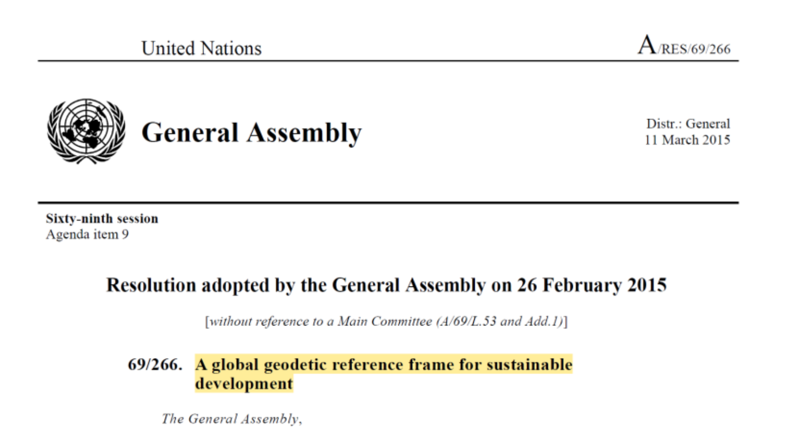
Genesis Mission Status & Key Topics

G. Fusco, P. Waller

Genesis Primary Objectives

Contribute to improve ITRF accuracy and stability by providing in-orbit colocation and necessary combined processing for the four space-based geodetic techniques that contribute to its realization. The goal is to contribute to the achievement of the Geodetic Global Observing System (GGOS) objectives for the ITRF realisation, aiming for a parameter **accuracy of 1 mm and a stability of 0.1 mm/year**, in order to provide significant scientific benefits in Earth modelling, and to support a wide range of societal applications (as endorsed by the United Nation resolution A/RES/69/266).

Contribute to improve the link between the ITRF and the ICRF, thanks to the increased consistency of the Earth Orientation Parameters (EOP). In particular, this mission shall allow for the first time a link between the orbit reference frame, ITRF and ICRF.


United Nations A/RES/69/266

General Assembly

Distr.: General
11 March 2015

Sixty-ninth session
Agenda item 9

Resolution adopted by the General Assembly on 26 February 2015

[without reference to a Main Committee (A/69/L.53 and Add.1)]

69/266. A global geodetic reference frame for sustainable development

The General Assembly,

Targets:
Accuracy: 1 mm
Stability: 0.1 mm per year

Genesis-enabled Science and Applications

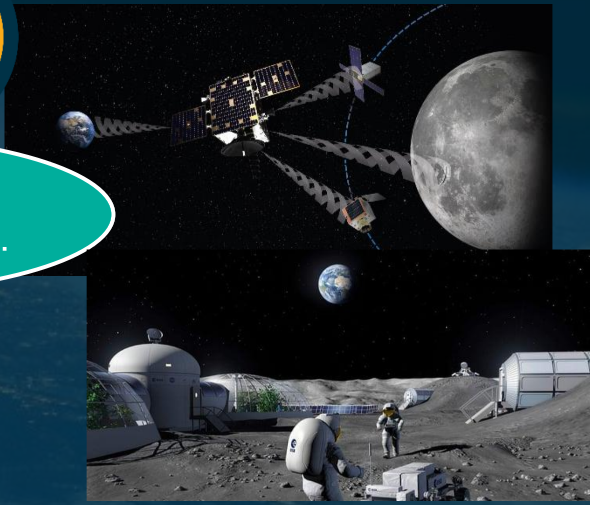
Geodesy, Reference Frames

Improved ITRF, EOPs, Unified Reference Frames

GNSS, Navigation

Improved GNSS POD (LEO, MEO, GEO), calibrations…

Navigation to the Moon, and beyond…

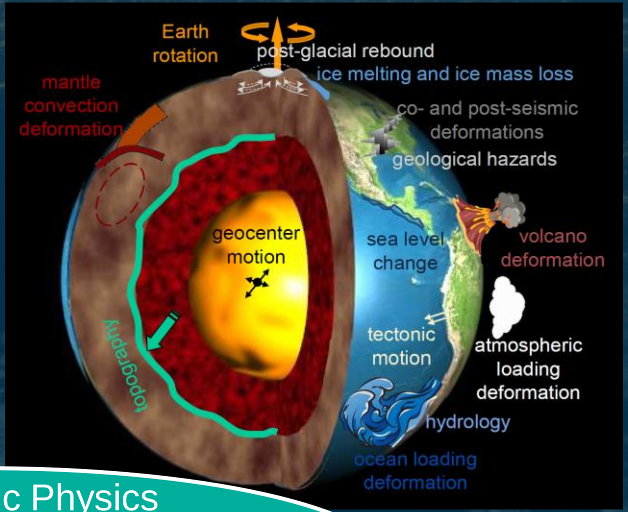


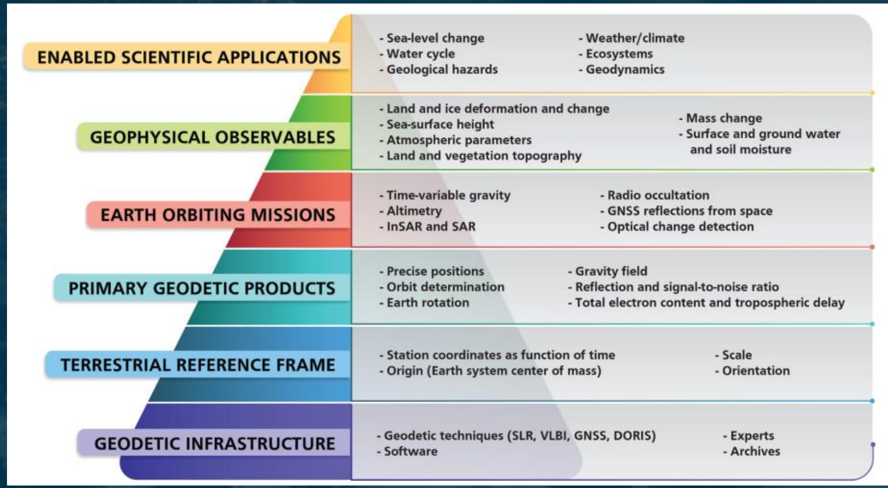
Earth Sciences

Geophysics: Deep Interior
- Geo-centre motion
- Core flows
- Magnetic field…

Geophysics: Mantle, Oceans
- Tectonic motions
- Post-glacial rebound
- Ice melting, Ice mass loss
- Sea level change…

Atmospheric Physics
- Iono, Plasmaspheric density
- Radiation budgets, Earth Energy imbalance…





"Evolving the Geodetic Infrastructure to Meet New Scientific Needs", National Academies of Sciences, Engineering and Medicine (2020)

