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

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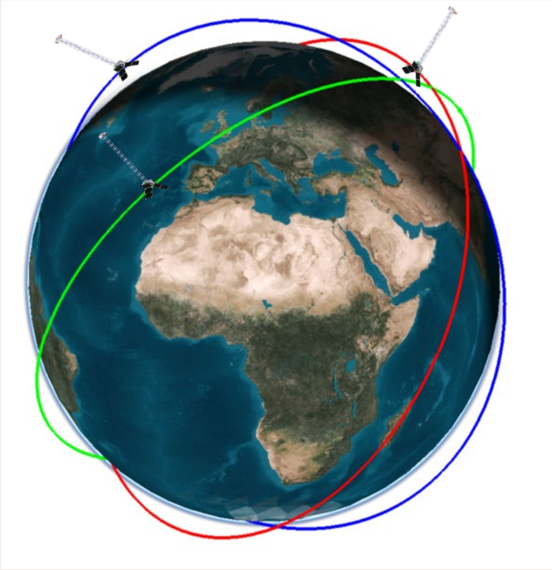
LPS 2022 - B7.03.2 New Space missions with small and nanosatellites - 26/05/2022

NanoMagSat overview

Monitoring the Earth's magnetic field and ionospheric environment

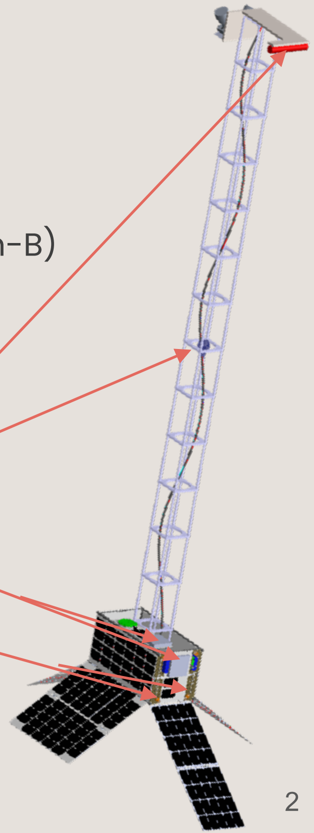


A 3x16U Cubesat constellation at 575 km initial altitude

- **1 satellite at 60° inclination**
- **1 satellite at 60° inclination offset by 90°-RAAN**
- **1 satellite in near-polar orbit** (optimised with Swarm-B)

State of the art compact payloads

- A **Miniaturised Absolute Magnetometer** (MAM) with a set of **two Star Cameras** (STR)
- A **High Frequency Magnetometer** (HFM)
- 2 **dual-frequency GNSS**
- A **multi-Needle Langmuir Probe** (m-NLP)



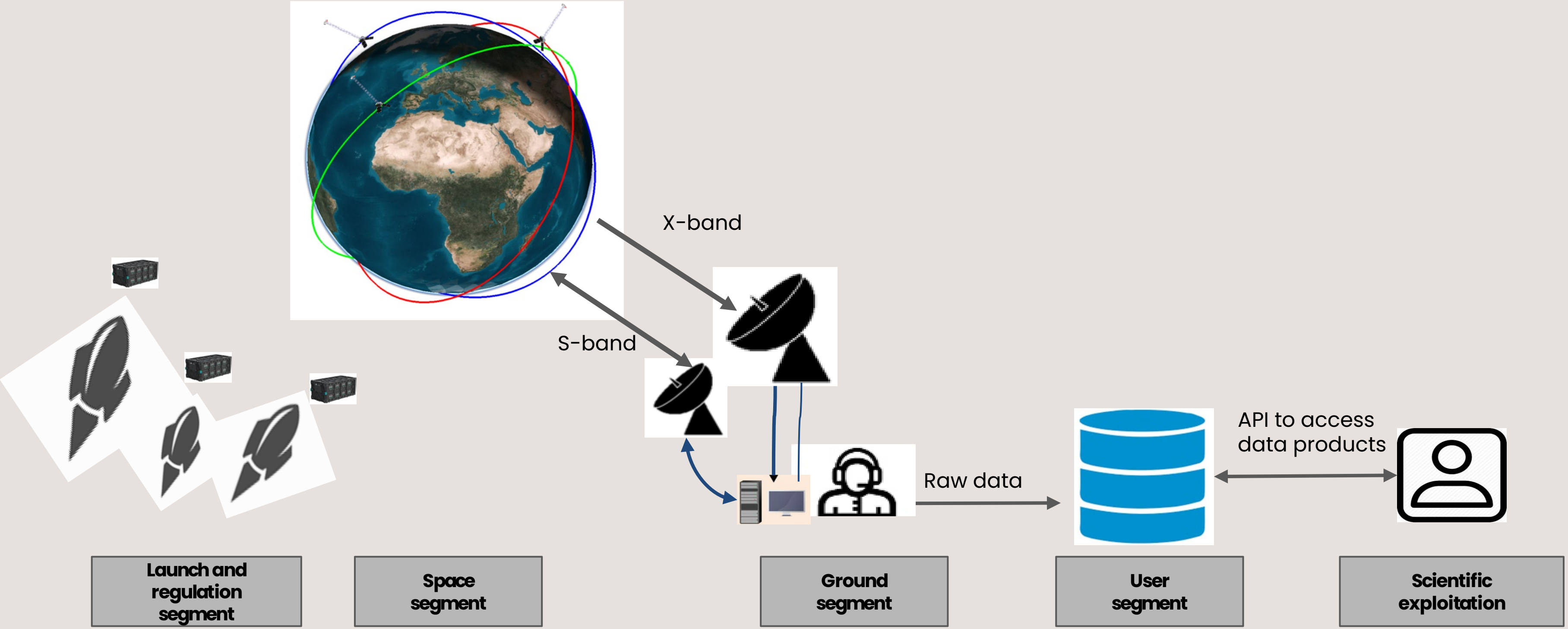
Initiating a **low-cost scalable collaborative constellation solution for very long-term observations** (extending to space the Intermagnet network of magnetic observatories)

