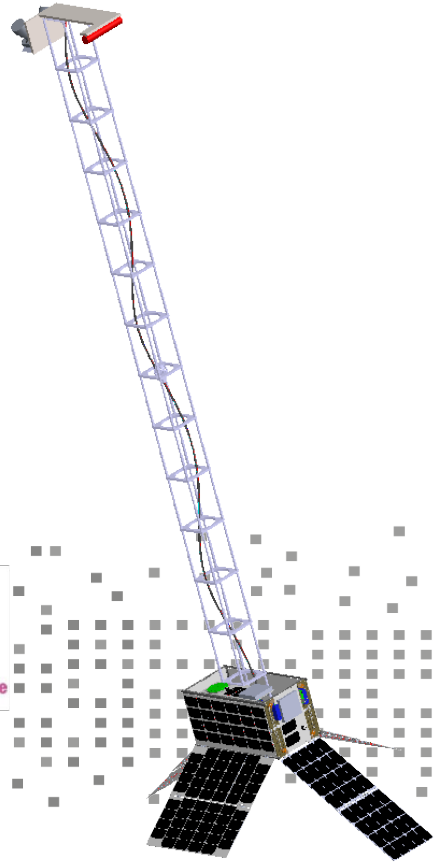

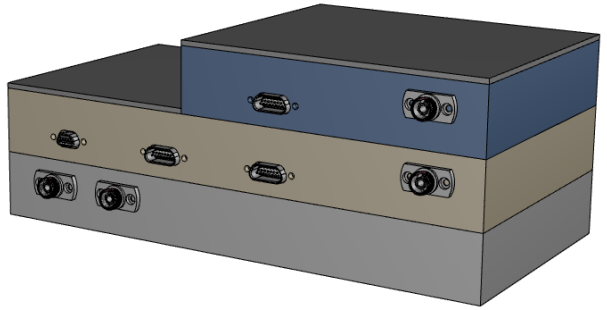

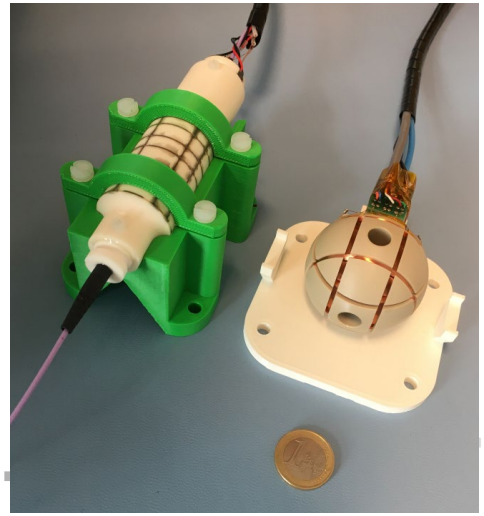

The NanoMagSat Magnetic Payload

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OTHER NANOMAGSAT ORAL PRESENTATIONS @ LPS 2022

- **Science objectives of the NanoMagSat mission** presented yesterday by G.Hulot (session B7.01.1 Scout: ESA NewSpace Science missions)

