IEEC
Institut d'Estudis Espacials de Catalunya

Temperature and Magnetic Diagnostic subsystem in LISA

LISA Spain Meeting 2024

ICE, Barcelona

Generalitat de Catalunya
Universitat de Barcelona
UAB Universitat Autònoma de Barcelona
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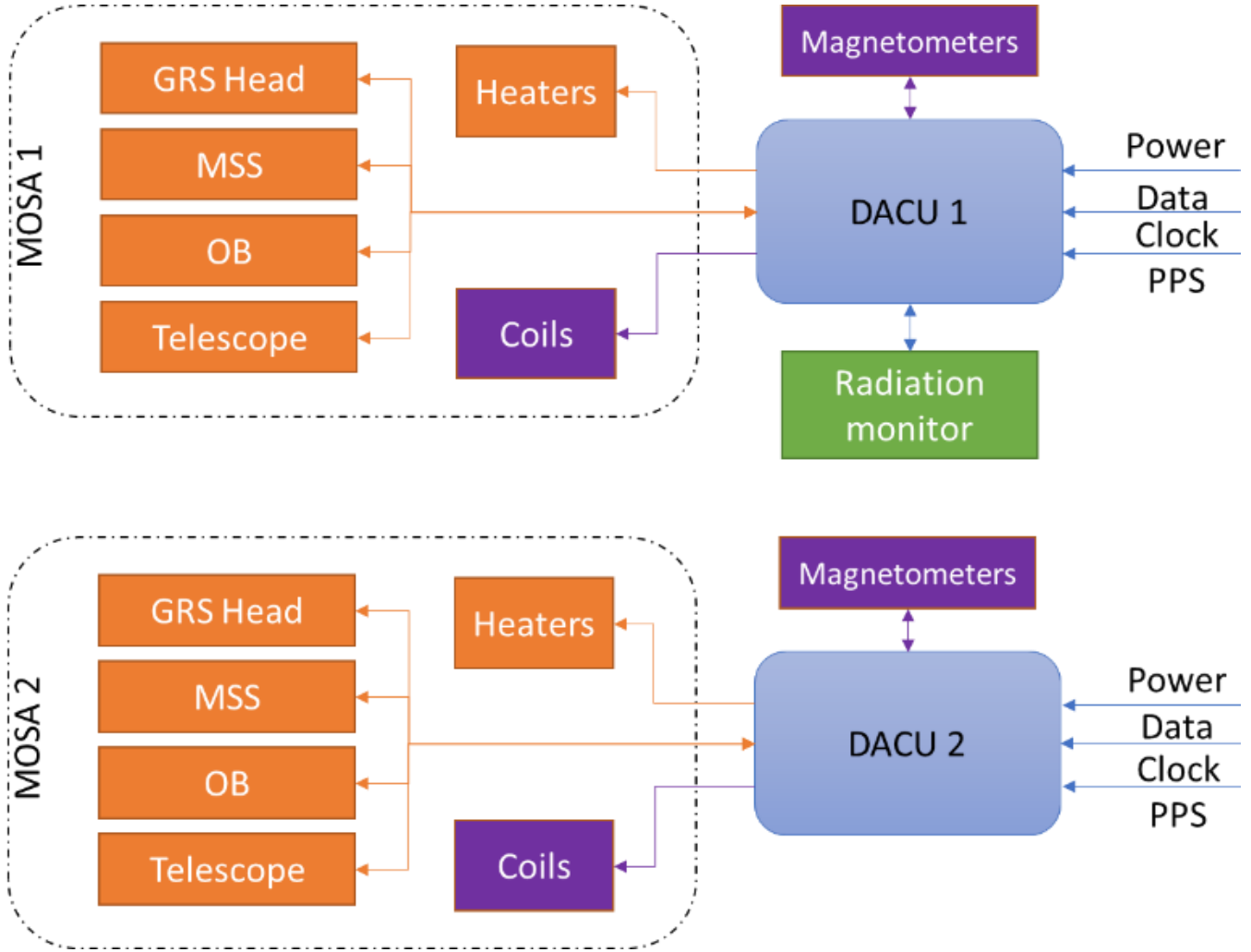
Outline

- SDS Overview
- Magnetics Subsystem
  - Audio-band magnetometer
  - Low-frequency magnetometer
- Temperature Subsystem
- Diagnostics Acquisition & Control Unit (DACU)
- Summary

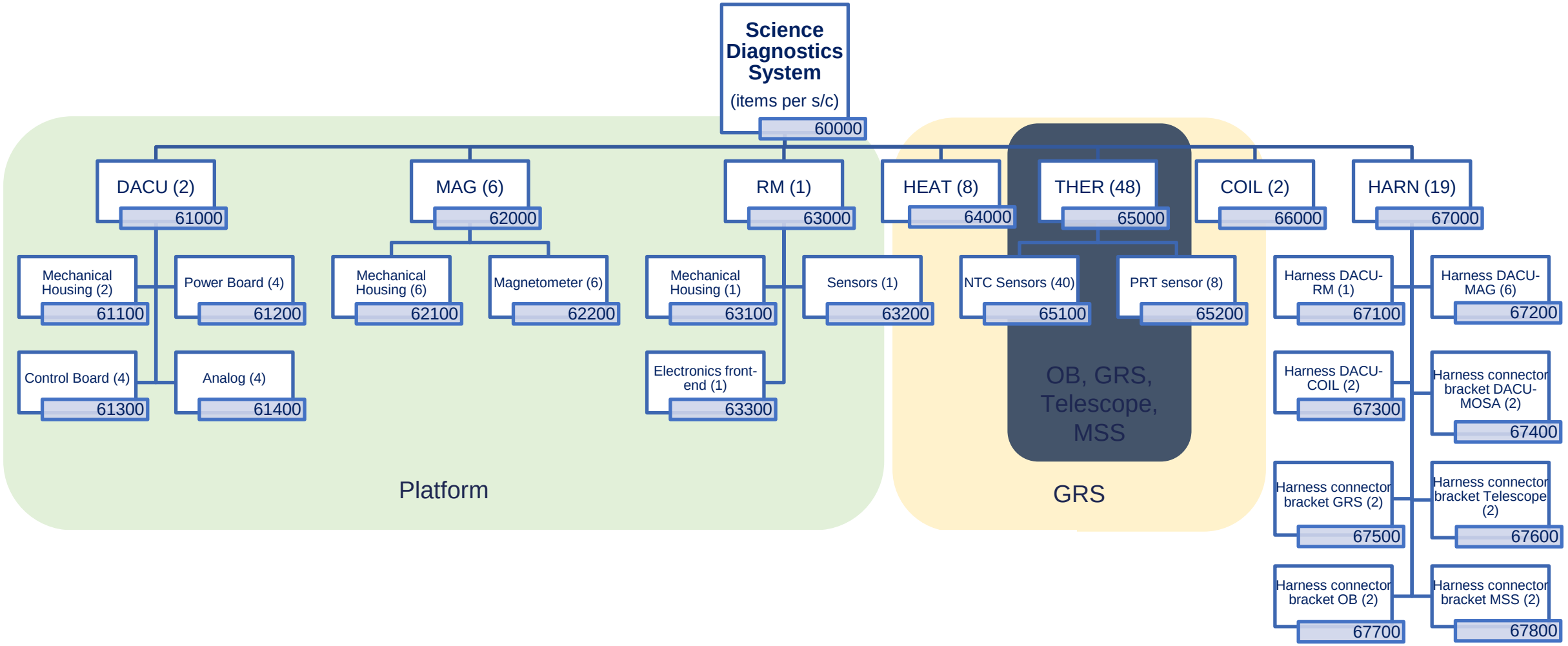
SDS Overview

Characterize and monitor the environment of LISA:

- Charged particles
- Temperature
- Magnetic Field

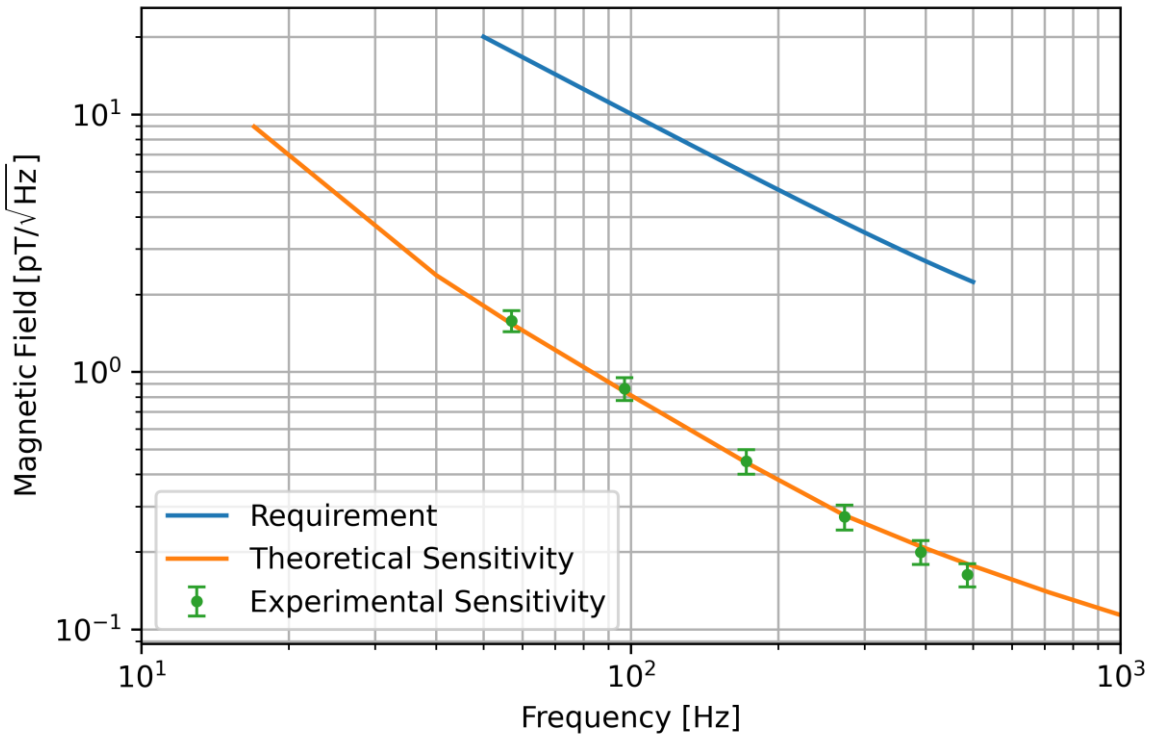


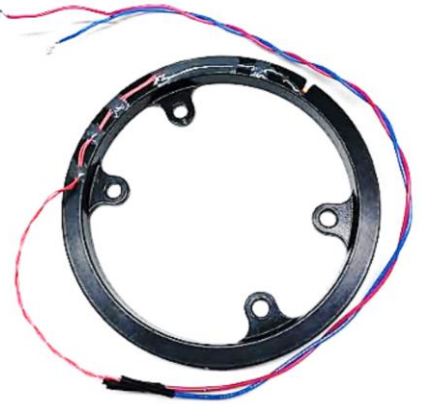
SDS Product Tree

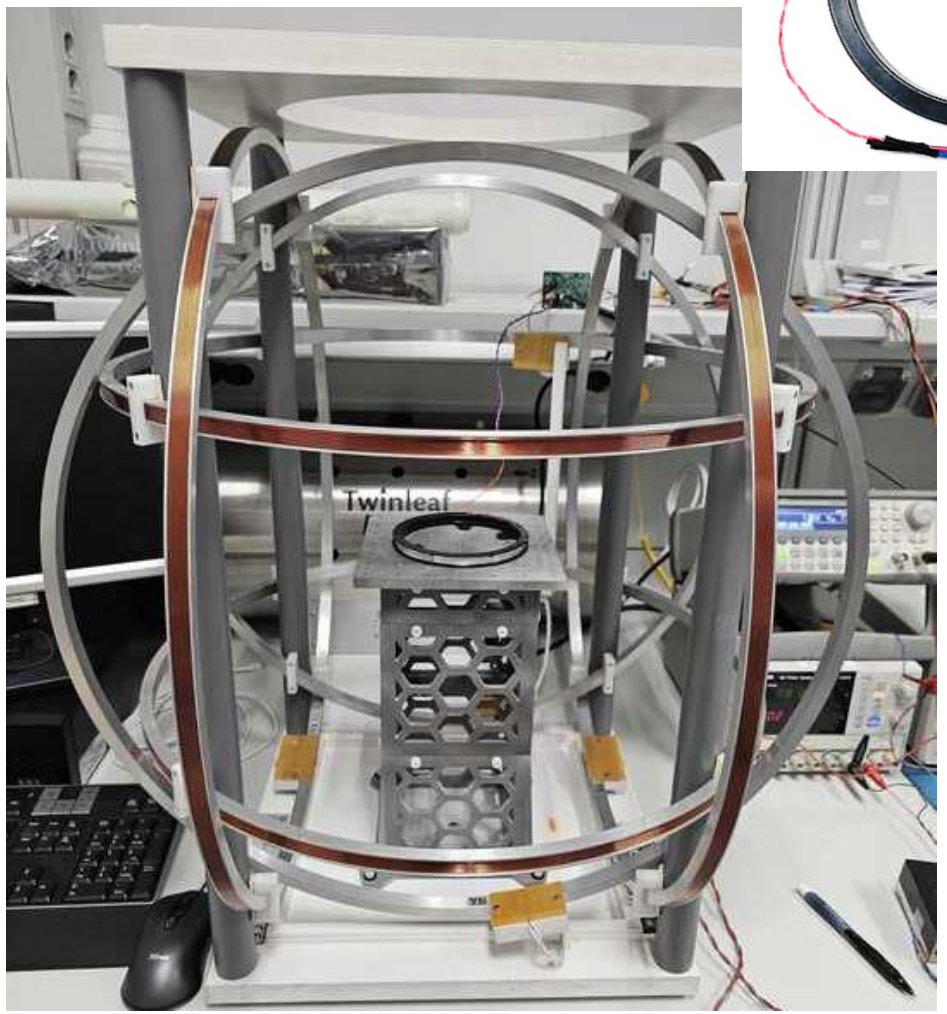


Diagnostics – Audio frequency magnetometer

Based on LPF coil and placed on the GRSH.
Sensitivity characterized, WIP for equivalent noise.