NanoMagSat presentations at LPS

Science | Payloads | Mission and platform

Wednesday 8:45am 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 Dr. Gauthier Hulot | Université de Paris, Institut de physique du globe de Paris, CNRS | France
Thursday 1:30pm A6.02.1 Upper/Lower Atmosphere Processes, Coupling and Ion-Neutral Interactions	Whistler in ELF detected from LEO: lightning detection and ionospheric monitoring using Swarm satellites and the future NanoMagSat mission Dr. Pierdavide Coïsson | Université de Paris, Institut de physique du globe de Paris, CNRS | France
Thursday 2:45pm B7.03.1 New Space missions with small and nanosatellites - 1	The NanoMagSat Magnetometry Payload Dr. Jean-Michel Léger | CEA-LETI | France
Thursday 3:55pm B7.03.2 New Space missions with small and nanosatellites - 2	NanoMagSat: a 3x16U satellite constellation for fast recovery of the Earth magnetic field and the ionospheric environment, an update Florian Deconinck | Open cosmos Ltd. | United Kingdom
Thursday 5:20pm Poster Session Day 4	Coupling of electromagnetic waves between the magnetosphere and the topside ionosphere: new proposed science targets for the NanoMagSat mission Prof. Ondrej Santolik | Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague, Czechia; Faculty of Mathematics and Physics, Charles University, Prague, Czechia | Czech Republic
	The multi-needle Langmuir probe on board NanoMagSat Dr. Lasse B.N. Clausen | University of Oslo | Norway Show details