Overview of the Genesis Mission

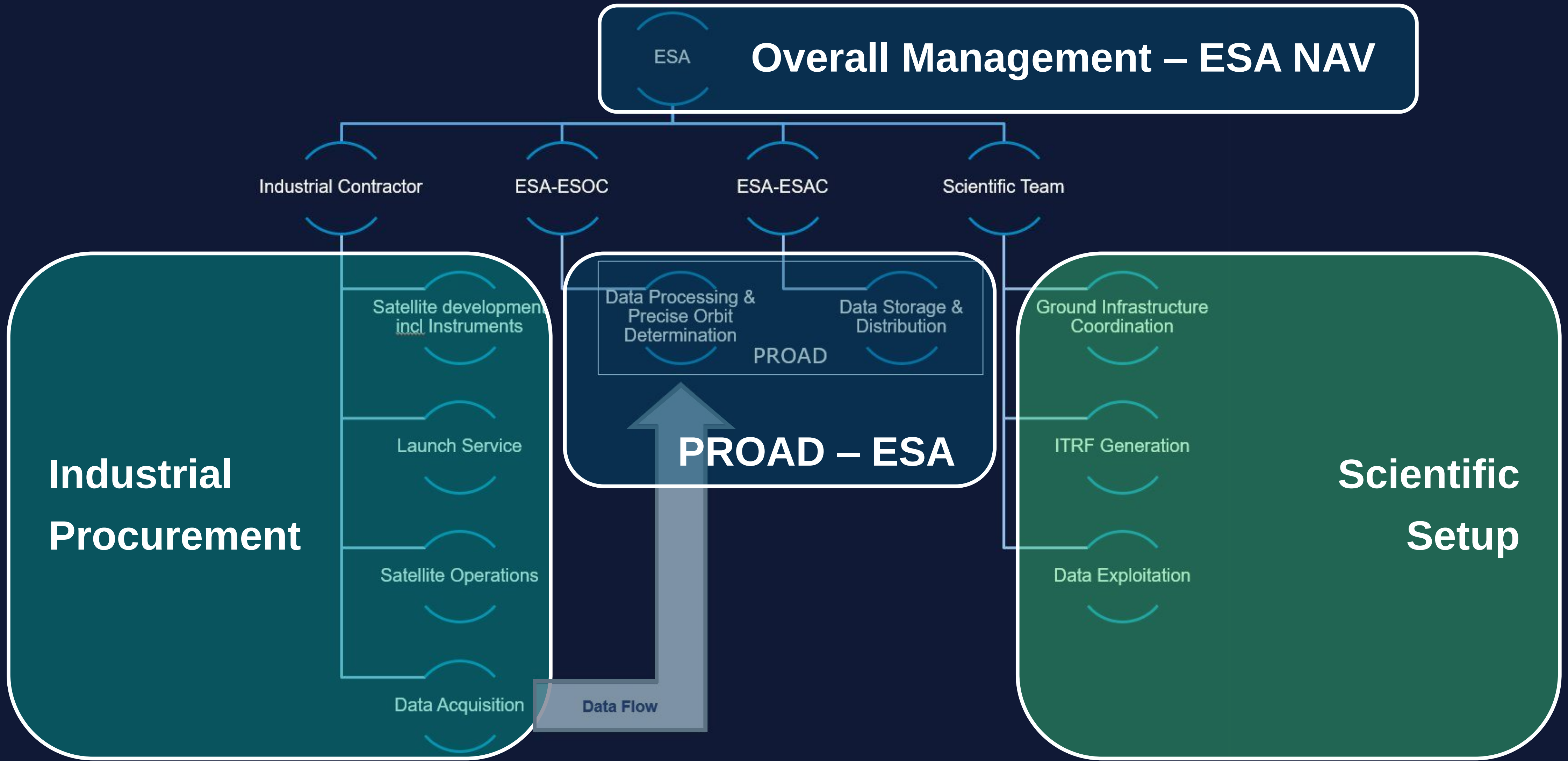
Overview

- Genesis is managed by the ESA Navigation Directorate and part of its **FutureNAV Programme**

Mission scope

- Design, development, qualification and calibration of the **satellite (incl. payloads) and ground segment**
- **Launch and early operations** including commissioning and calibration
- **Operations** (2 years, option for extension)
- **Data exploitation** (Including processing, archiving and data distribution from ESA facilities)
- Strong involvement of the **Scientific Community** and **International Geodetic Services**

Overview of the Genesis Mission



Genesis Mission Status

Contract Signature and Kick Off of activities
March-April 2024

System Requirements Review (SRR)
Q4 2024

Preliminary Design Review (PDR)
2025

Critical Design Review (CDR)
2026

Qualification and Acceptance Review (QAR)
2028

LAUNCH 2028
2 years of Operations with option for extension

Scientific exploitation

Genesis System Overview

System:

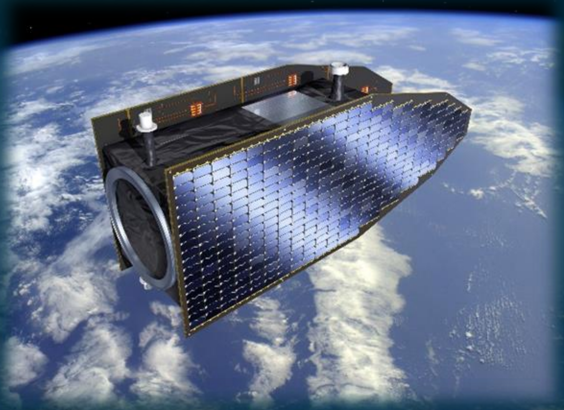
- Satellite
- GCS (Ground Control Segment)
- ESA PROAD (PROcessing, Archiving & Distribution)
- Existing infrastructure (GNSS, SLR, VLBI, DORIS)