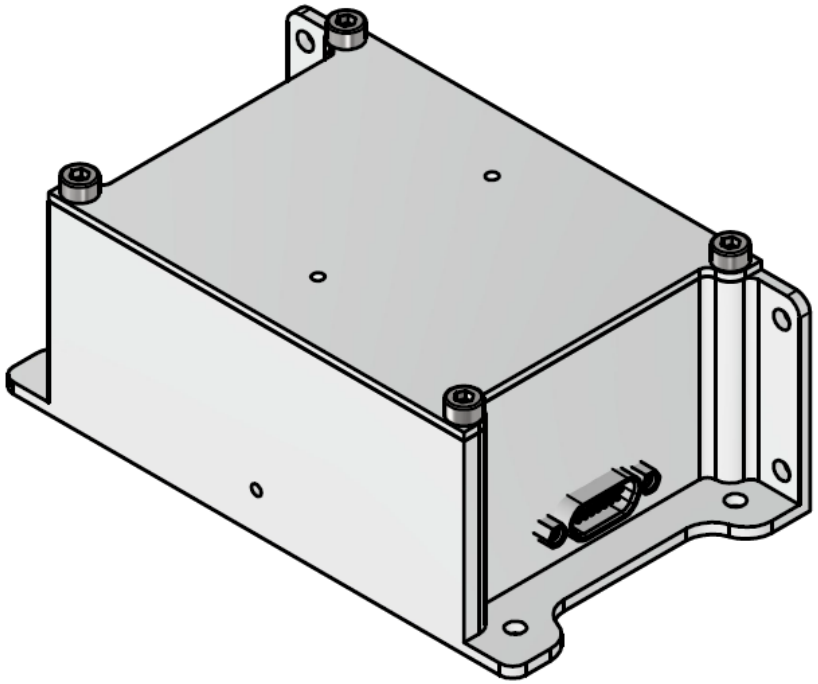


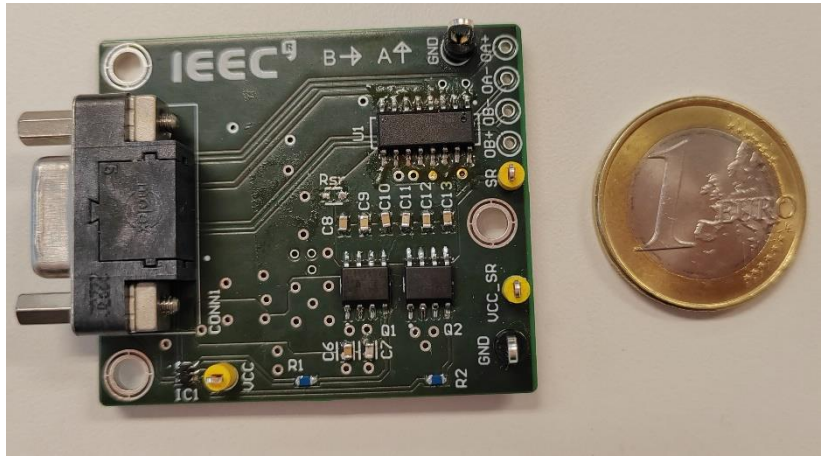


Diagnostics – Low-frequency magnetometer

Based on Anisotropic Magnetoresistive (AMR) 2-D sensors, allowing having less power dissipation and magnetic material content than fluxgate sensors. Thus, less impact at critical locations in LISA.

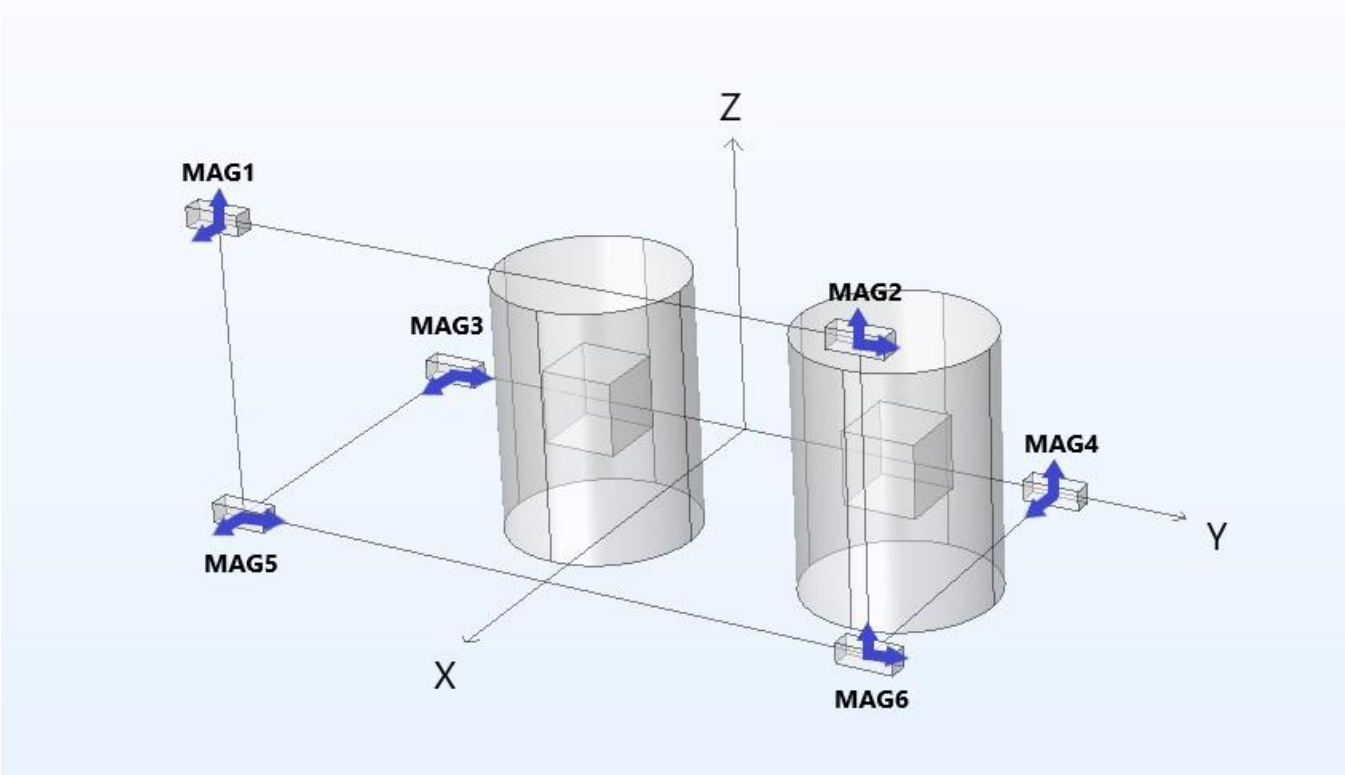
Performance sensing range: ± 10 µT with 2 % absolute accuracy.





Diagnostics – Low-frequency magnetometer

They shall allow characterizing both the absolute magnetic field and its gradients in all three axes/directions. The proposed distribution is complaint with this, even in the case of failure of one of the magnetometers.