NanoMagSat mission architecture

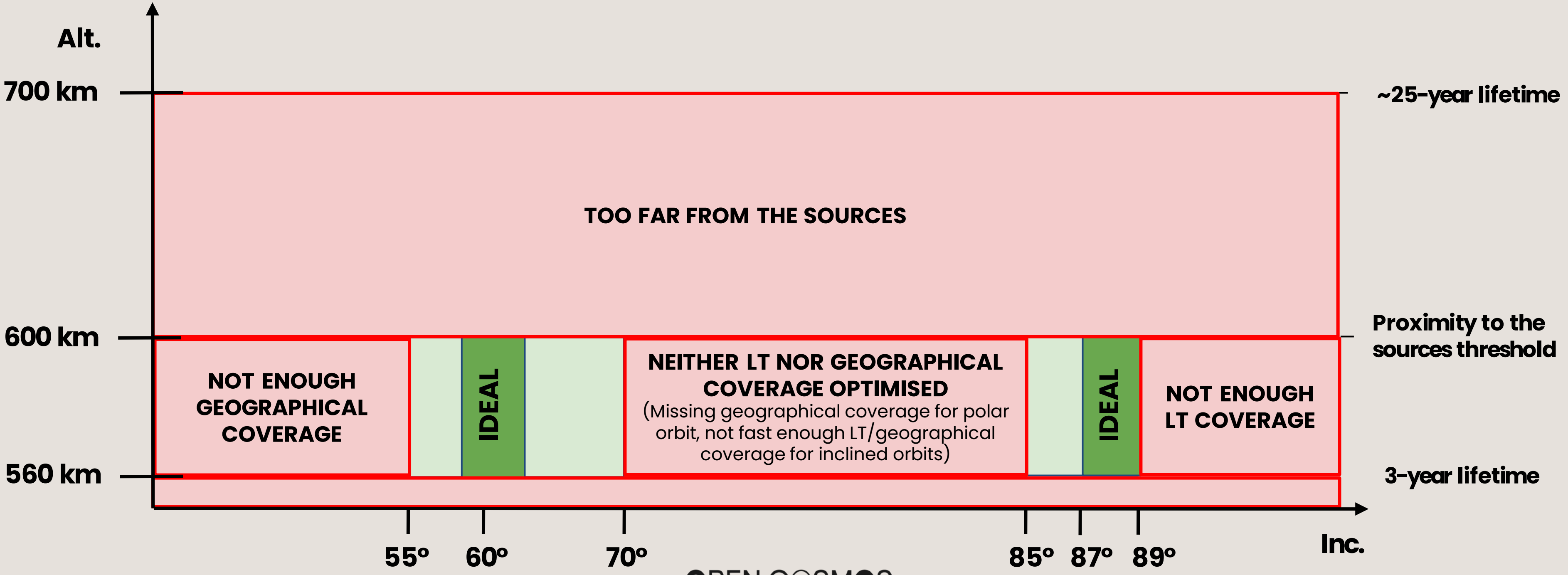


NanoMagSat mission characteristics

Launch segment	Orbits	1x 87° inclination, circular orbit at 575 km altitude 2x 60° inclination, circular orbit at 575 km altitude offset in RAAN by 90°
	Launch	**3 dedicated launches**
	Design Lifetime	4 years: 1 year constellation build up, **3 years nominal operations**

NanoMagSat driving observation requirements