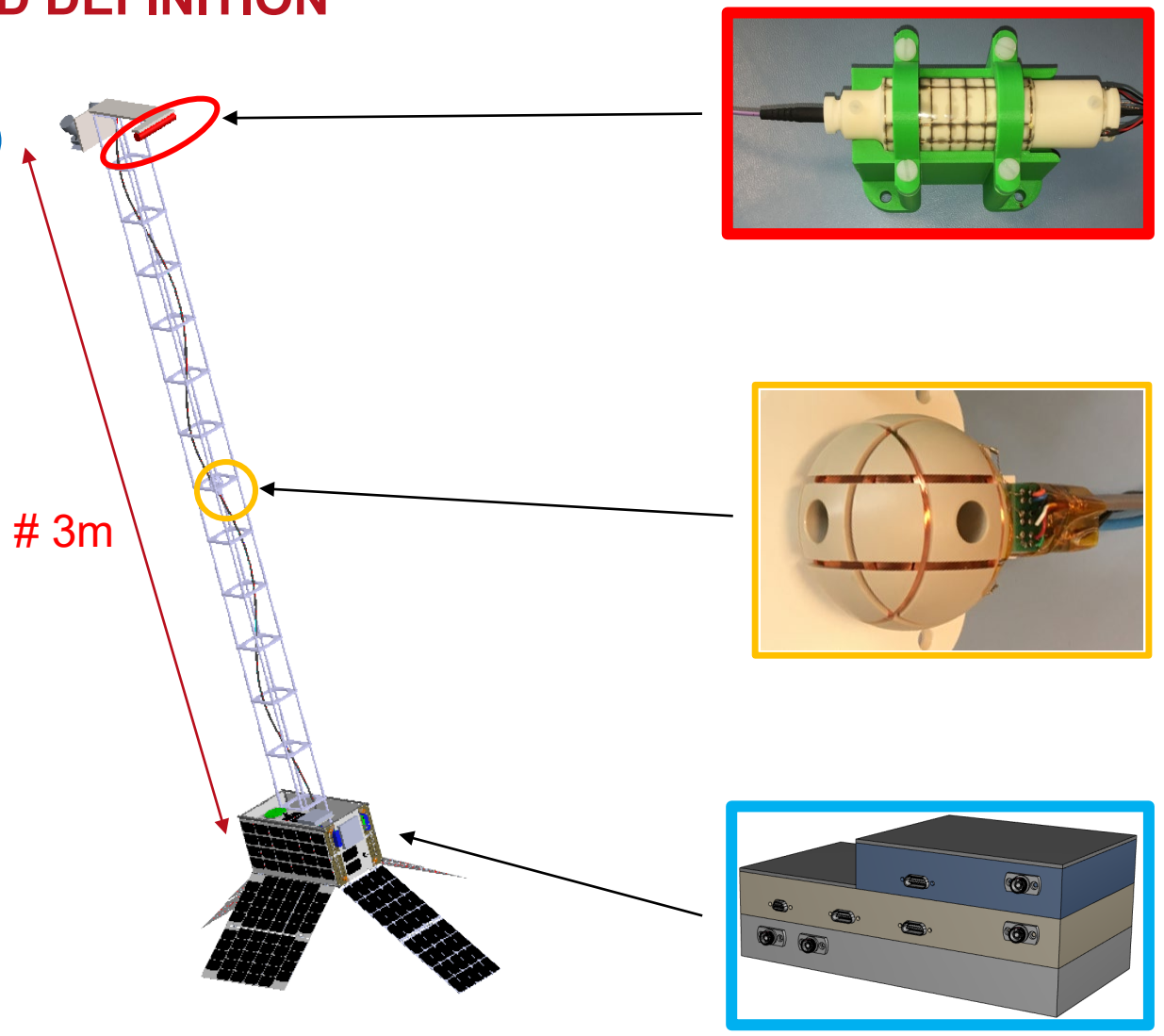
  “NanoMagSat, an optimal New Space low-Earth orbiting nanosatellite constellation to investigate Earth’s magnetic field and ionospheric environment”

- **General information on the mission** to be presented by F.Deconinck (session B7.03.2 New Space missions with small and nanosatellites – 2, today @ 3:55 pm)

  “NanoMagSat: a 3x16U satellite constellation for fast recovery of the Earth magnetic field and the ionospheric environment, an update”

NANOMAGSAT MAGNETIC PAYLOAD DEFINITION

- The MAM (Miniaturized Absolute Magnetometer) sensor head is accomodated on the Optical Bench assembly at the top of the boom with the Star Tracker optical heads. It provides absolute scalar measurements as well as fully calibrated vector data
- The HFM (High Frequency Magnetometer) sensor head is set at half mast. It will deliver very low noise / high frequency vector measurements
- The mutualized MAM+HFM electronics is located inside the spacecraft body
- Instrument harnesses link sensor heads to the electronics and will be deployed along the boom



NANOMAGSAT MAGNETIC L2 PRODUCTS REQUIREMENTS

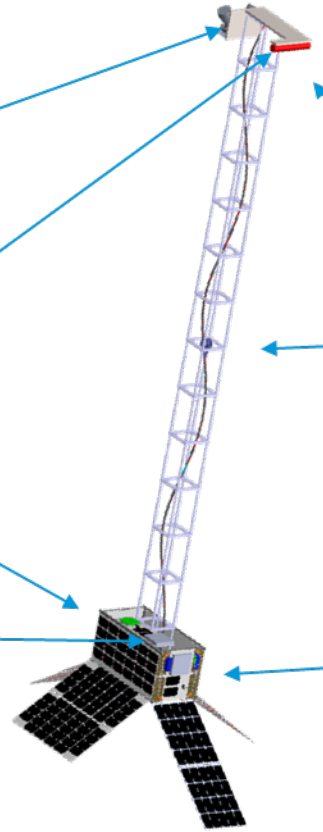
1 Hz product synchronized to 1 ms
(SWARM heritage requirements)

Attitude : σ < 5 arcseconds

B vector (instrument) : σ < 0.8 nT
B vector (NEC frame) : σ < 1 nT
B scalar : σ < 0.2 nT

GNSS products (TEC, IP, SCI):
standard requirements

POD (r, θ, φ, 1 Hz) within 8 m



2 kHz product synchronized to 1 µs
(Specific requirements)

B scalar
Noise below 1 pT/√Hz over 10-800 Hz

B vector (instrument)
B vector (NEC frame)
Noise below 1 pT/√Hz over 10-800 Hz

Electron density:
1 σ <1% for $n_e > 10^{10}$ m^{-3}
1 σ <10% for $10^9 < n_e < 10^{10}$ m^{-3}