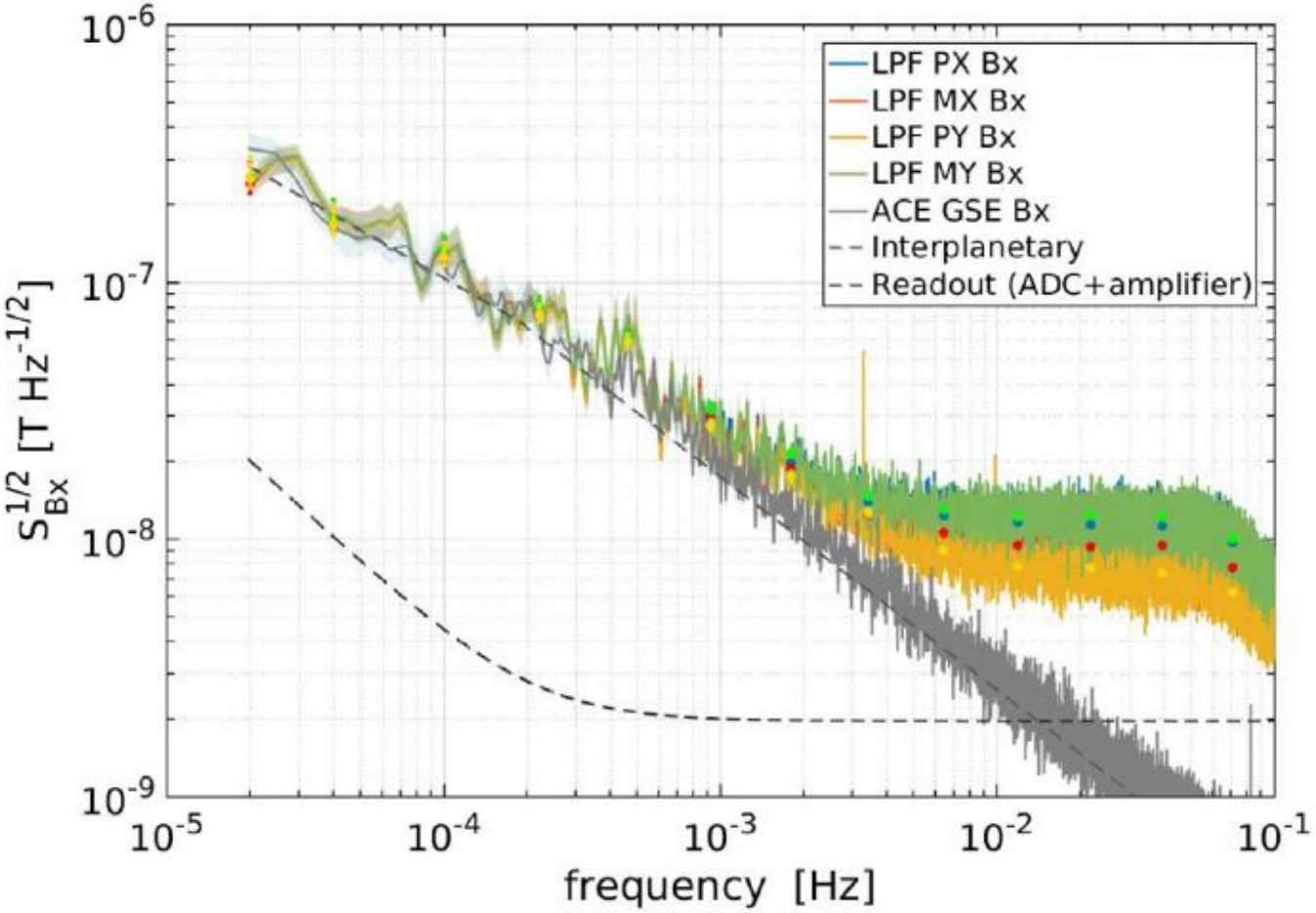


Low-frequency magnetometer requirements

- Stability from 0.1 Hz down to 0.1 mHz:

$$10\left[1+\left(\frac{1\,mHz}{f}\right)^2\right]^{\frac{1}{2}}\ nT/\sqrt{Hz}$$

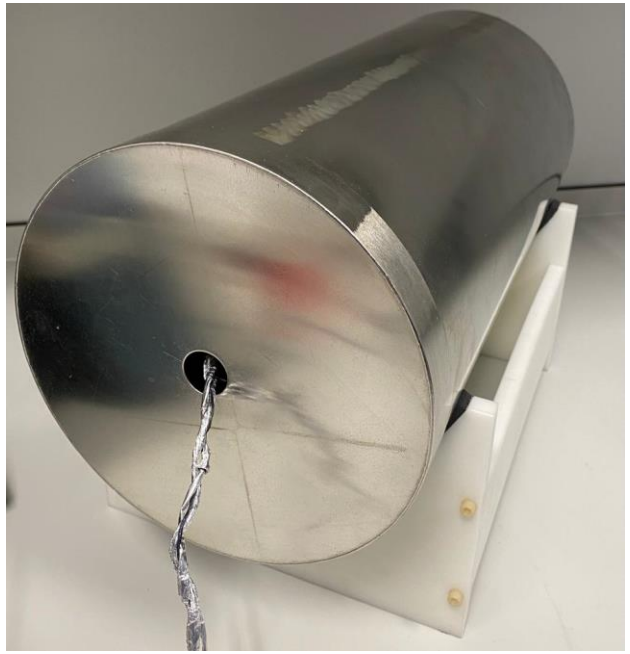
- Volume (W x L x H): 35 x 83 x 32 mm
- Max. power dissipation: 100 mW each
- Maximum mass: 140 g
- 6 sensors per spacecraft
- LPF used tri-axial fluxgates



[https://doi.org/10.1093/mnras/staa830]