- Spatio-temporal grid requirement: **[±6° long. ; ±6° lat. ; ±1.5h LT]** covered as often as possible
- 3-year minimum duration plus the combination of Local Time and geographical coverage
- Stability of the constellation configuration: shift in RAAN by 90°



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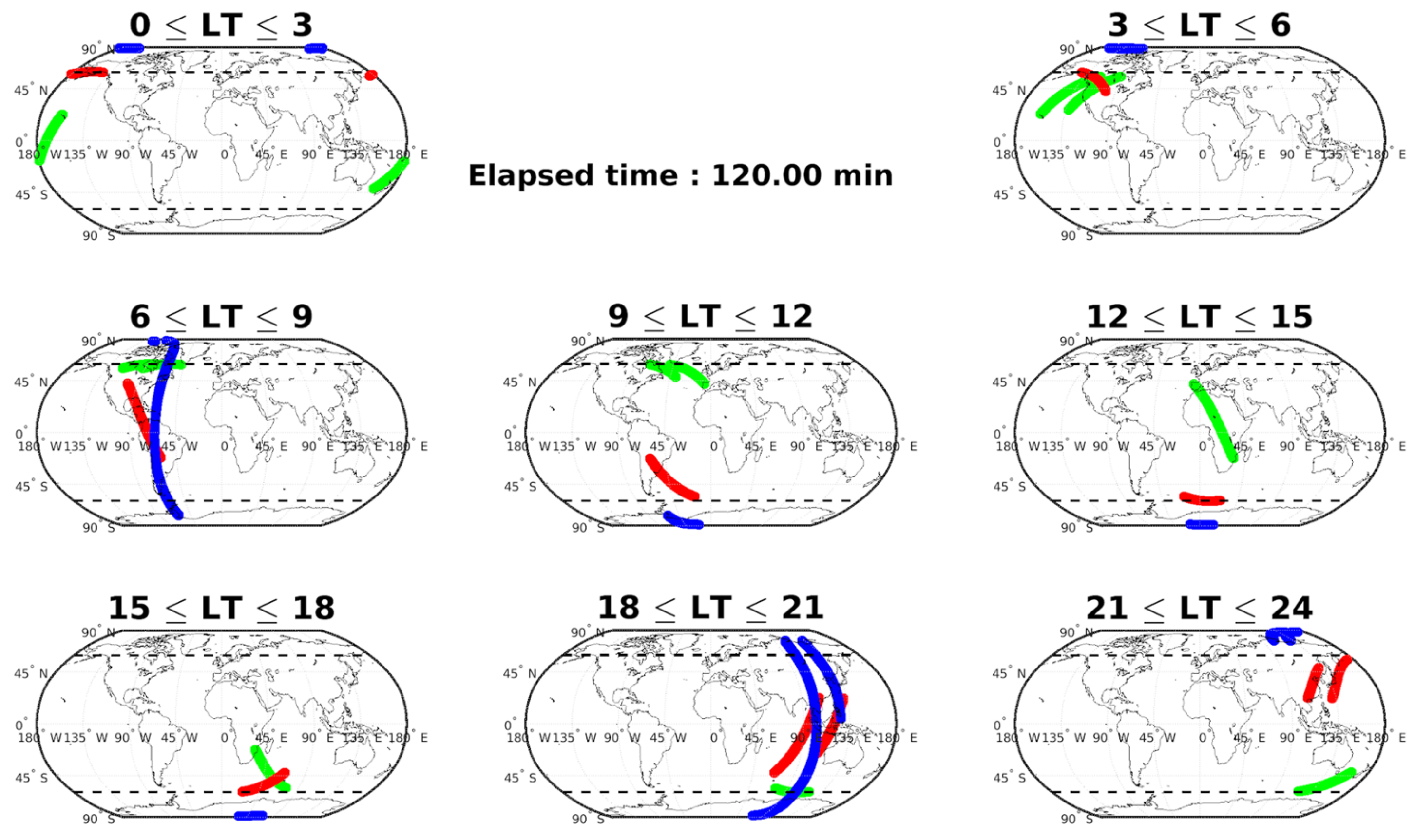
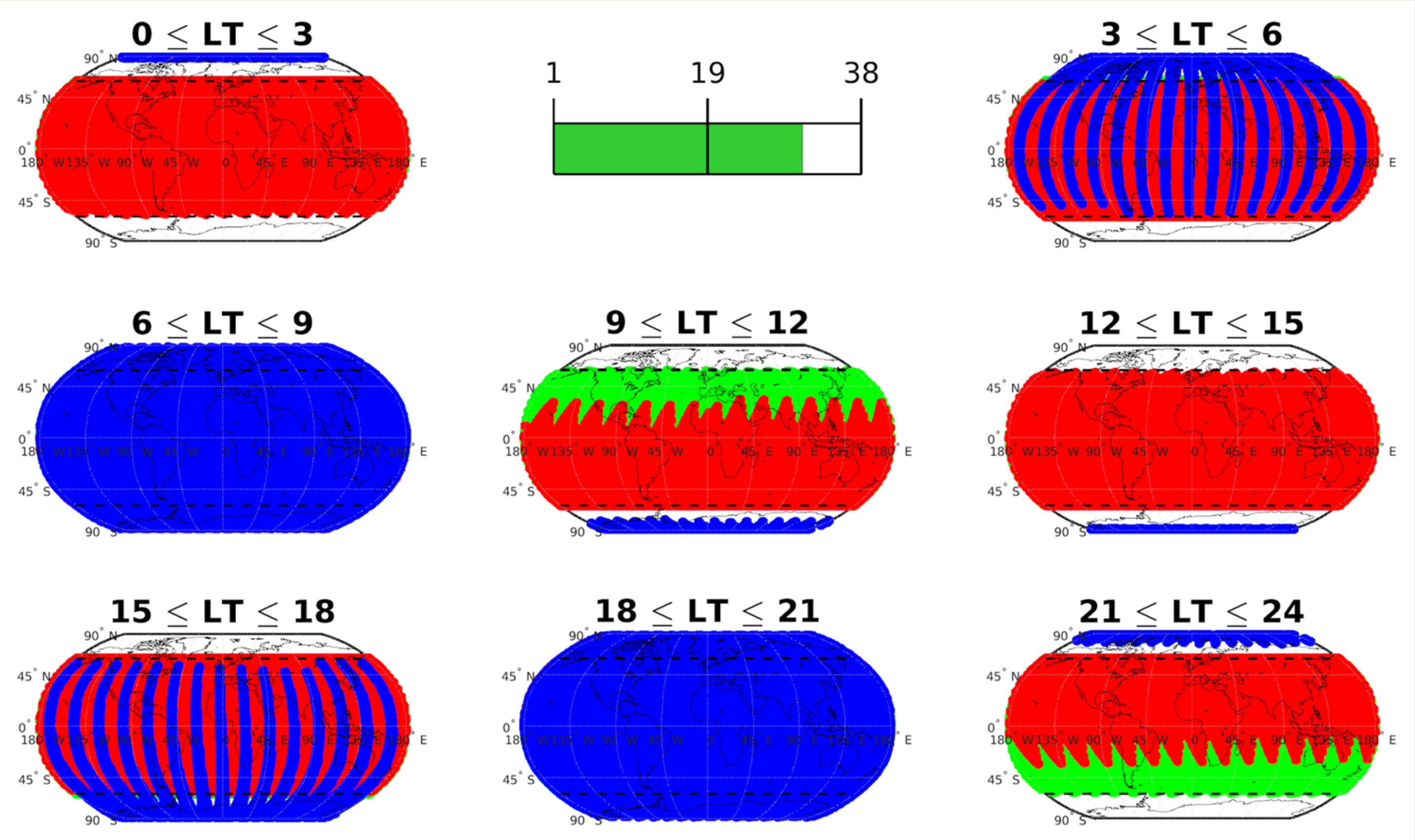


