and remove the GENEO-02 and misalignment contributions from the magnetic field.

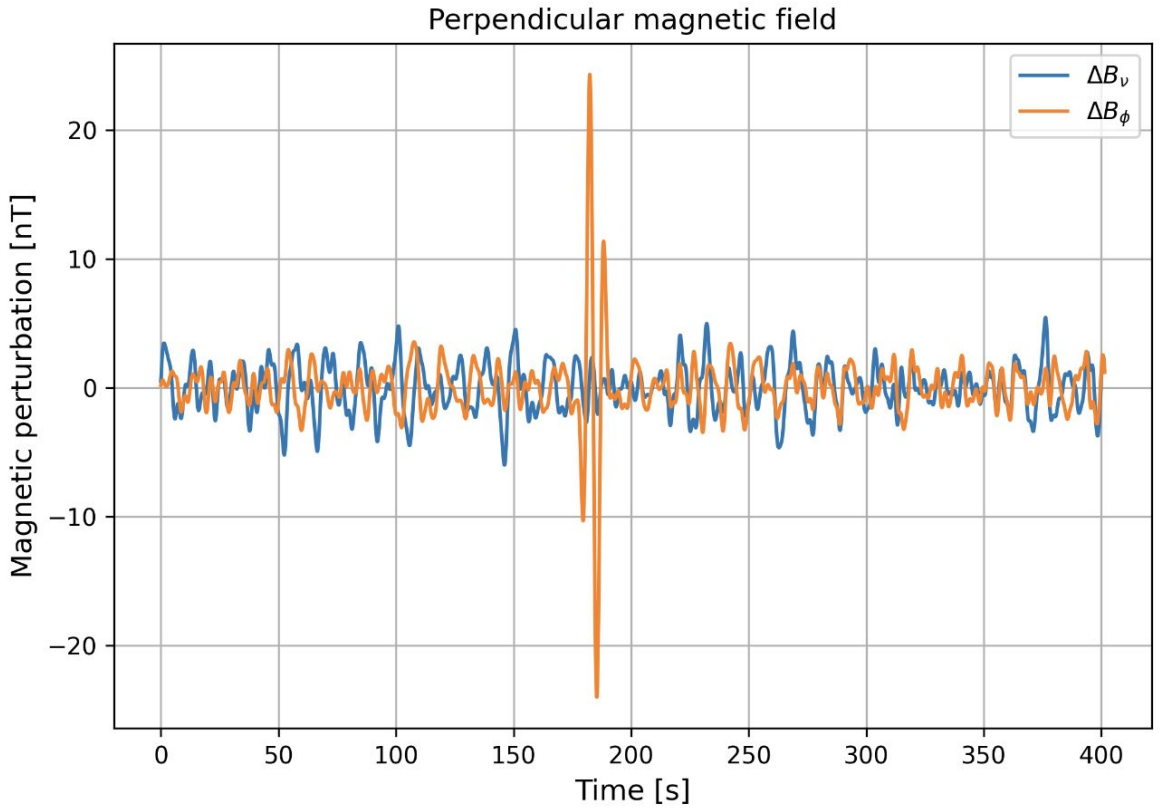




B = IGRF + ~~GENEO-02~~ + Birkeland current + Noise

Data processing: Band-Pass

A band-pass filter (0.4–0.9 Hz) is applied to the signal to remove magnetic contributions, isolating the magnetic transients associated with Birkeland currents. **Only the perpendicular components to IGRF are computed.**