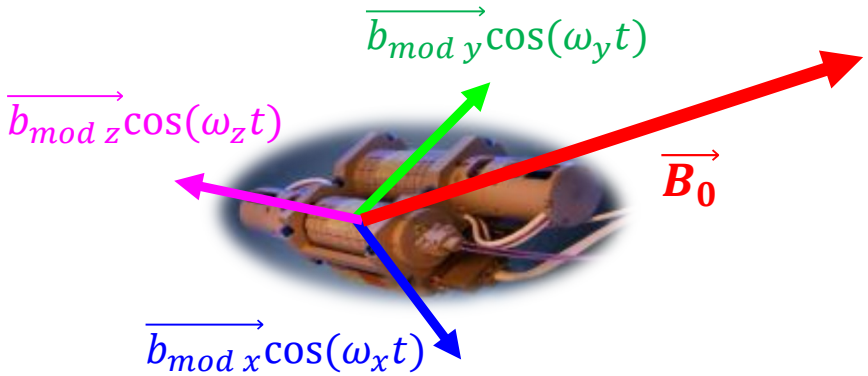
The **M**iniaturized **A**bsolute **M**agnetometer (**MAM**) instrument

The **H**igh **F**requency **M**agnetometer (**HFM**) instrument

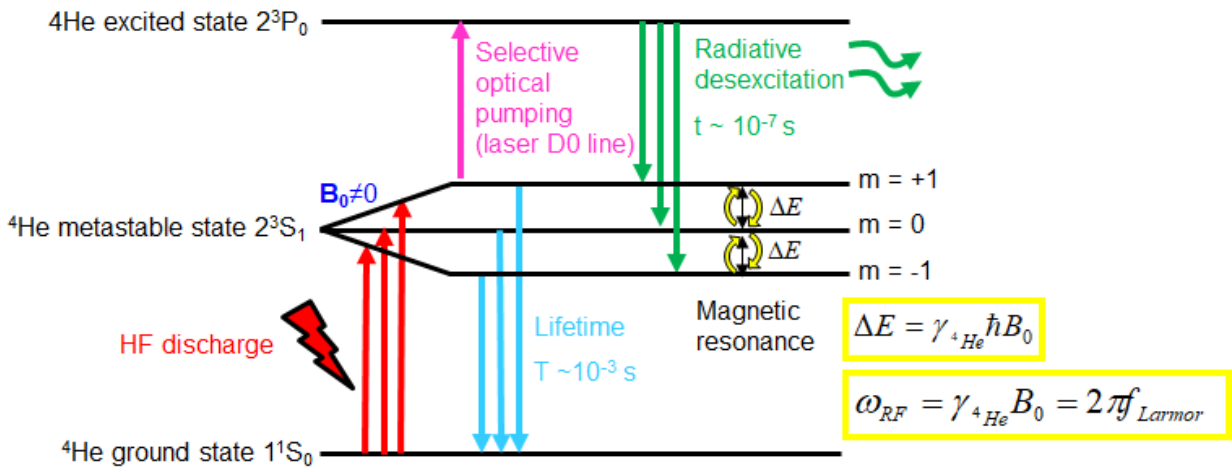
THE MAM INSTRUMENT (SWARM ASM-V HERITAGE)

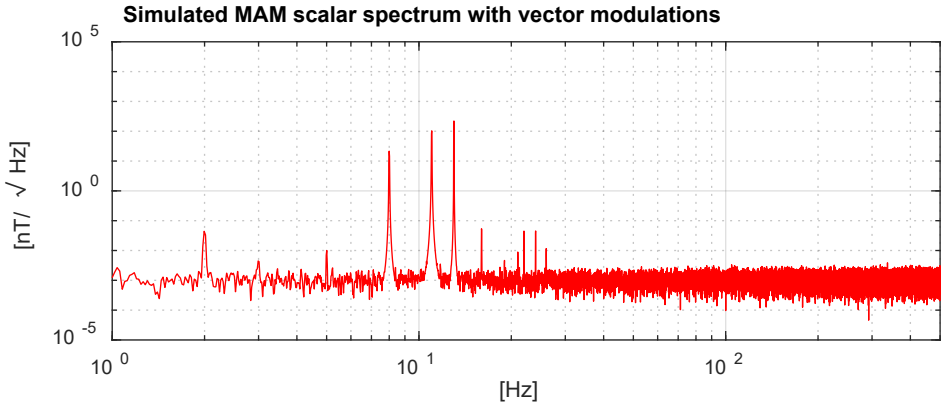
- Optically pumped scalar and vector magnetometer derived from the Swarm ASM-V
- Simultaneous operation of scalar burst (2 kHz) and vector modes (not possible on Swarm)

Superposition of 3 vector modulations (~50 nT) along 3 orthogonal directions



$$\left\|\overrightarrow{B_{tot}}(t)\right\| = \left\|\overrightarrow{B_0}(t) + \sum_{i=x,y,z} \overrightarrow{b_{mod\,i}}\cos(\omega_i t)\right\|$$