NanoMagSat driving observation requirements



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Space segment	Magnetic cleanliness	Optimised for the instruments: **no reaction wheels**, **no propulsion, 3m boom, wiring design, accommodation optimisation**
	Volume per spacecraft	**16U Cubesat**, 19 litres of internal volume
	Power per spacecraft	Double deployables for **>42W** (depending on inclination/RAAN/date)
	AOCS	Gravity gradient stabilised, air-torquers, GNSS, sun sensors, magnetometers
	Link per spacecraft	S-Band uplink: 256 kbit/s S-Band downlink: 1 Mbit/s X-Band downlink: 100 Mbit/s

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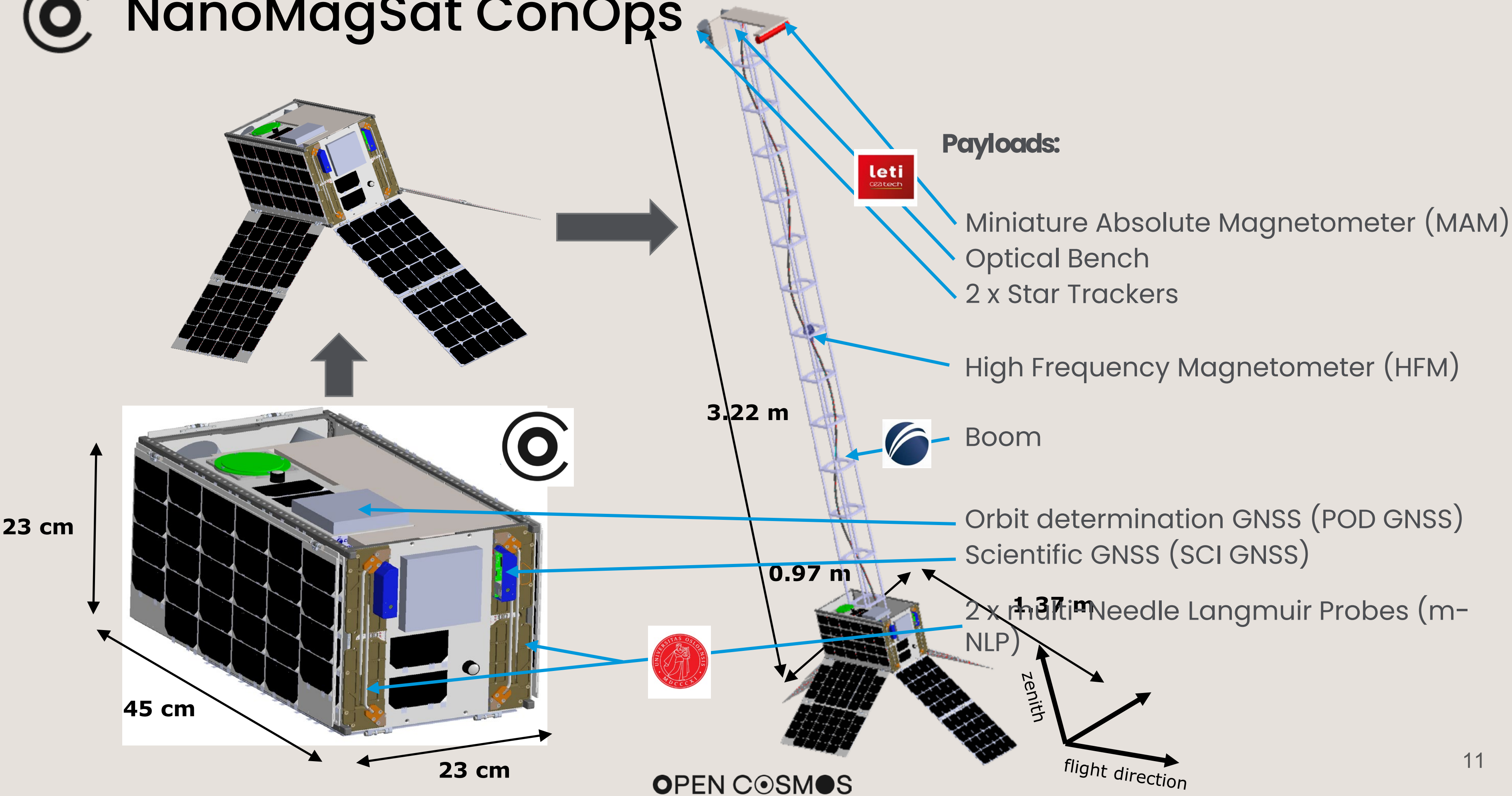
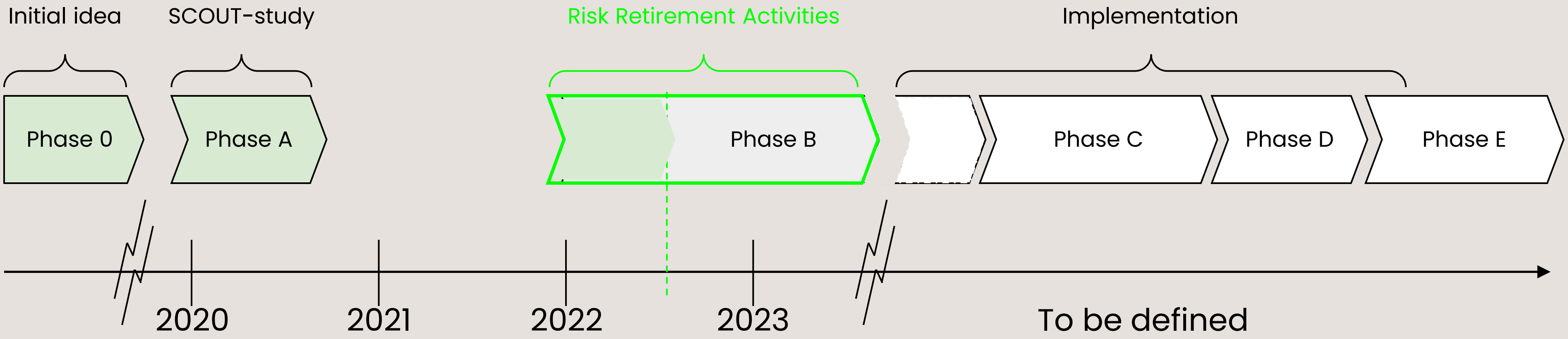
Ground segment	Ground stations	3 polar ground stations and 4 mid-latitude ground stations 2 passes/day for TT&C, 4 passes/day for data downlink
	Data per spacecraft	Payload and science-relevant auxiliary data: **5 GByte / day** Platform telemetry: 17 MByte / day