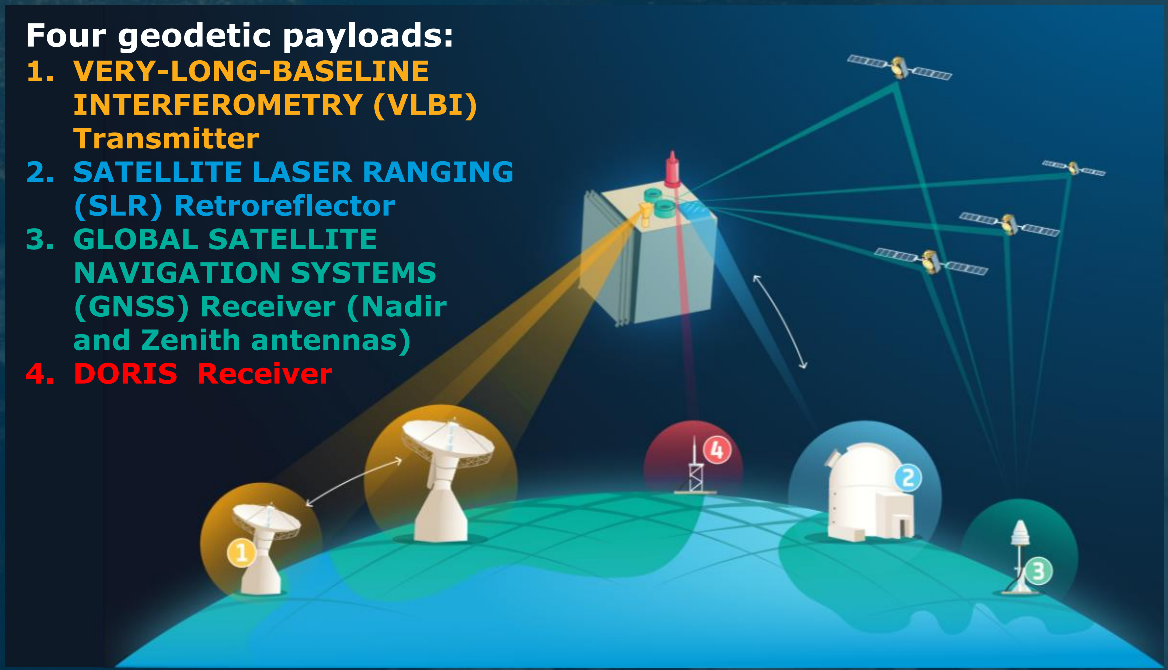
Four on-board geodetic Instruments:

- SLR: passive reflector
- DORIS, GNSS: on-board receivers
- VLBI: on-board transmitter in existing VLBI frequency bands

Mission Phases:

- Launch and commissioning
- In-orbit test and calibration
- Operations
- End of mission