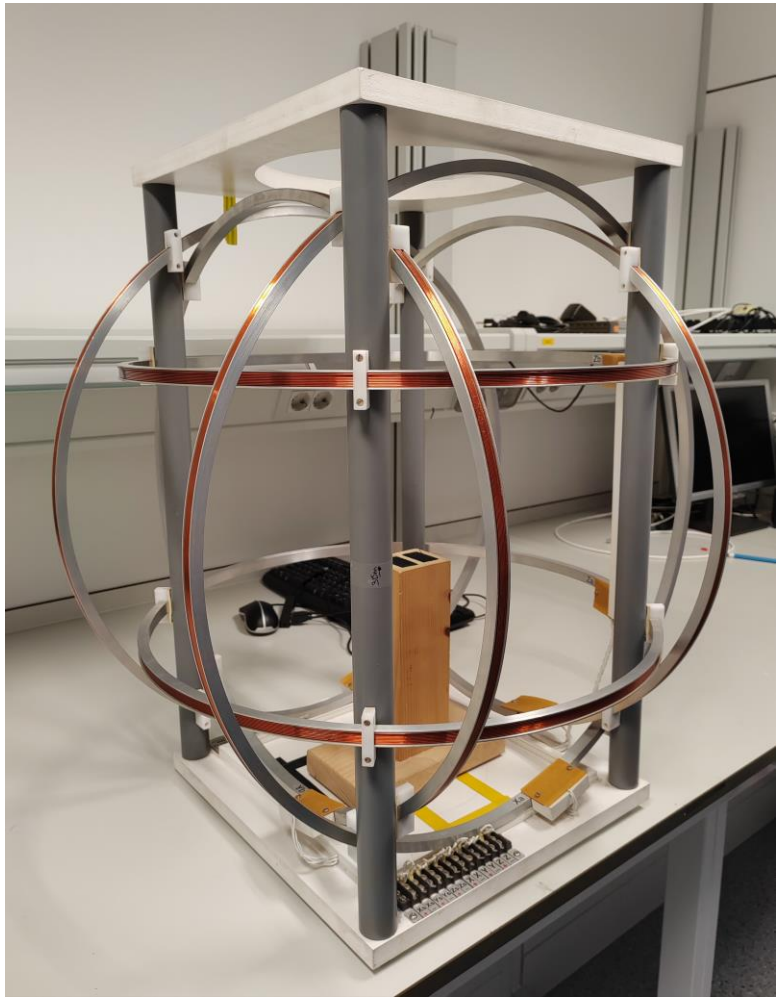
Magnetic Set Up

Mu-metal chamber



Temperature controlled chamber

Helmholtz Coil

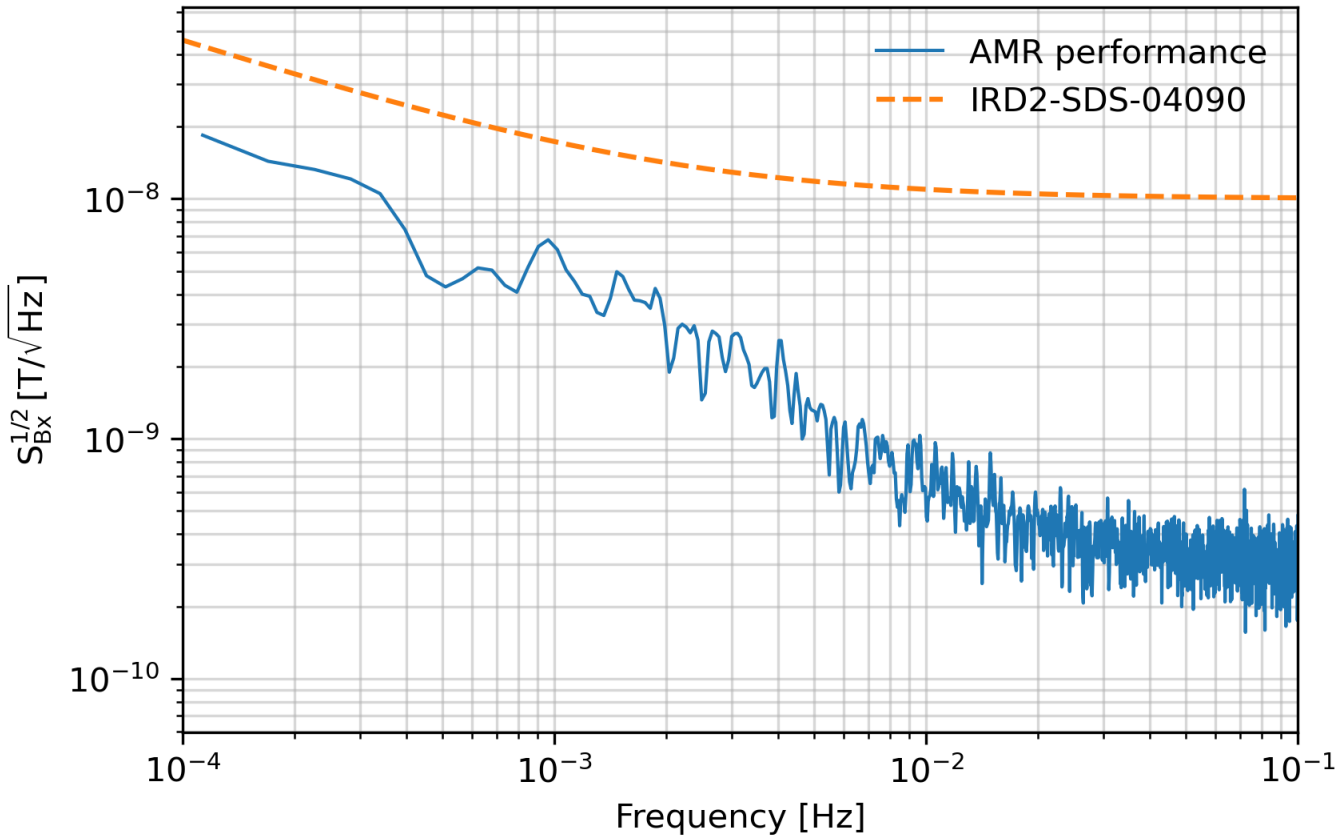


Diagnostics – Low-frequency magnetometer

Noise performance below requirements.

Conditions:

- 3 layers of mu-metal
- Inside the ATCU



Diagnostics – Temperature sensors

Sensor's quantity is per MOSA (two per S/C, three S/C in the LISA constellation)

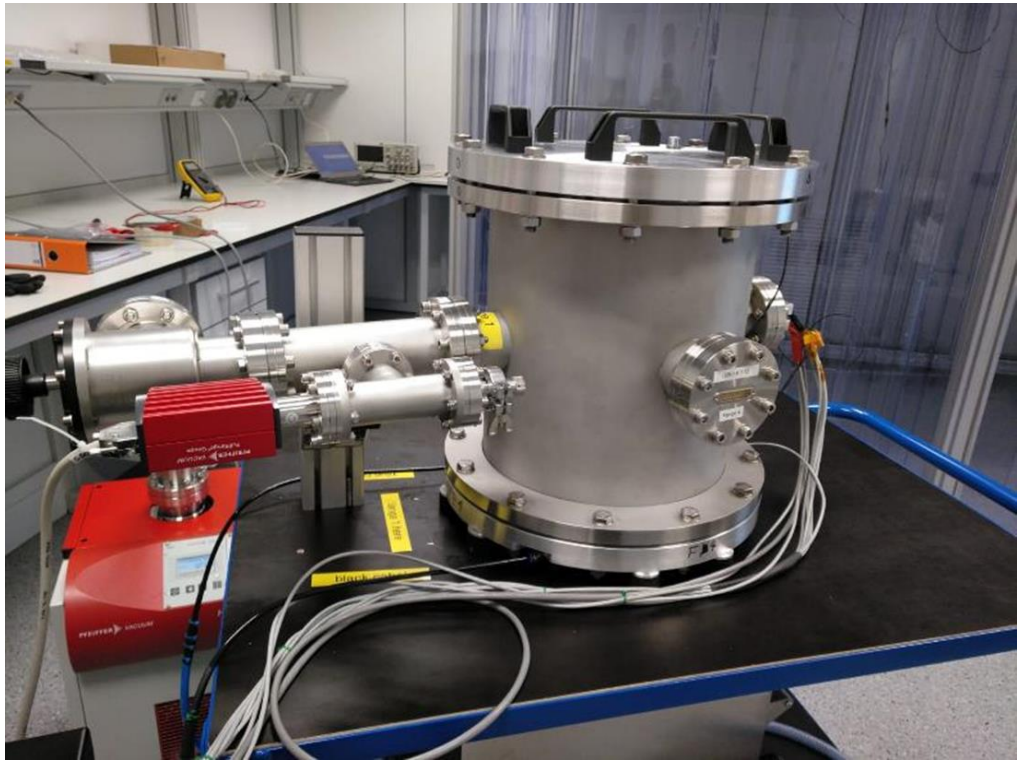
Unit	Sensors	Sensor kind	Temperature range	Thermal stability (0.1 Hz down to 0.1 mHz)
Telescope	7 (6+1R)	10k NTC	(-10°C) 0°C to +30°C	$10\left[1+\left(\frac{2\,mHz}{f}\right)^4\right]^{1/2}$ µK/$\sqrt{Hz}$
GRSH	4	10k Pt RTD	(+5°C) +13°C to +27°C	$20\left[1+\left(\frac{2\,mHz}{f}\right)^2\right]^{1/2}$ µK/$\sqrt{Hz}$
MSS	6	10k NTC	(-10°C) +6°C to +34°C	$10\left[1+\left(\frac{2\,mHz}{f}\right)^4\right]^{1/2}$ µK/$\sqrt{Hz}$
OB	7	10k NTC	(-10°C) +6°C to +34°C	$10\left[1+\left(\frac{2\,mHz}{f}\right)^4\right]^{1/2}$ µK/$\sqrt{Hz}$

() = Aim for degraded performance range

Pt RTD placed at magnetic sensitive locations, but have reduced sensitivity

Diagnostics – Testing is challenging

Join us for a lab tour!