NanoMagSat ConOps



NanoMagSat mission concept status



Scope of Risk Retirement activities:

- Development of the magnetometers electronics
- Structural model of the deployable boom
- Satellite platform optimised for magnetic cleanliness

The NanoMagSat Magnetometry Payload
Dr. Jean-Michel Léger | CEA-LETI | France

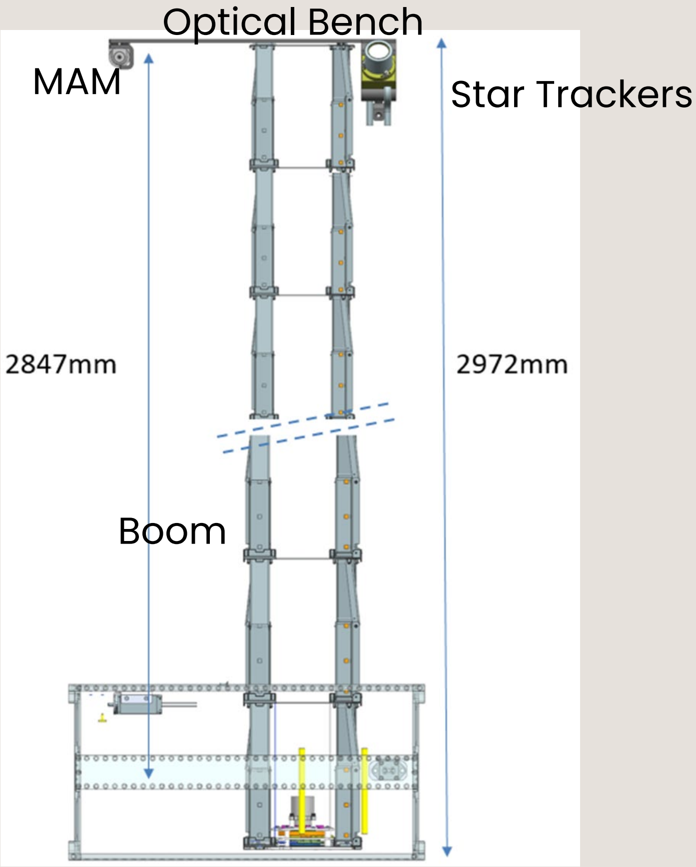
NanoMagSat boom - deployed

Boom

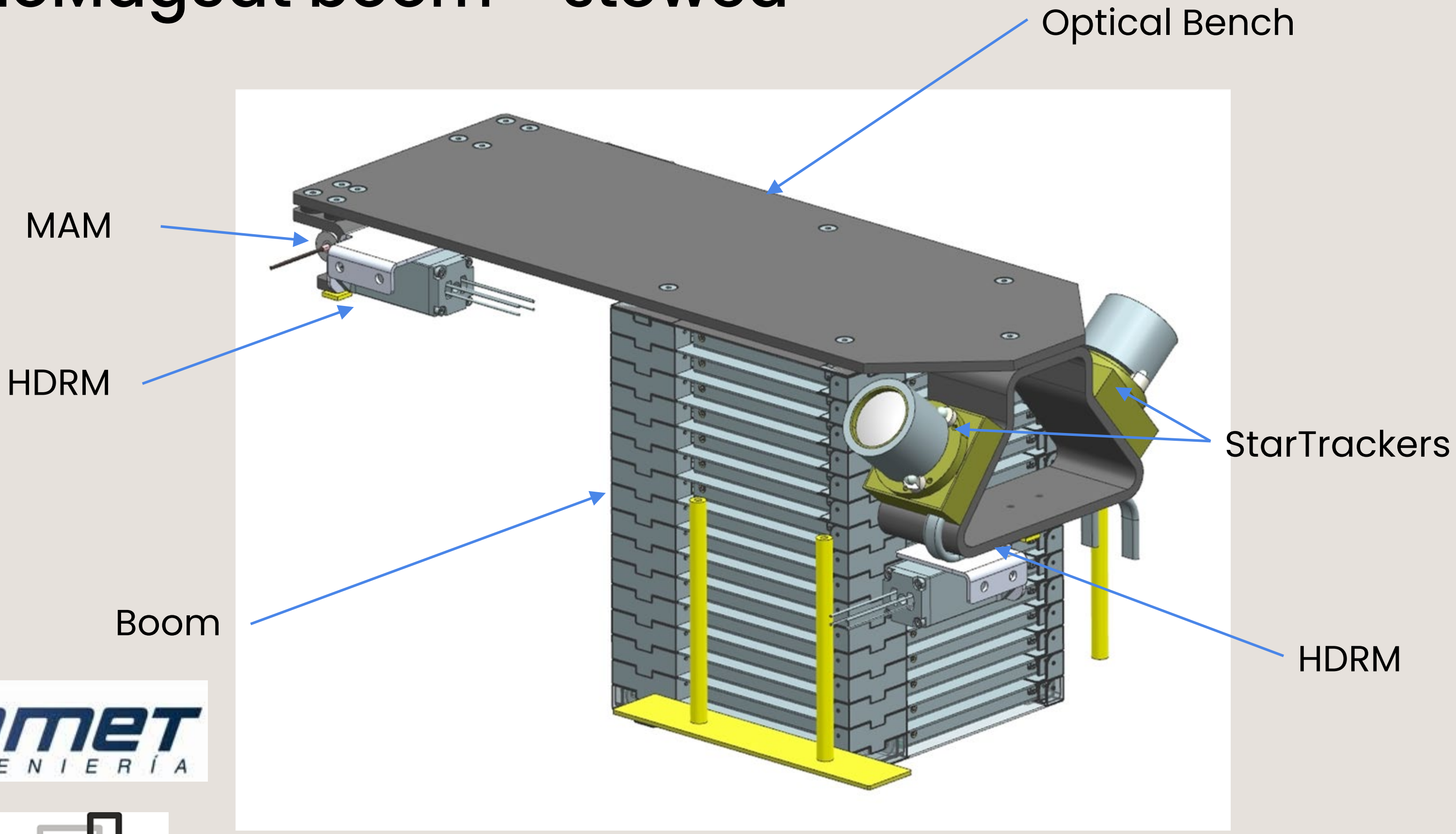
- High Stiffness & dynamic behaviour optimisation
- High Thermoelastic stability
- Extensive use of amagnetic materials
- Self deploying without electric actuation
- Extra motorisation to deploy harnesses
- Inner accommodation of harness and HFM