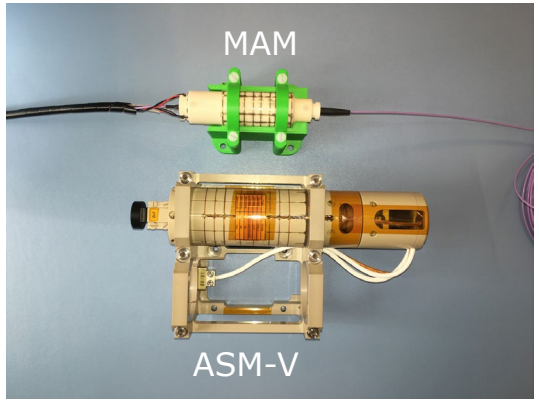


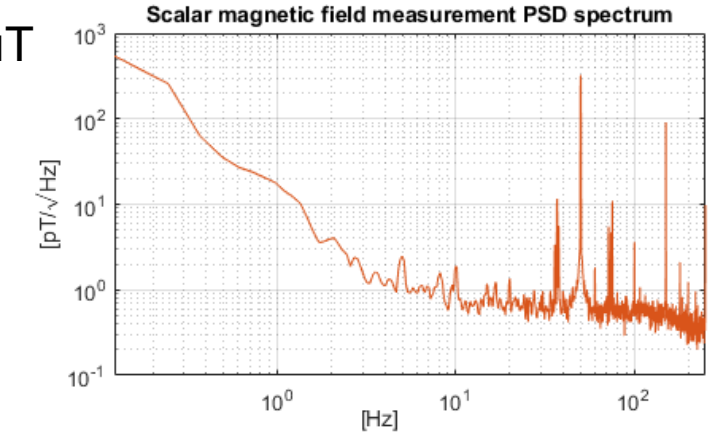


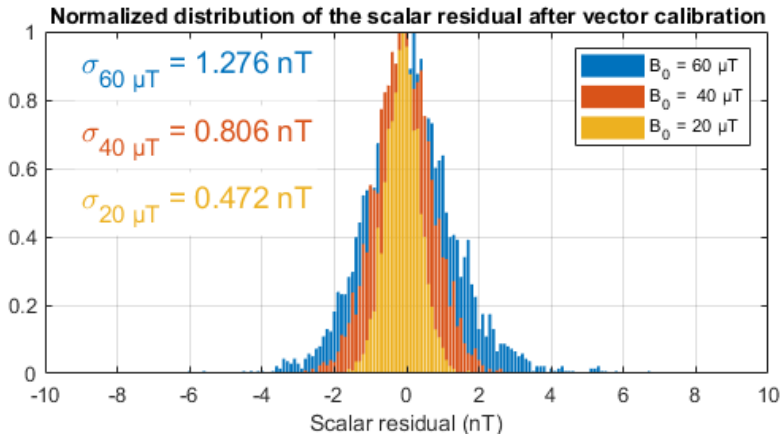
Real time analysis of the scalar output

MAM INSTRUMENT: STATUS & PERFORMANCE SUMMARY

- Operation principle unchanged, but replacement of two subsystems opening the way to a very significant miniaturization (R&D activities supported by CNES):
  - Sensor head : 0.5 l ➡ 70 cm^3
    - sensor head rotor driven by a piezoelectric motor ➡ liquid crystal polarization rotator
  - Electronics : 5 l ➡ # 1,3 l…for two instruments (MAM + HFM)
    - fiber laser ➡ laser diode
- Improved scalar and vector resolutions w.r.t. Swarm ASM-V
  - Scalar resolution : < 1 pT/√Hz (~0.5 pT/√Hz)
  - Vector resolution : < 1 nT/√Hz @ 50 µT
- Accuracy at least similar to ASM-V :
  - Scalar accuracy : < 50 pT (1 σ)
  - Vector accuracy : < 1 nT (1 σ)







STAR TRACKERS

- µASC developed by the Danish Technical University

DTU Danmarks Tekniske Universitet

- Dual head system providing the attitude determination to transpose MAM vector data in NEC (North East Center) reference frame
- Single image accuracy is better than 1 arcsecond 1σ (pointing) and 8 arcsecond 1σ (roll)
- Very low magnetic signature (# 35 µA.m^2) thus allowing to operate it quite close to the MAM
- Space heritage from numerous magnetic field mapping missions (Oersted, Champ, SAC-C, Swarm) TRL9

OPTICAL BENCH

- Developed by Comet Ingenieria

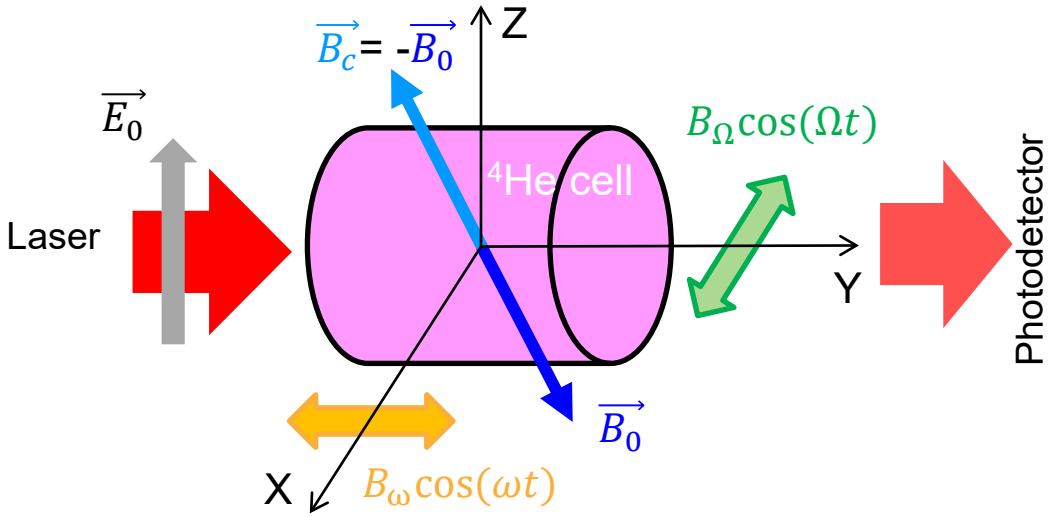
- Ultra-stable structure to ensure an in-orbit alignment error between the star tracker heads and the MAM reference frames lower than 3 arcsec (inter-calibration on ground)