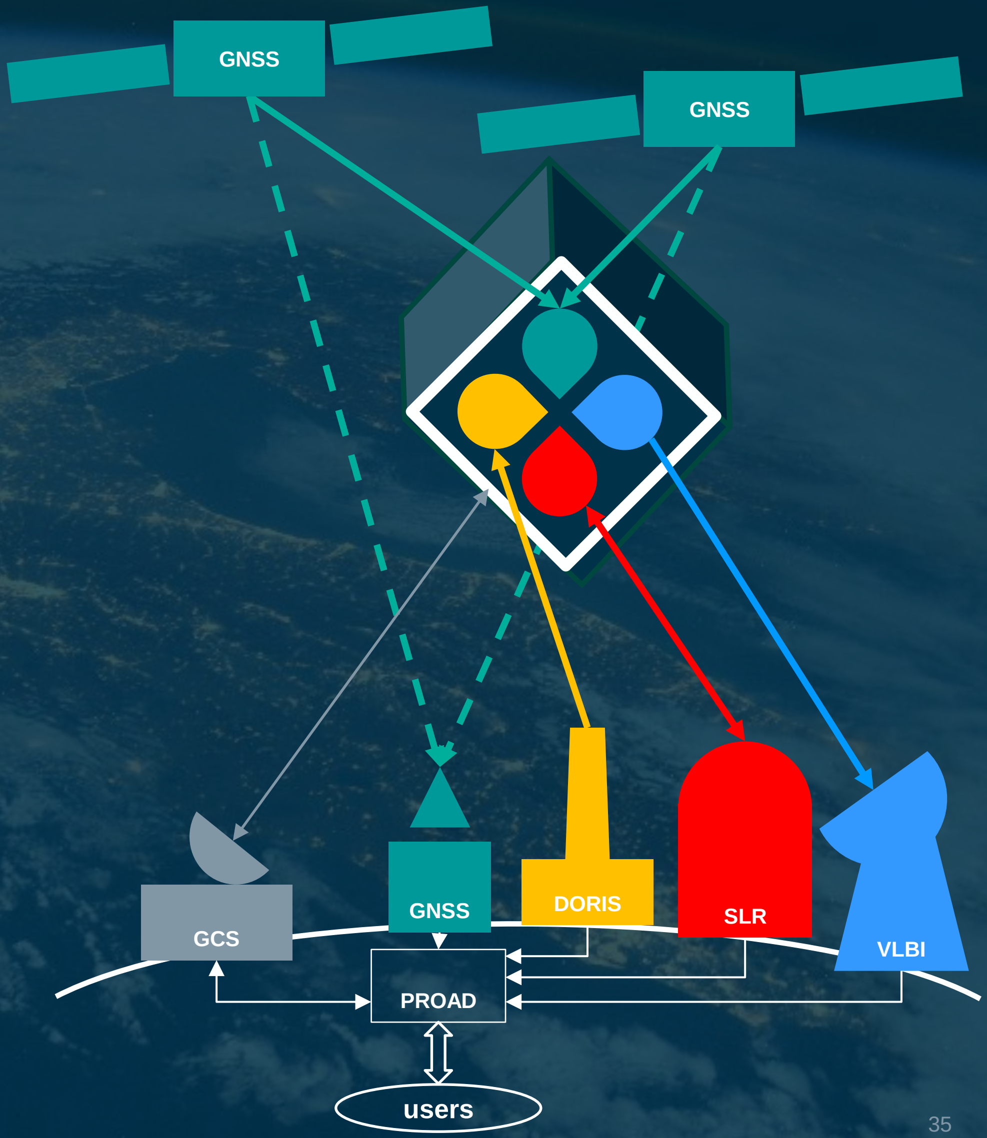




Genesis System Overview

Description

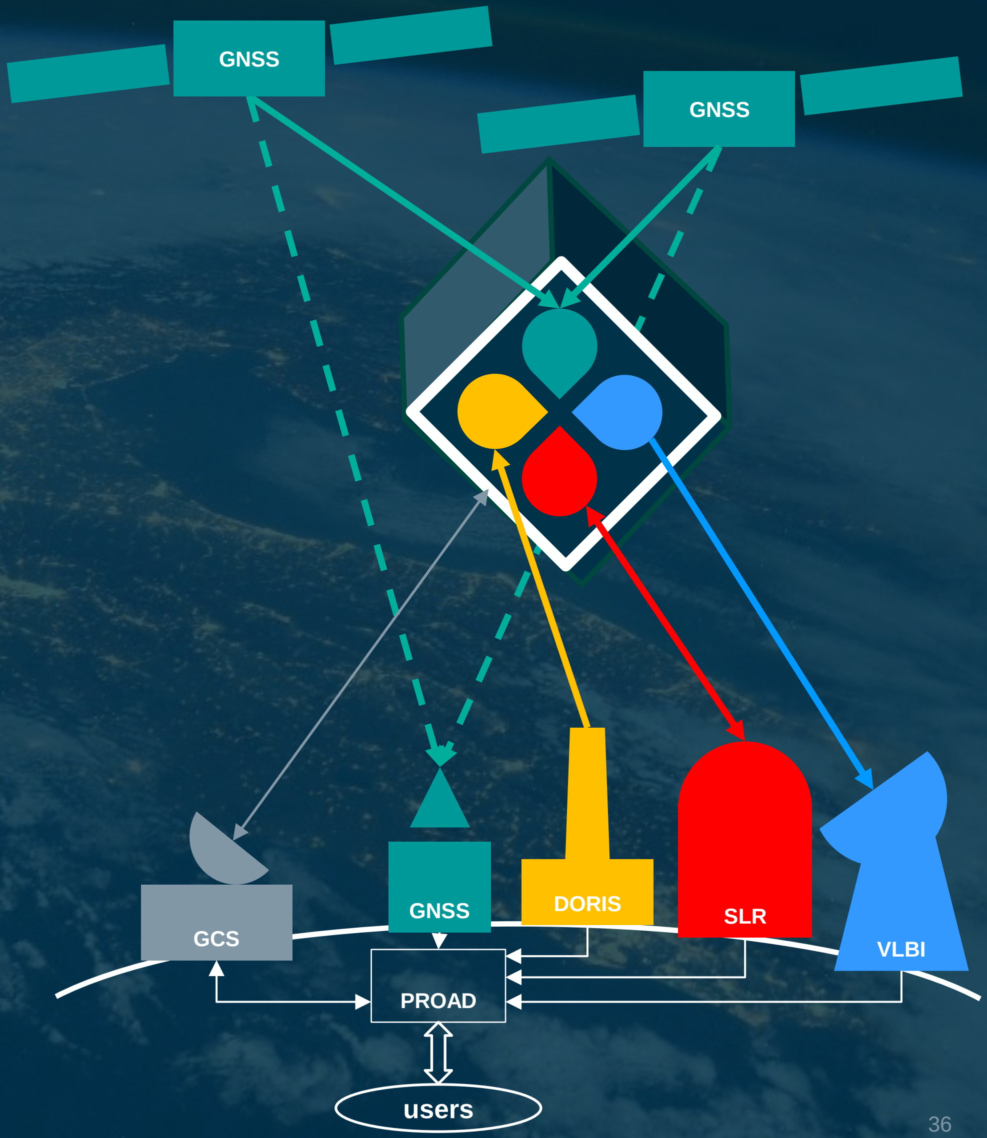
- Satellite
  - Mass: ~400 kg
  - Power: ~275 W (nominal)
  - Envelope: 1.7m X 0.7m X 2.6m
- Orbit:
  - ~6000km alt. (low MEO)
  - ~95.5º inclination
- Platform:
  - maximum reuse of qualified equipment
- Payload:
  - 4 co-located geodetic instruments
    - GNSS, DORIS, SLR, VLBI
  - ultra-stable oscillator for synchronisation



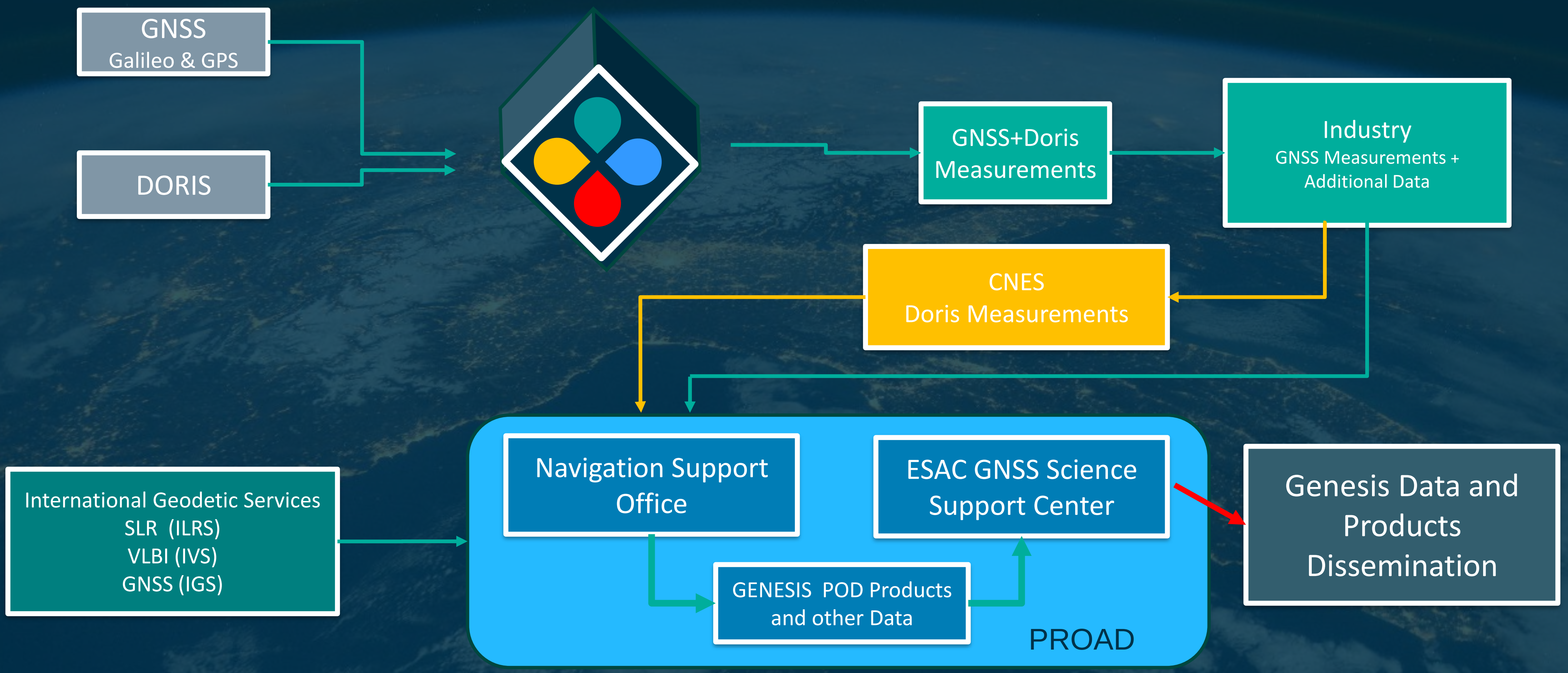
Genesis System Overview

Key drivers:

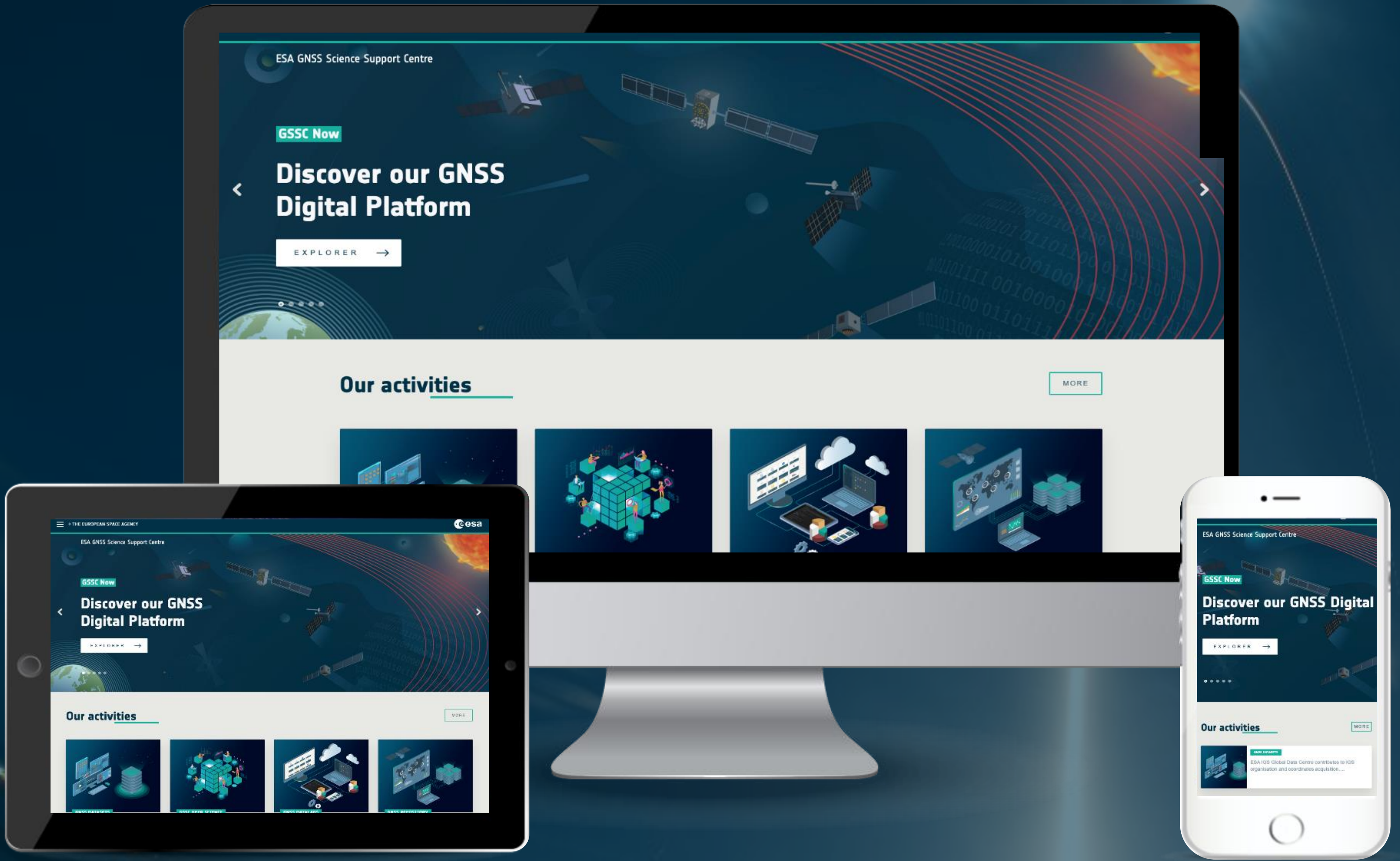
- Radiation environment (total dose and single events effects)
  - Need for radiation shielding
- Precise knowledge of the centre of mass position and variation during the lifetime
  - No propulsion, no mechanisms
- Timing
  - Synchronisation of active instruments to USO
- Radiofrequency and electromagnetic compatibility
- Non-gravitational forces
  - Mechanisms, geometry, materials…
- On-board instruments systematic biases
  - Calibrations: phase centres + group delays

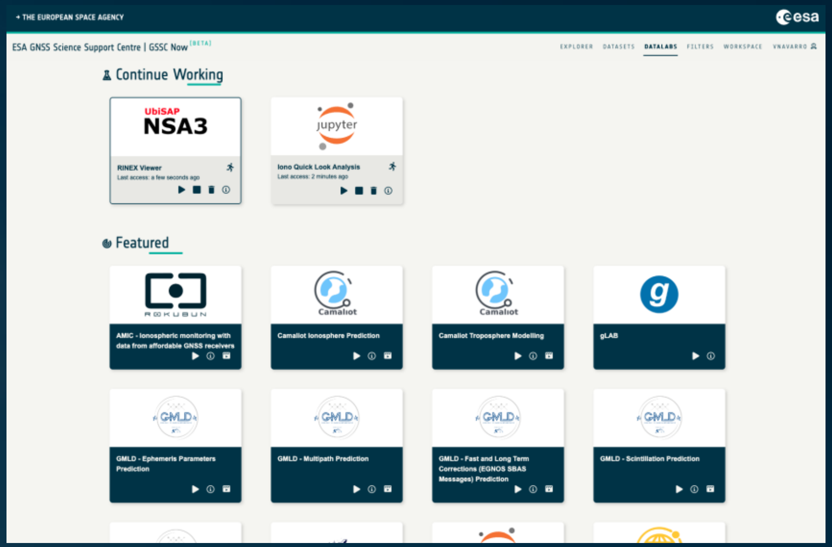


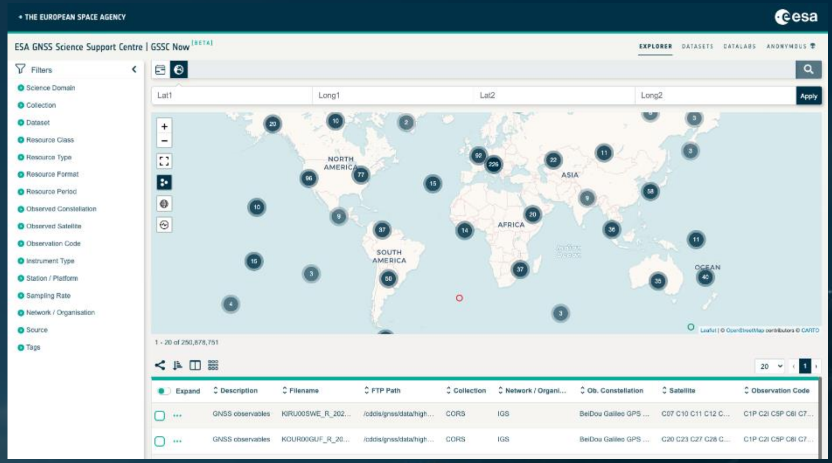
Genesis – PROAD Data Flow



Future Genesis PROAD Portal in GSSC







Goal → Single Point of Access to all Genesis resources

Genesis Science Team Setup

Genesis Science Team

Genesis Science Management Board

- ESA Scientific Representative
- Lead Science Coordinator
- Lead Science Co-Coordinator
- Working Groups Chairs

Genesis Science Exploitation Team (GSET)

- Lead Science Coordinator
- Lead Science Co-Coordinator
- Working Groups (WGs)
  - WG1: ITRF and Combination of Techniques
  - WG2: GNSS
  - WG3: VLBI
  - WG4: DORIS
  - WG5: Laser Ranging