Optical Bench

- High thermoelastic stability
- High accuracy for Star Trackers accomodation and orientation
- Extensive use of amagnetic materials



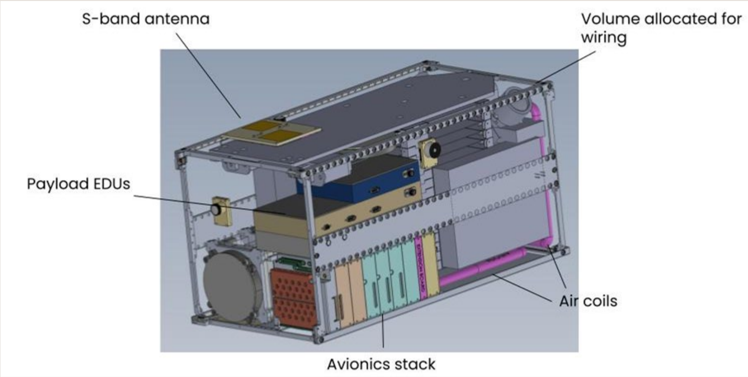
NanoMagSat boom - stowed



NanoMagSat platform

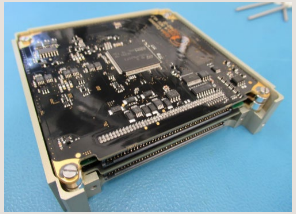
Satellite-level analysis

- Mass budget: being refined with latest 16U deployer limitations
- Accommodation to be iterated to minimise the magnetic signature
- Thermal analysis ongoing



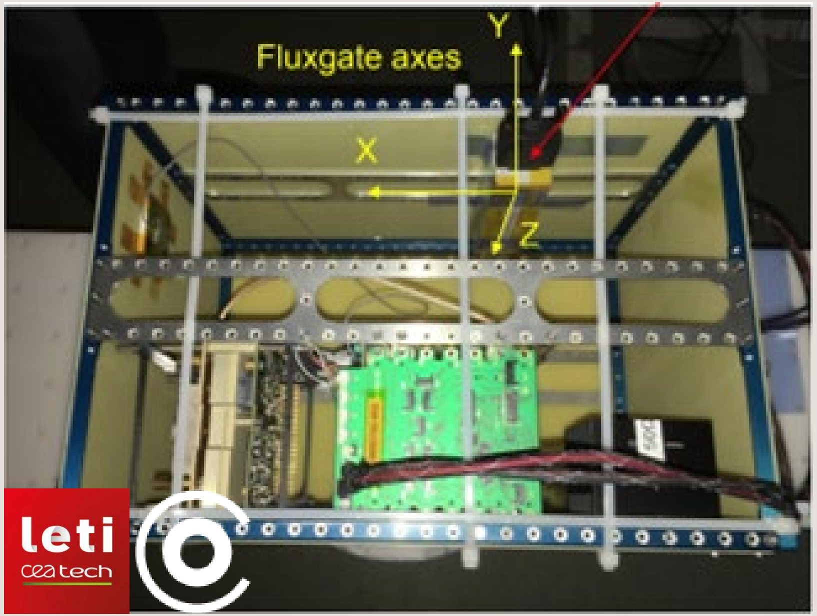
Magnetic budget specific contributors

- AOCS -> use of air coils
- EPS representative models for test
  - Batteries
  - EPS distribution board
  - Solar panel
- Wiring concept