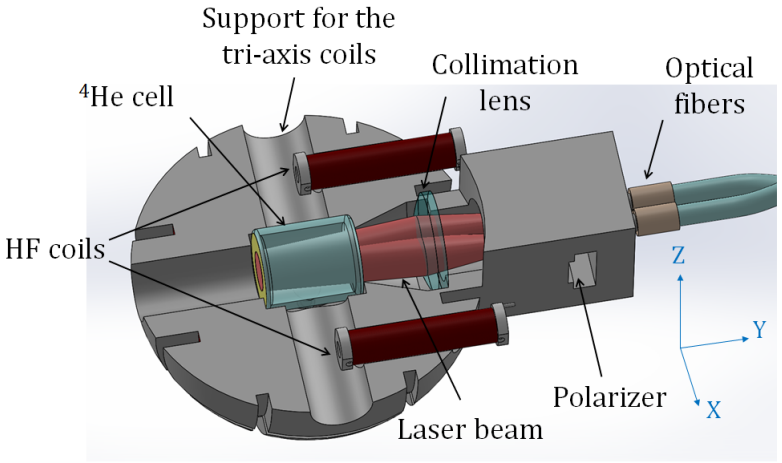
- Material : CFRP (amagnetic, low electrical conductivity, high mechanical stability)

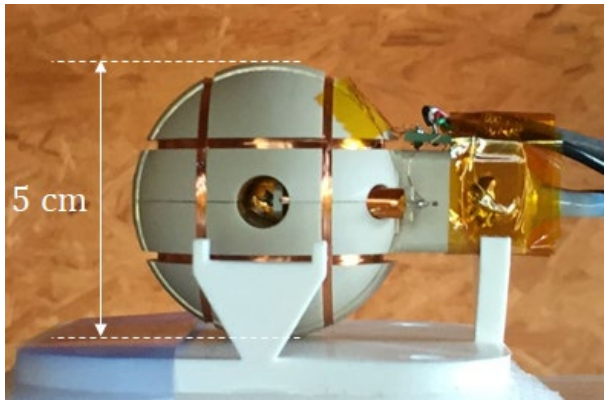
- Thermal control: passive (Optical bench wrapped in MLI) + AC heaters beneath the MAM, design in progress

HFM INSTRUMENT ⇔ SPACE WEATHER RELATED ISSUES

- Instrument issued from developments for MagnetoEncephaloGraphy adapted for operation in Earth field (R&D activities supported by CNES and BRGM),
  - Same optical pumping process as for the MAM instrument
  - Parametric resonance of metastable ^{4}He atoms in near zero magnetic field
  - Closed-loop operation (ambient field compensation ⇔ similar to fluxgate operation)