Layers placed inside a vacuum chamber to reduce convection thermal transfer

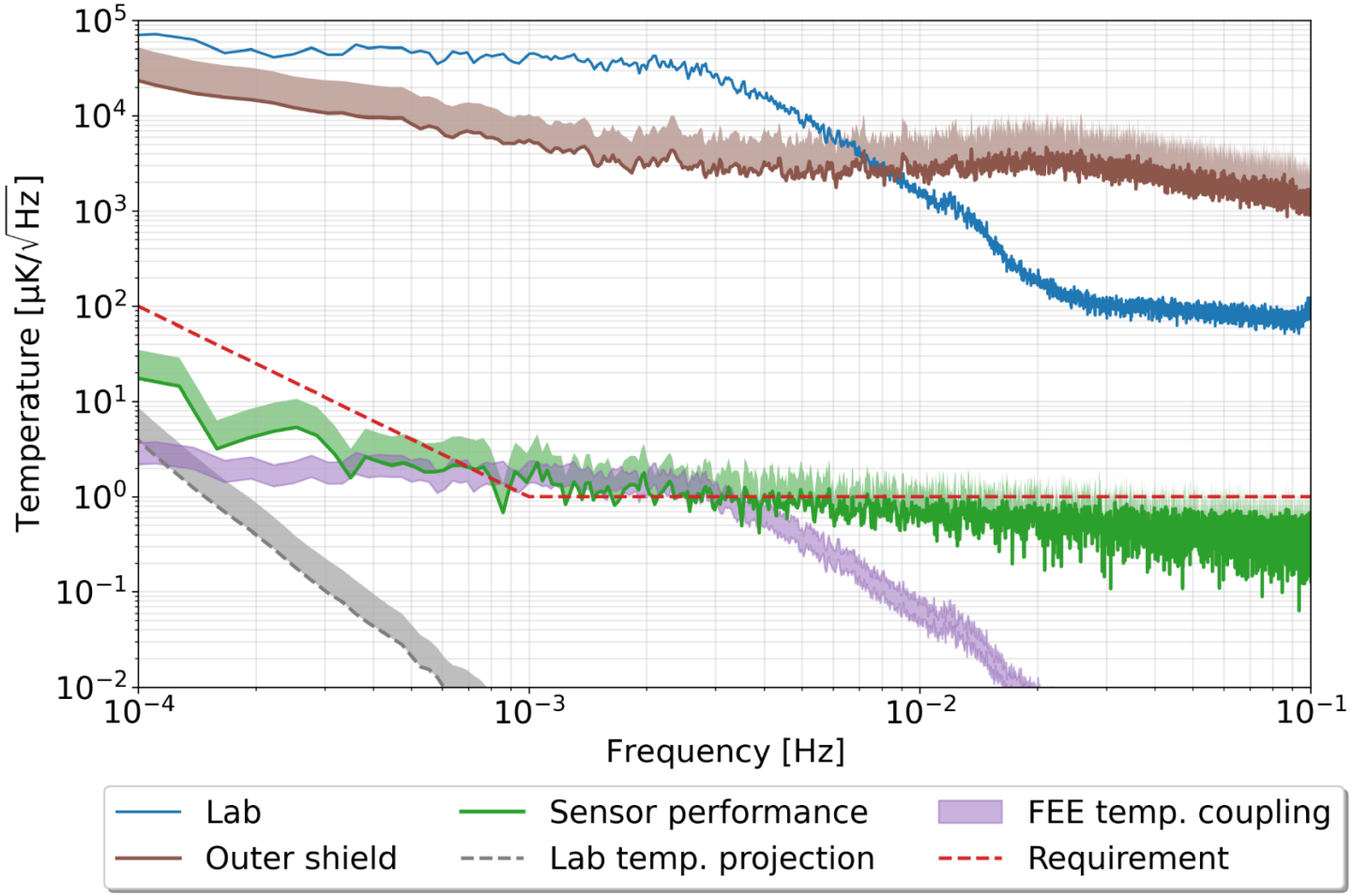
And inside ICE's special thermal stabilized enclosure

Diagnostics – Temperature sensors

LISA Enhanced Temperature Subsystem (LETS) -- ESA Activity

Results inline with objectives, but without multiplexing (expected degradation by a factor of $\sqrt{N}$) and only with NTCs (degradation expected for RTDs of a factor of ~3).

100 µW power dissipation

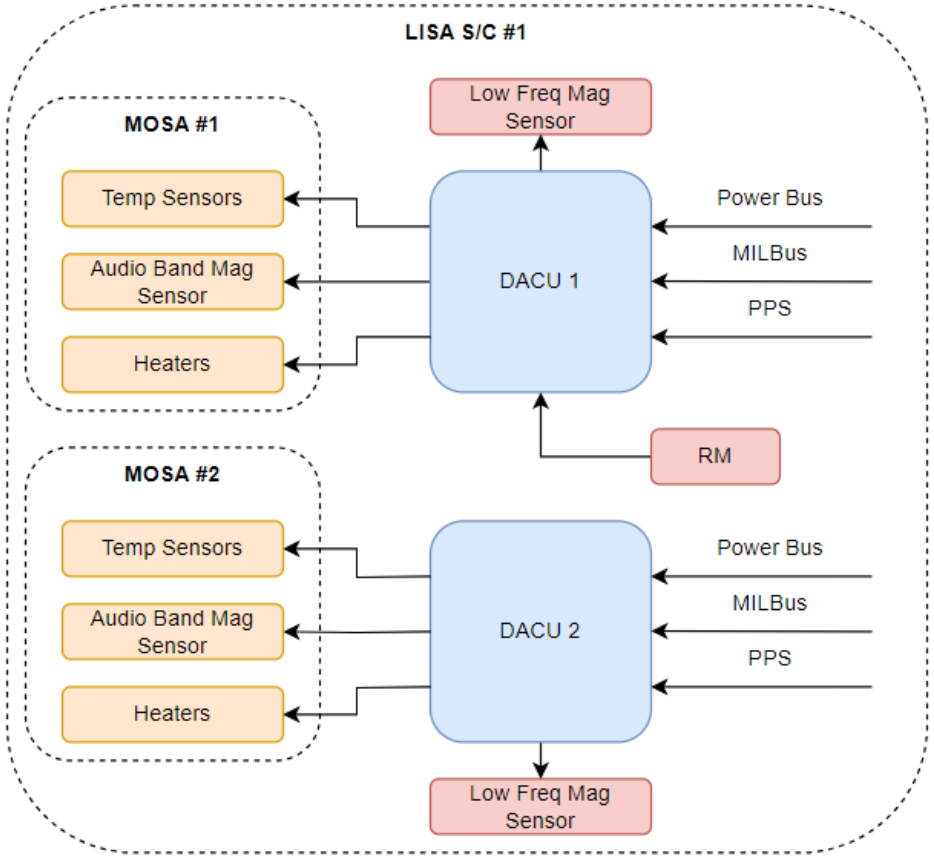


Roma-Dollase, D., Gualani, V., Gohlke, M., Abich, K., Morales, J., Gonzalvez, A., ... & Nofrarias, M. (2023). Resistive-Based Micro-Kelvin Temperature Resolution for Ultra-Stable Space Experiments. *Sensors*, *23*(1), 145.