B = ~~IGRF~~ + ~~GENEO-02~~ + Birkeland current + ~~Noise~~

Data processing: Birkeland Current Computation

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$$

Ampère-Maxwell

$$J_{\parallel} = \frac{1}{\mu_0} (\nabla \times \mathbf{B}) \cdot \hat{\mu}$$

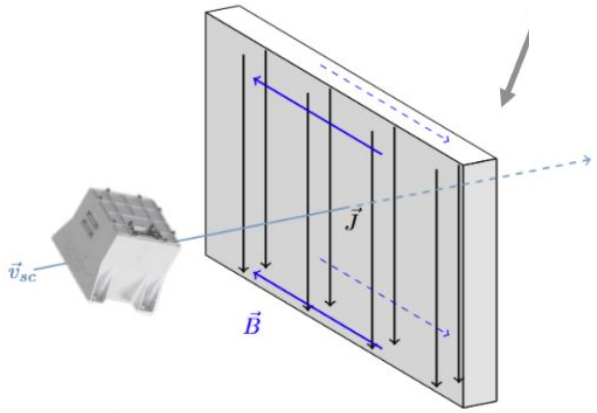
Space → time, via the crossing speed v⊥

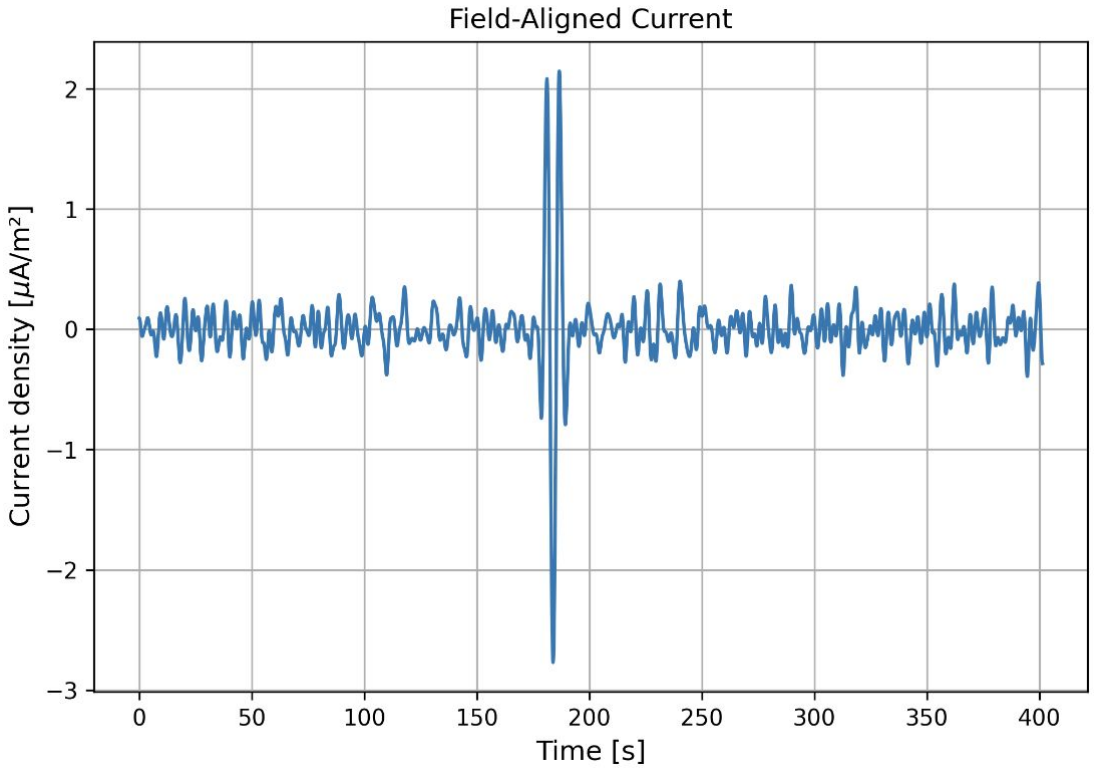
$$\frac{\partial}{\partial n} \approx \frac{1}{v_\perp} \frac{d}{dt}$$

$$\hat{\mathbf{n}} = \frac{\hat{\mu} \times \mathbf{v}}{\|\hat{\mu} \times \mathbf{v}\|} \qquad v_\perp = \|\mathbf{v} \times \hat{\mu}\|$$

$$J_{\parallel} = \frac{1}{\mu_0 v_\perp} \frac{d}{dt} (\mathbf{B}_\perp \cdot \hat{\mathbf{n}})$$

Lühr method





Thank you!