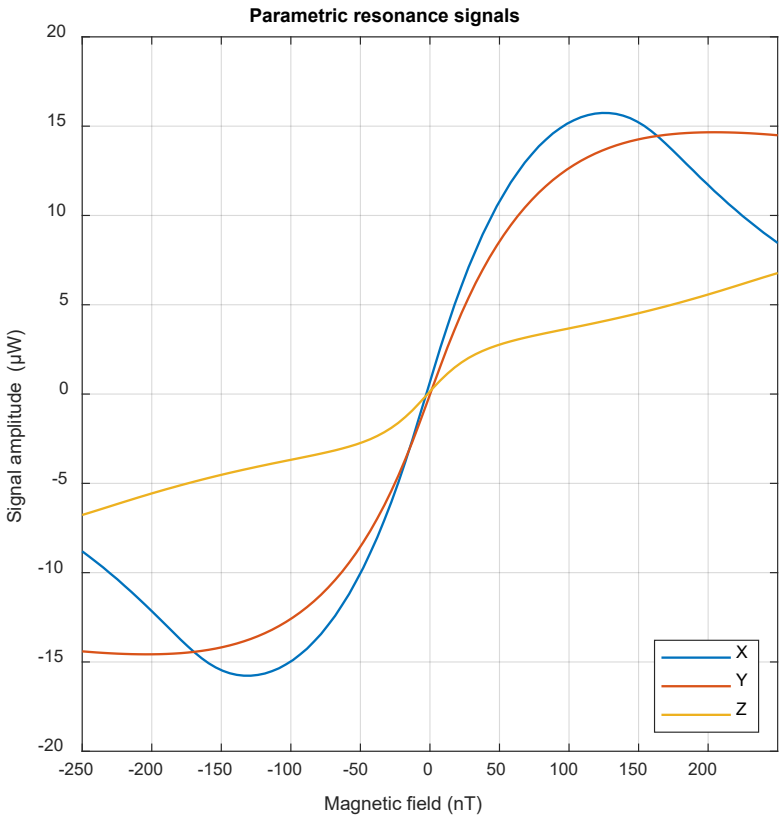


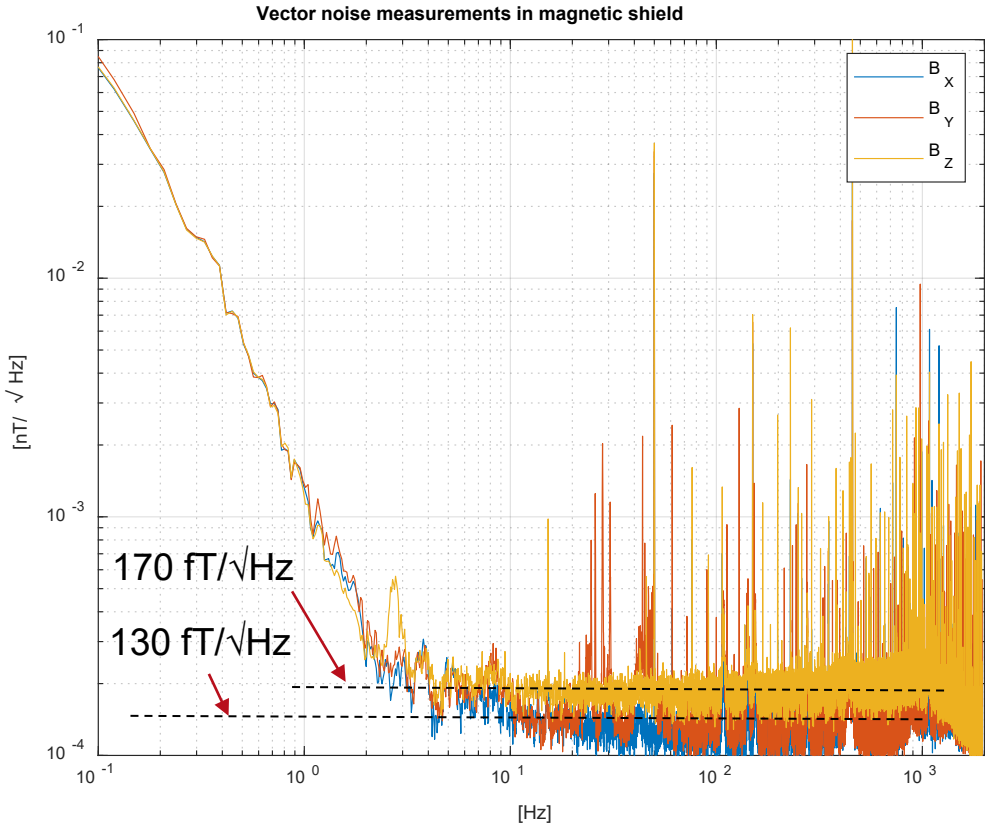


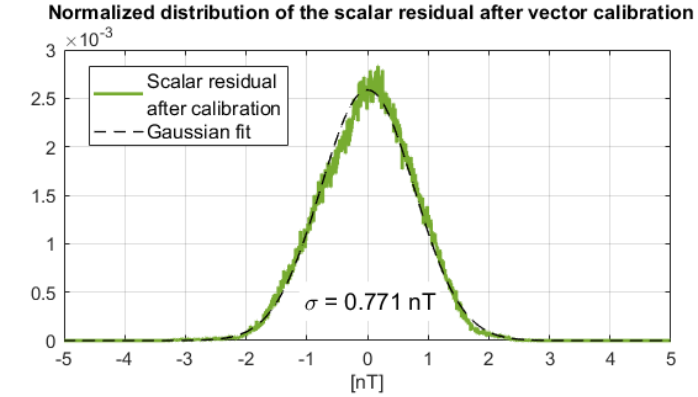
- No space heritage yet, but with numerous sub-systems common to MAM -to the point that their electronics will be mutualized-, including all main ones