NanoMagSat platform and magnetic cleanliness

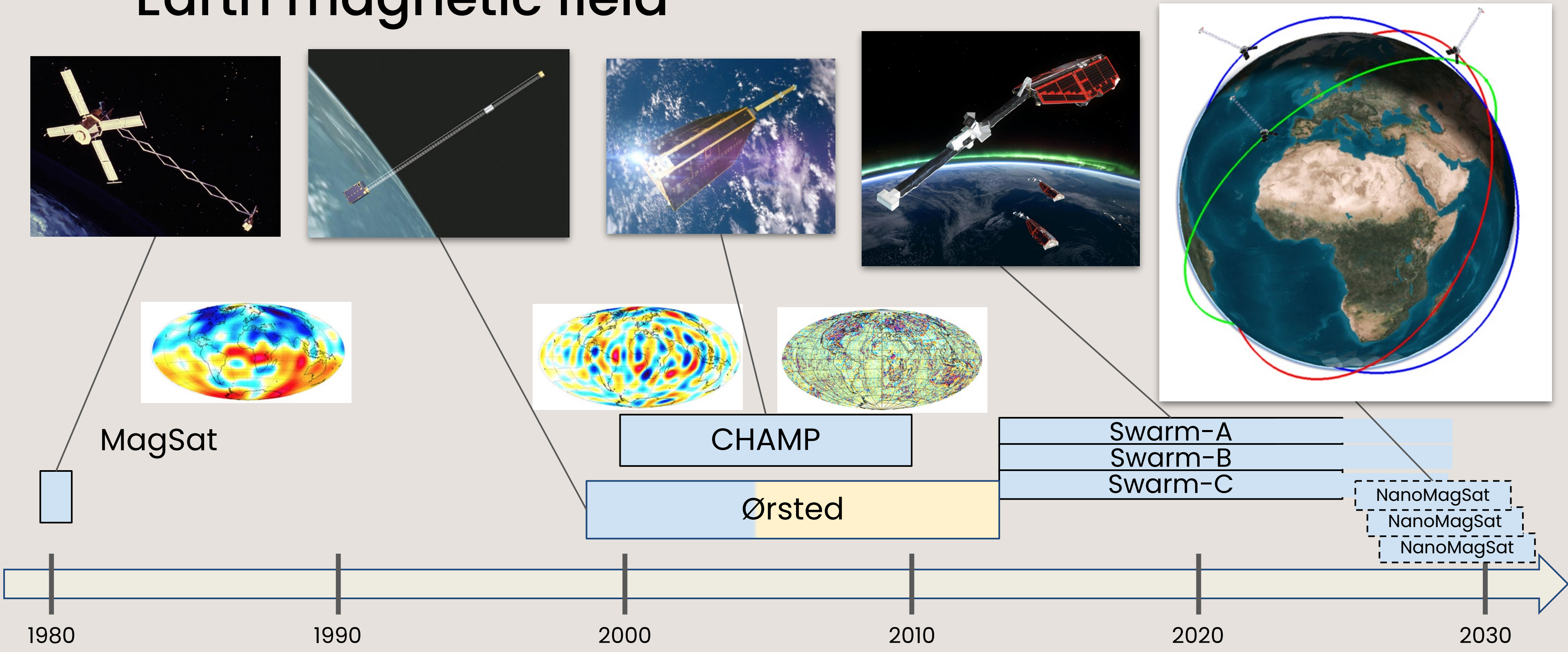
- **Threshold of 135 mA.m2 at 3m**
- Initial tests done in 2020 at CEA-Leti premises



Sub-system	Measured during the consolidation study	Proposed moment allocation (nT or mA.m²)
STR + OB	Partially (1 STR)	1 nT before compensation (included in the anisotropy characterization)
Boom	N	0,2 nT before compensation
HFM	Y	0,5 nT before compensation
EPS	N	50 mAm² for batteries & power distribution (bonding, shielding, grounding) still subject to significant changes
COMMS TT&C	N	5 mA.m² TBC
COMMS HDR	N	5 mA.m² TBC
ADCS	Partial tests only	20 mA.m²
Structure + OBDH	Y (12U) # 7 mA.m²	10 mA.m²
Fixed Panels	Y	2 mA.m²
Solar Panels	N	50 mAm² (preliminary estimate by OC) Lessons learnt from Swarm : if properly designed (back wiring), could be reduced to a point where stray fields compensation is no longer required
Harness	N	Grounding concept & thermoelectric effects to be taken into account
MAM & HFM DPUs	N	15 mA.m²
STR DPU	Y	1 mA.m²
M-NLP	Y, but evolutions expected (material replacement & electron emitter integration)	5 mA.m² (including electron emitter stray field to be evaluated during the RRA)
GPS	Partial tests only (no antenna) < 0,1 mA.m²	1 mA.m²

Magnetic cleanliness budget

NanoMagSat: ensuring continuous monitoring of the Earth magnetic field



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