DACU: Functions

The DACUs (2) are in charge of:

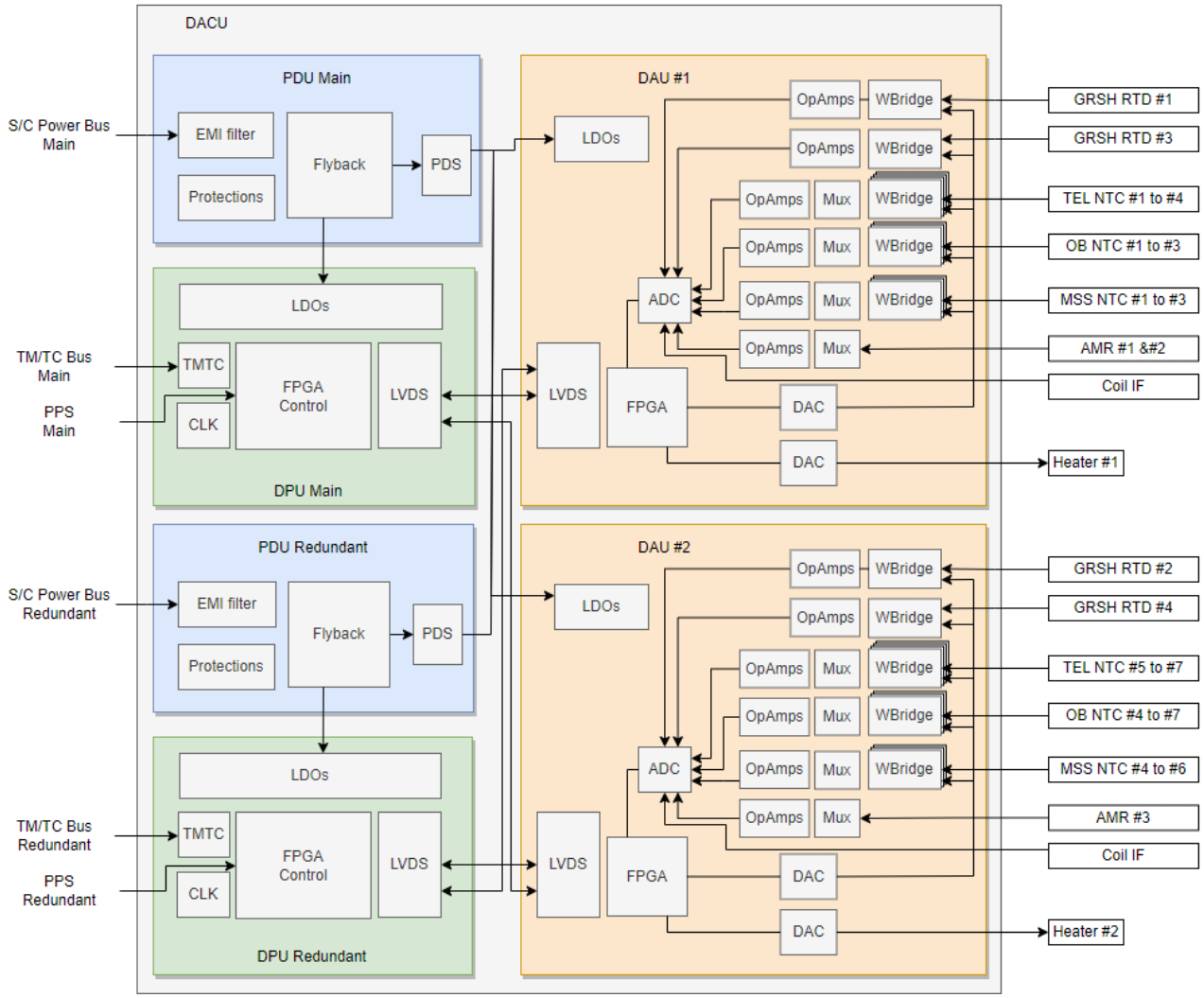
- Interfacing with the platform elements:
  - Power Bus
  - TLM/TLC with the OBC
  - PPS Synchronization
- Acquiring (per DACU):
  - 20 NTC Temperature Sensors.
  - 4 Platinum RTD Temperature Sensors.
  - 3 Low freq Mag Sensors.
  - 1 Audio band Mag Sensor (Coil)
- Actuate on (per DACU):
  - 4 Resistors acting as heaters.
- Interfacing the RM (one DACU):
  - Controlling and reading out the data of the radiation monitor
  - Provide regulated power to the radiation monitor



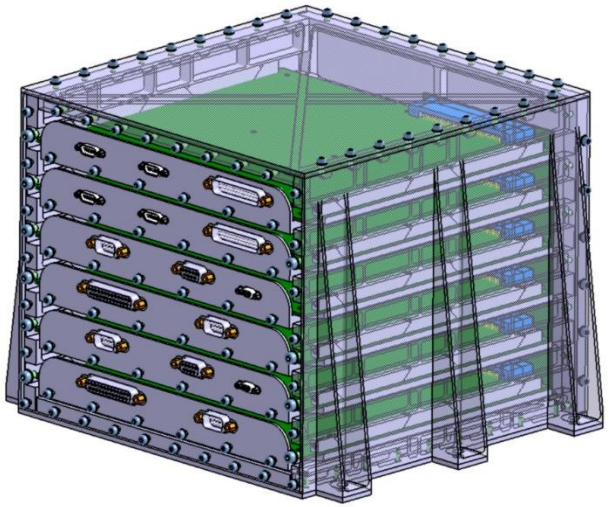
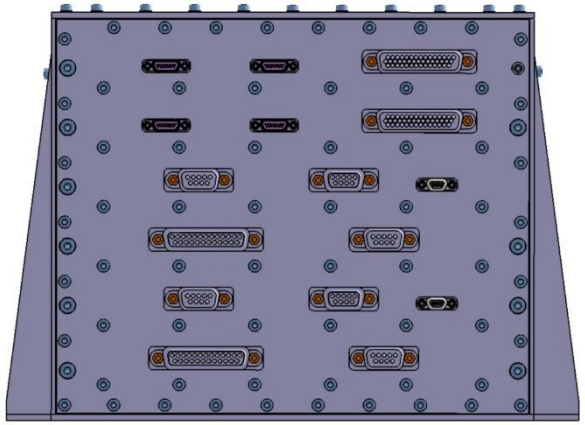
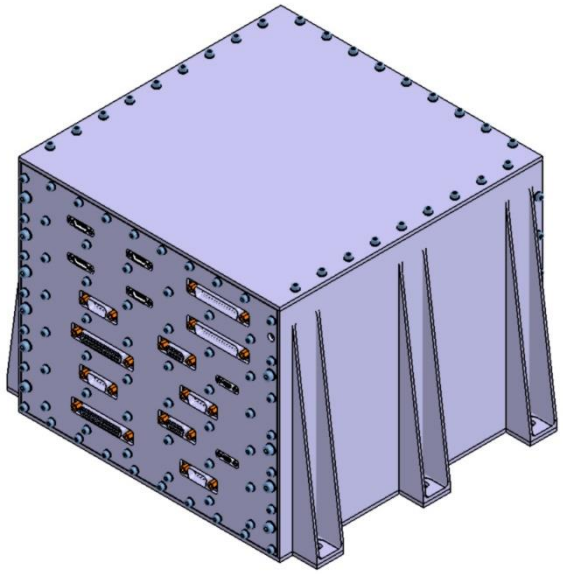
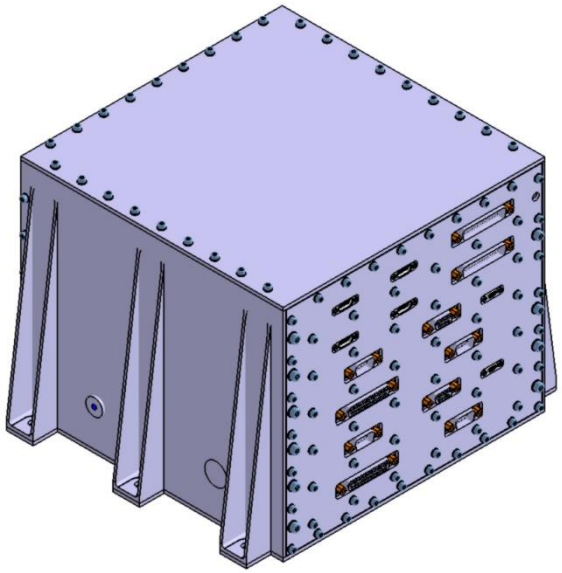
DACU: Architecture