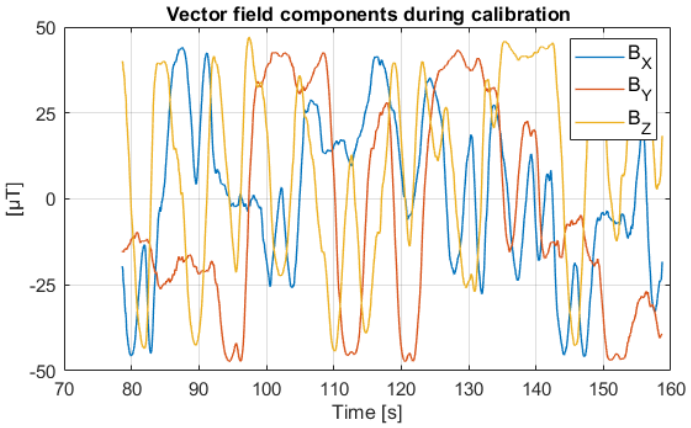
THE HFM INSTRUMENT: PERFORMANCE SUMMARY

- High vector resolution combined to high magnetometer bandwidth:
  - Demonstrated resolution of 130 fT/√Hz for X & Y axes, 170 fT/√Hz for Z axis
  - Sampling rate 2 kHz (bandwidth set to [DC - 800 Hz])