GSET Coordinators, WG Chairs and Participants established in 2024

Implementation Plan

<u>Phase A: successfully concluded in Q4 2024</u>

- ✓ Thorough review of the System Requirements
- ✓ Consolidation of the System Requirements:
  - ✓ Iterative process between industry and ESA
  - ✓ Support from the science community through the GSET
- ✓ Outcome of the consolidation phase:
  - ✓ Formal release of the System Requirements Document 2.0 (SRD 2.0)
- ✓ Planning of the intended requirements' flow-down, i.e. how industry will translate/allocate system-level requirements into lower-level specs
- ✓ Review of the readiness and completeness of the required margins for different phases and components

Support of the Genesis Science Team = contribution to:

- **Requirements' consolidation**
- **Initial satellite and instruments' concept**

Implementation Plan

Phase B: ongoing

- ✓ Establish a preliminary design for the satellite and ground segment along with an operations concept
  - ✓ Confirm technical solution(s) for the system and operations by “trade-off” studies
  - ✓ Freeze system configuration
  - ✓ Establish a preliminary design definition for the selected system concept and retained technical solution(s), down to equipment level
  - ✓ Preliminary analyses
- ✓ Requirements’ flow-down from system to equipment level
- ✓ Consolidate verification approach

Support of the Genesis Science Team = contribution to:

- **Requirements’ flow-down**
- **Preliminary satellite and instrument design trade-offs**
- **Definition of preliminary calibration and verification concepts**
- **Definition of preliminary data processing concepts**

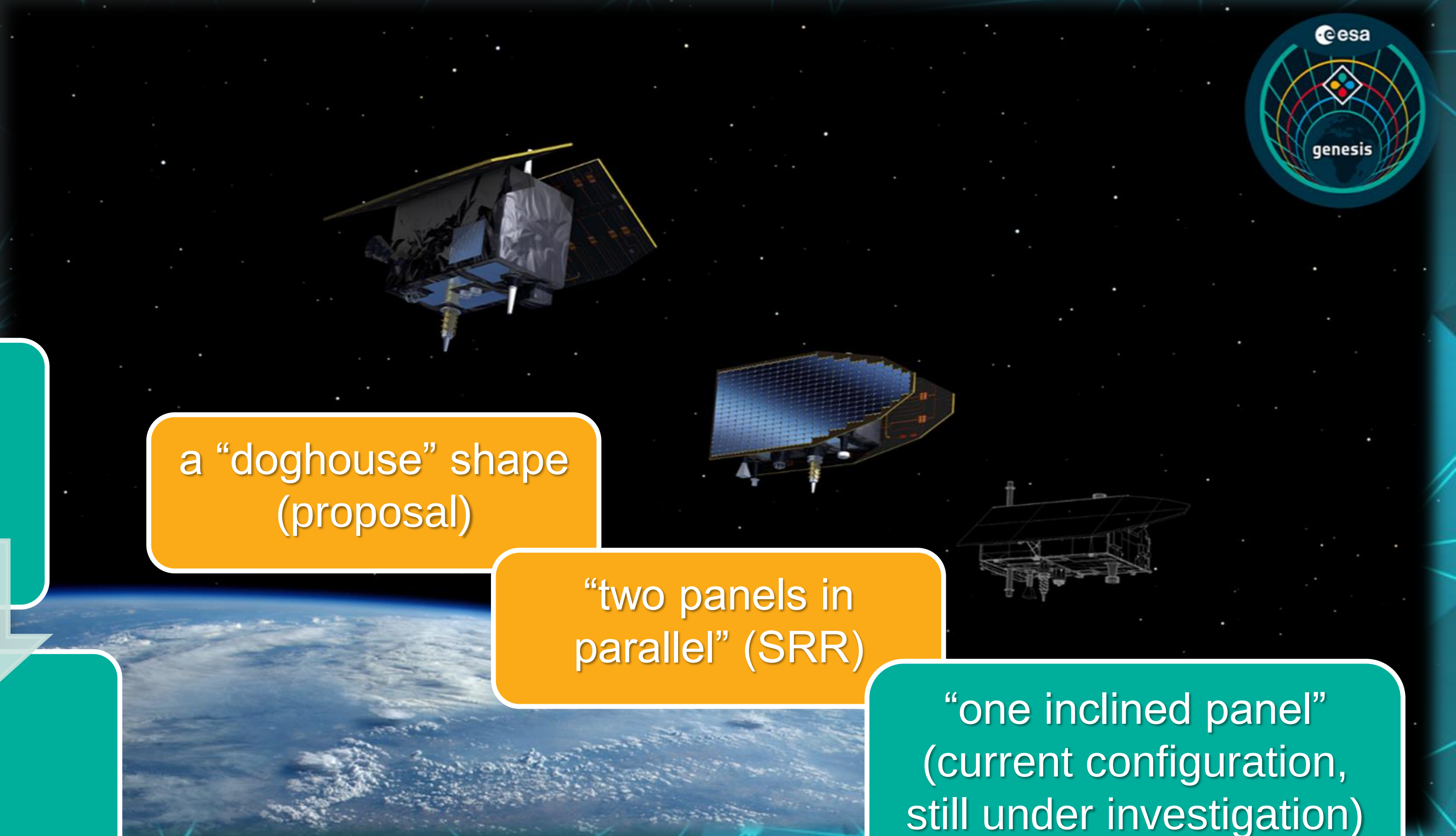
Design trade-offs and current configuration

Example of ongoing trade-offs in phase B:

Solar panel position

Antennae accommodation

Optimization of the power generation and satellite guidance law driving the shape and position of the solar panels (together with fairing envelope constraints)



a "doghouse" shape (proposal)

"two panels in parallel" (SRR)

"one inclined panel" (current configuration, still under investigation)

Genesis Orbit Inclination (1/2)

Current baseline inclination is confirmed to be ~ 95 deg,
based on the following assumptions/considerations:

The processing of the Genesis data will be conducted in combination with other satellites (e.g for SLR processing together with Lageos) and not in a stand-alone manner

Orbital parameters (including inclination) are optimized considering:

- Scientific aspects with a focus on main mission objectives
- Visibility considerations
- Number and quality of observations for processing
- Spacecraft design
- Radiation environment
- Thermal characteristics and stability
- Power
- Flight Dynamics (forces and torques acting on a satellite and respective force modelling)
- Operational concept (level of autonomy, on ground and on-board)
- Launcher (performance, availability and costs)

Genesis Orbit Inclination (2/2)

In the context of the Genesis SRR and science community activities, it was highlighted that the Genesis orbit inclination needs further discussions and consolidation

This discussion is ongoing in Genesis WG1

- Simulations have been carried out and iterated within the WG1
- Feedback from ESA is continuously provided
- Further simulations will be performed

In this early phase of the mission, ESA encourages WG1 to provide a feedback on inclination which is acceptable from scientific point of view – to be refined as the mission matures