The DACU will consist of 6 electronics boards:

- 2x PDUs (Main & Red):
  - Interface with the power bus (50V)
  - Protections
  - Internal power regulation and RM
- 2x DPUs (Main & Red):
  - Interface with the OBC via MilBus.
  - Receive the PPS from the platform
  - Control of the subsystem with the finite state machine
  - Synchronization of the system
  - Data processing
  - Interface the Data TLM with RM
- 2x DAUs :
  - Temperature sensors acquisition
  - Low freq mag sensors acquisition
  - Audio band mag sensors acquisition
  - Heaters excitation



DACU: Size ad Mass Budget

Item	Total Mass (Kg)	Maturity Margin (%)	Maturity Margin (kg)	Mass with margin (kg)
DACU Structure (225 (h) x 280 (w) x 250 (l) mm) Thickness [3mm]	4,505	20	0,901	5,406
Screwing	0,296	20	0,0592	0,355
PCBs + Connectors + Internal Screwing	2,165	20	0,433	2,598
EEE Parts (w/o Connectors)	0,635	20	0,127	0,762
Total DACU Mass	7,601	-	-	9,121

DACU: Data Budget

Nominal mode	Bit rate [bits/s]	Margin (%)	Bit rate with margin [bits/s]
Temperature sensors	192	20	230,4
Magnetometers	96	20	115,2
Coil	48	20	57,6
Heaters	0	20	0
Radiation monitor	113	20	135,6
Housekeeping	50	20	60
Total			538,8
Actuation mode			
Temperature sensors	192	20	230,4
Magnetometers	96	20	115,2
Coil	48	20	57,6
Heaters	256	20	307,2
Radiation monitor	113	20	135,6
Housekeeping	50	20	60
Total			846,0
Debug mode			
Total	640.000	20	768.000,0

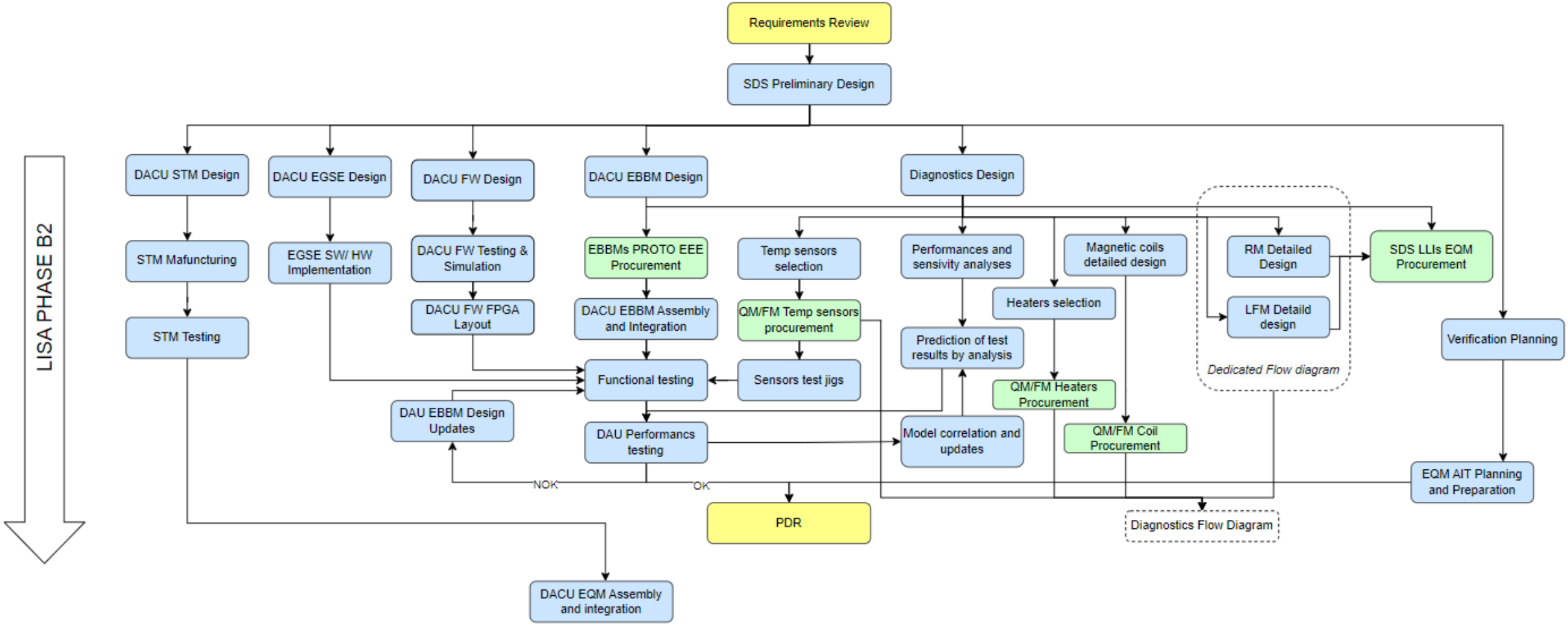
The data rate is assuming 32 bits samples. The budget assumes (per DACU):

- 24 temperature sensors being sampled at 0.25 Hz
- 3 (2-axis) magnetometers being sampled at 0.5 Hz
- One coil being sampled at 0.1Hz
- Heaters being sampled at 4Hz (only operating in actuation mode)
- The radiation monitor is providing 4 histograms (1024 coincidence samples, 40 singles samples) each 600s

The debug mode assumes the sampling of a given 32 samples magnitude (a temperature sensor, for instance) at 20KHz. This mode would only be used in case of debugging needs.

Road to PDR

Successfully passed adoption at beginning this year, next milestone is PDR.



Summary

- De-risking activities have been done to valid the technical feasibility of the required instrumentation
- Currently, the most challenging performance requirements measured with the developed instrumentation have been successfully achieved.
- This paves the way for the next key milestone of the LISA instrumentation, the Preliminary Design Review (PDR) in mid-next year.

Thanks for your attention! Questions?