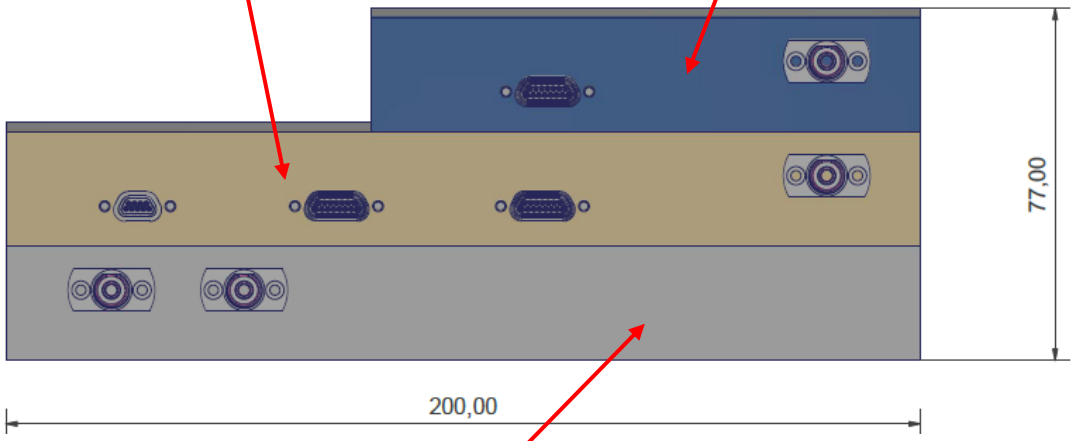


MAM + HFM MUTUALIZED ELECTRONICS

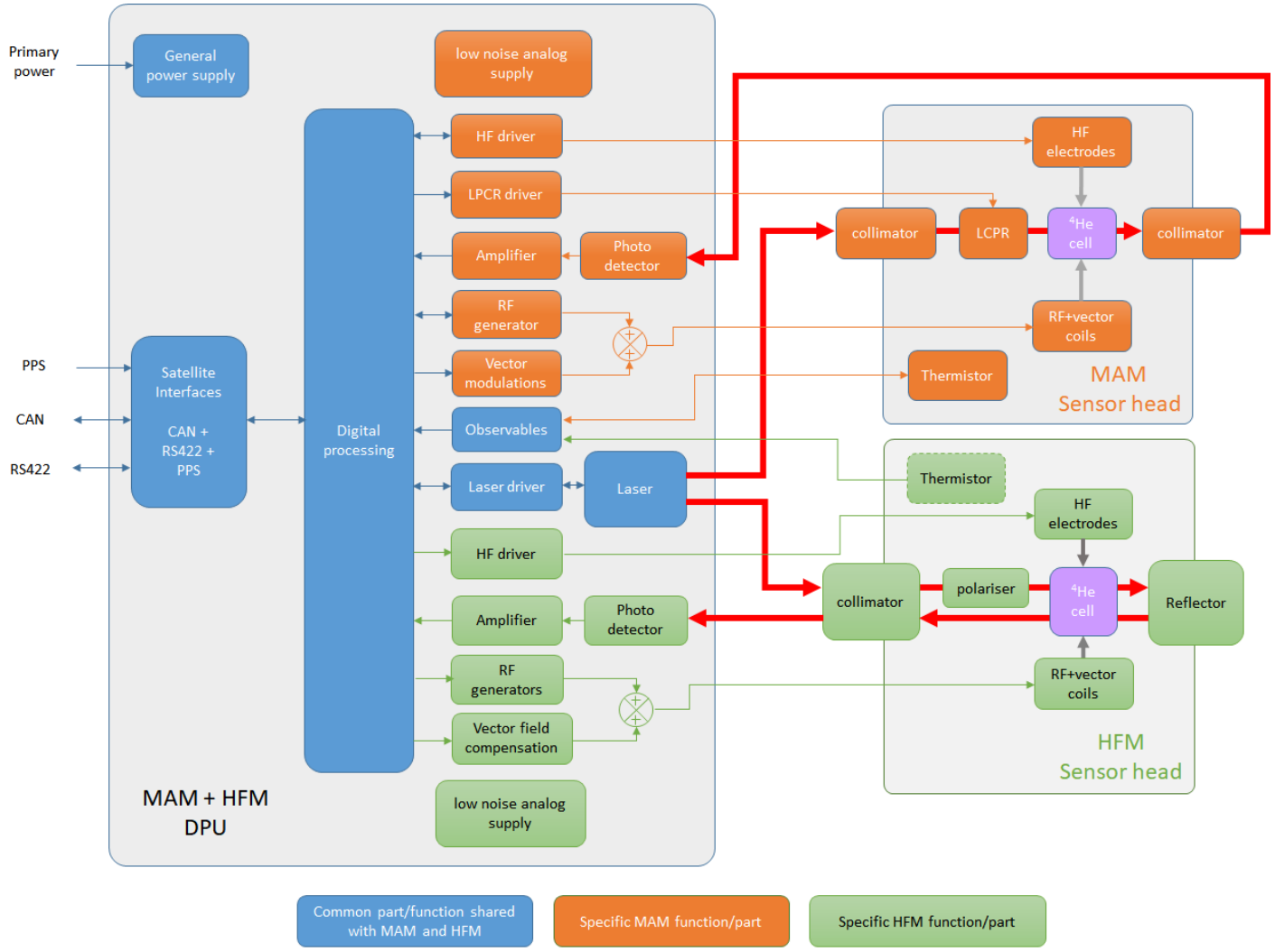
Volume # 1,3 l

- Satellite Interface
- General Power supply
- Digital Processing
- Analog MAM drivers

Analog HFM drivers



- Laser
- Analog drivers



MAIN MAM AND HFM ON-GOING ACTIVITIES (NANOMAGSAT RRA)

- **Current status**
  - Breadboard demonstration of metrological performance for both MAM & HFM instruments
  - Preliminary electronics design

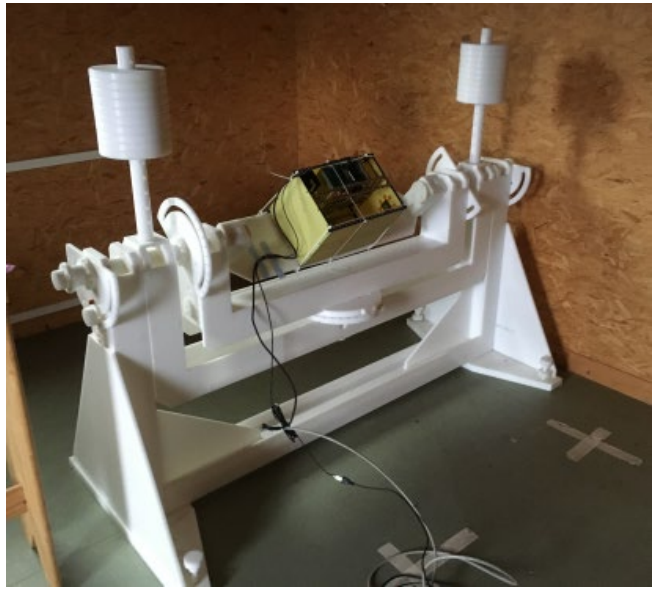
- **Magnetic payload related activities**
  - Qualification of key optical components (08/2022)
    - Laser diode
    - Polarization rotator
  - Development of the MAM+HFM integrated electronics (T1 2023)
  - Development & qualification of the Optical Bench (T3 2022)
  - Platform magnetic perturbation characterization (mid 2023)

- **PDR level achieved by mid 2023, with some key components (boom/optical bench) already at CDR level**

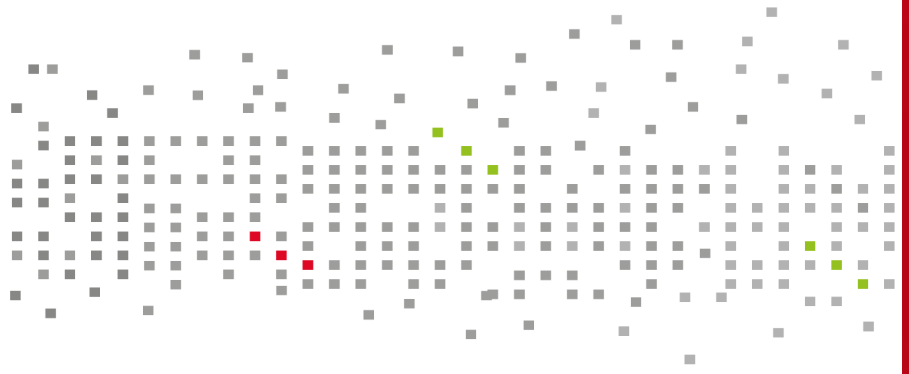
Still room for minor changes, should extra scientific needs be expressed…

MAGNETIC CLEANLINESS ACTIVITIES FOR PLATFORM SUBSYSTEMS

- **Grounding and EMC concepts definition, taking into account the lessons learnt from previous missions**
- **Thorough materials selection + systematic screening @ Leti premises**
- **Magnetic characterization of the hardware through differential high resolution measurement**
- **Stray field perturbation @ MAM location modelization**
- **Magnetic budget update as new results come in**



THANKS FOR YOUR ATTENTION



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