Genesis Payload

Four Instruments, tightly tied:

GNSS Receiver

- Galileo E1/E5a, GPS L1/L2/L5
- Nadir + Zenith Antennae
- Tracking optimised for Genesis orbit
- High quality code and phase observables

Laser Retro-Reflector

- Compatible with ILRS stations (532nm)
- Nadir deck
- CCR & geometry optimised for Genesis orbit
- Increased optical cross-section (6Mm2)

Master USO

VLBI Transmitter

- Wideband signals in S, C and X-bands
- Compatible with VGOS stations
- New multiband Tx antenna
- One-way ranging capability

DORIS Receiver

- Legacy DGXX-S instrument, UHF/S-band
- Legacy LEO Antenna
- On-board processing tuned for Genesis orbit
- Use of external USO signal

GNSS Instrument Status

Achieved:

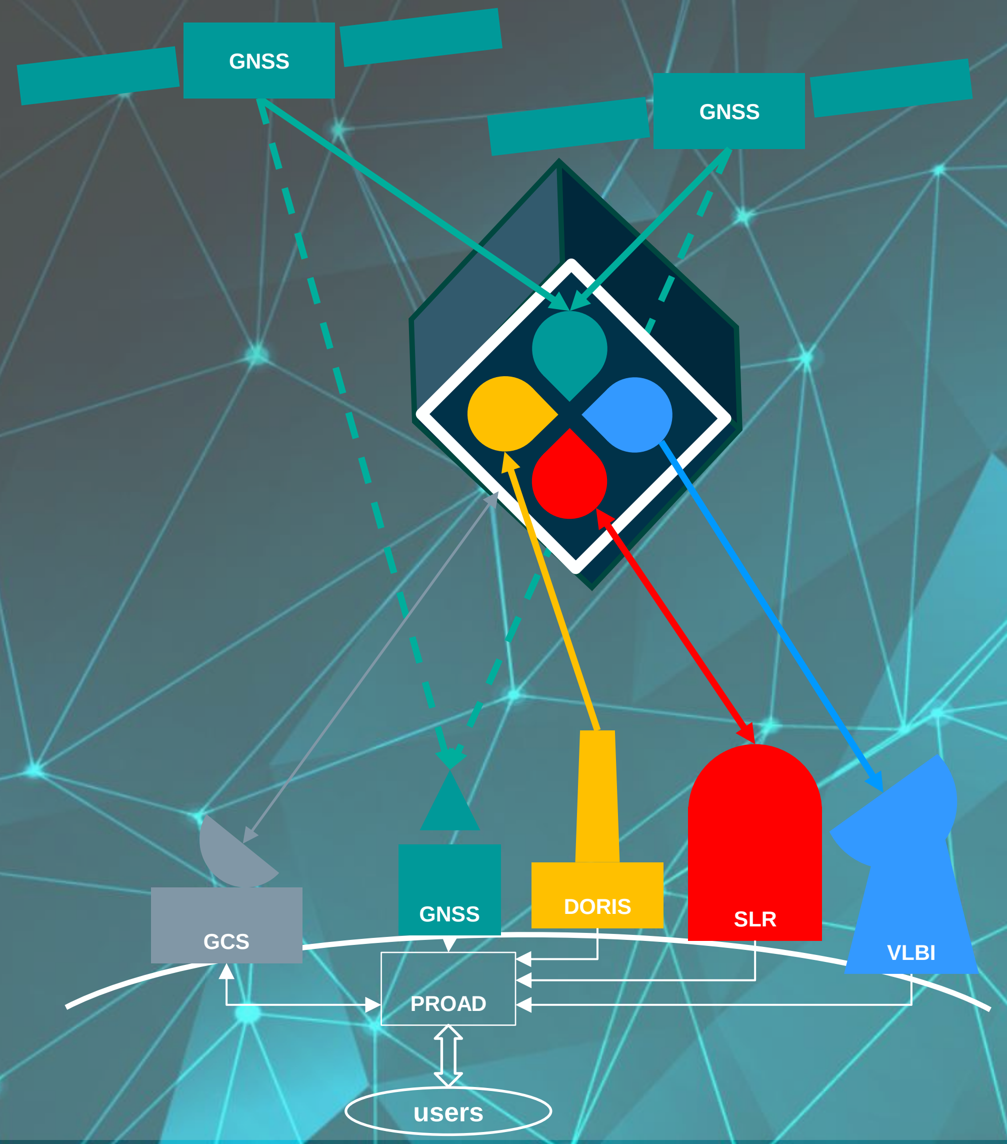
- ✓ Receiver supplier selected: SpacePNT (CH)
- ✓ SRD-level requirements consolidated:
  - ✓ Galileo (E1, E5) and GPS (L1, L2, L5)
  - ✓ PCO/PCV and gain patterns knowledge clarified

On-going:

- Link-budget, C/No, visibility analyses consolidations
- Antenna trade-offs
- Requirement flow-down, Equipment Qualification Status Review

Next Key Point:

- Satellite PDR: preliminary performance confirmation, verification/calibration approach



LRR Instrument Status

Achieved:

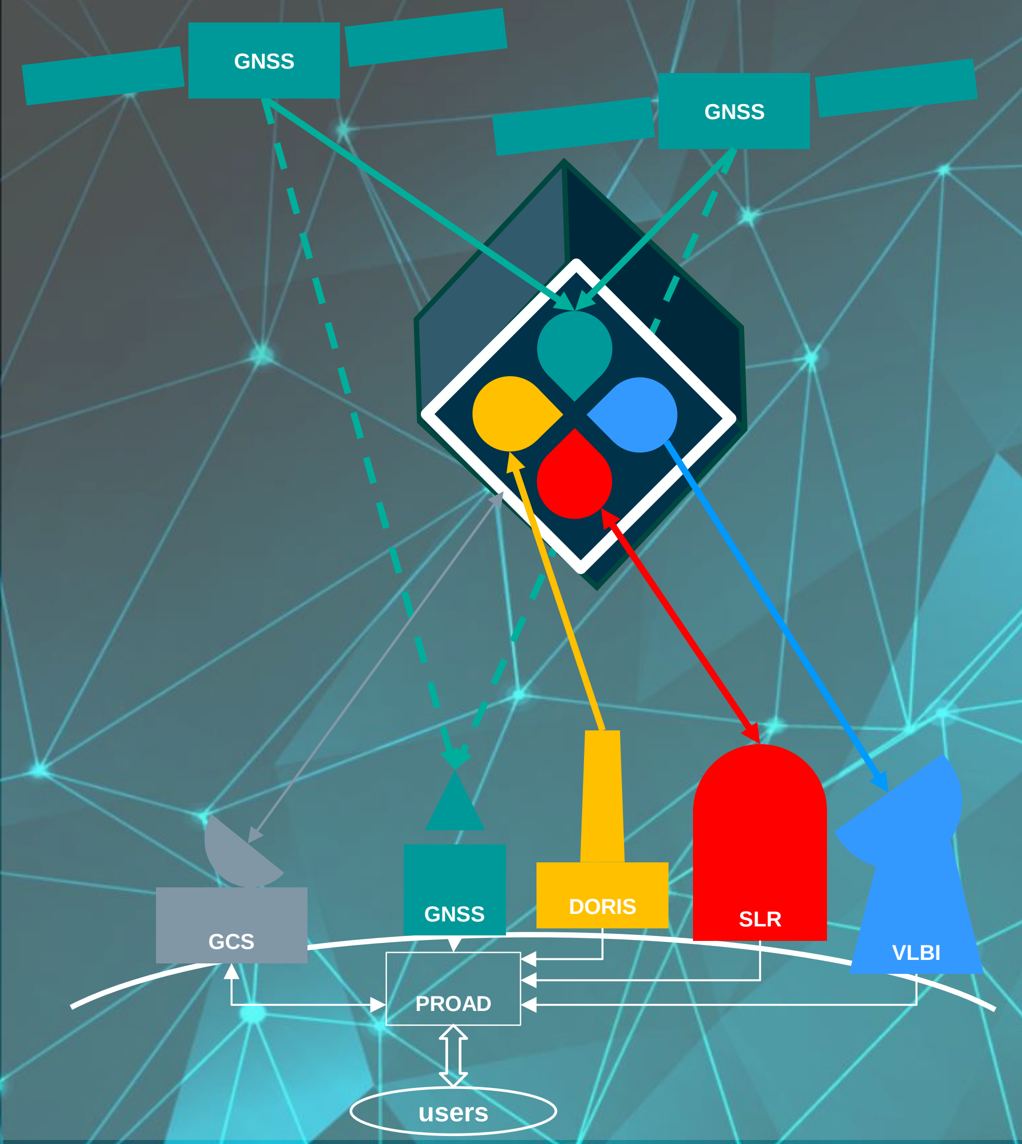
- ✓ Receiver supplier selected: INFN (IT)
- ✓ SRD-level requirements consolidated:
  - ✓ Optical Cross-Section increased from 3Mm2 to 6Mm2
  - ✓ Position Vector Knowledge and Range Correction definitions clarified

On-going:

- Preliminary design and trade-offs
- Corner-Cube Reflectors procurement
- Requirements flow-down, Equipment Qualification Status Review

Next Key Point:

- Satellite PDR: preliminary LRR design, verification/calibration approach



VLBI Instrument Status

Achieved: Brand New Instrument!

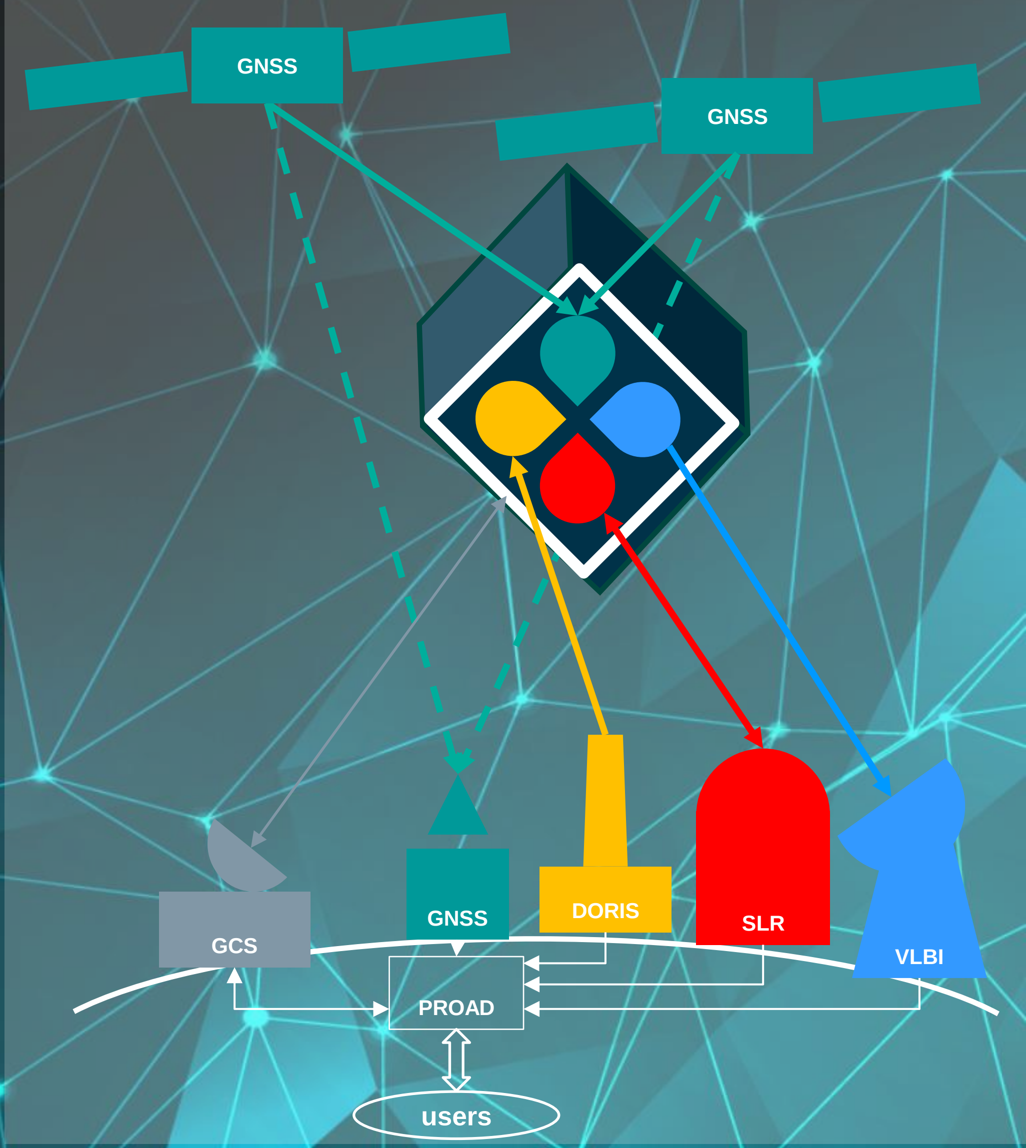
- ✓ E-box supplier: AntwerpSpace (B), Antenna supplier: UCL (B)
- ✓ SRD-level requirements consolidated
  - ✓ 4 frequency bands selected and frozen (S-, C-, Xlow-, Xhigh-bands)
  - ✓ Spectral Power Flux Density range and variation over FoV consolidated
  - ✓ Polarisation and One-way ranging function confirmed

On-going:

- Preliminary design and analyses for the E-box and Antenna
- One-way ranging mode definition

Next Key Point:

- VLBI Instrument PDR (Apr-May-25)



DORIS Instrument Status

Achieved:

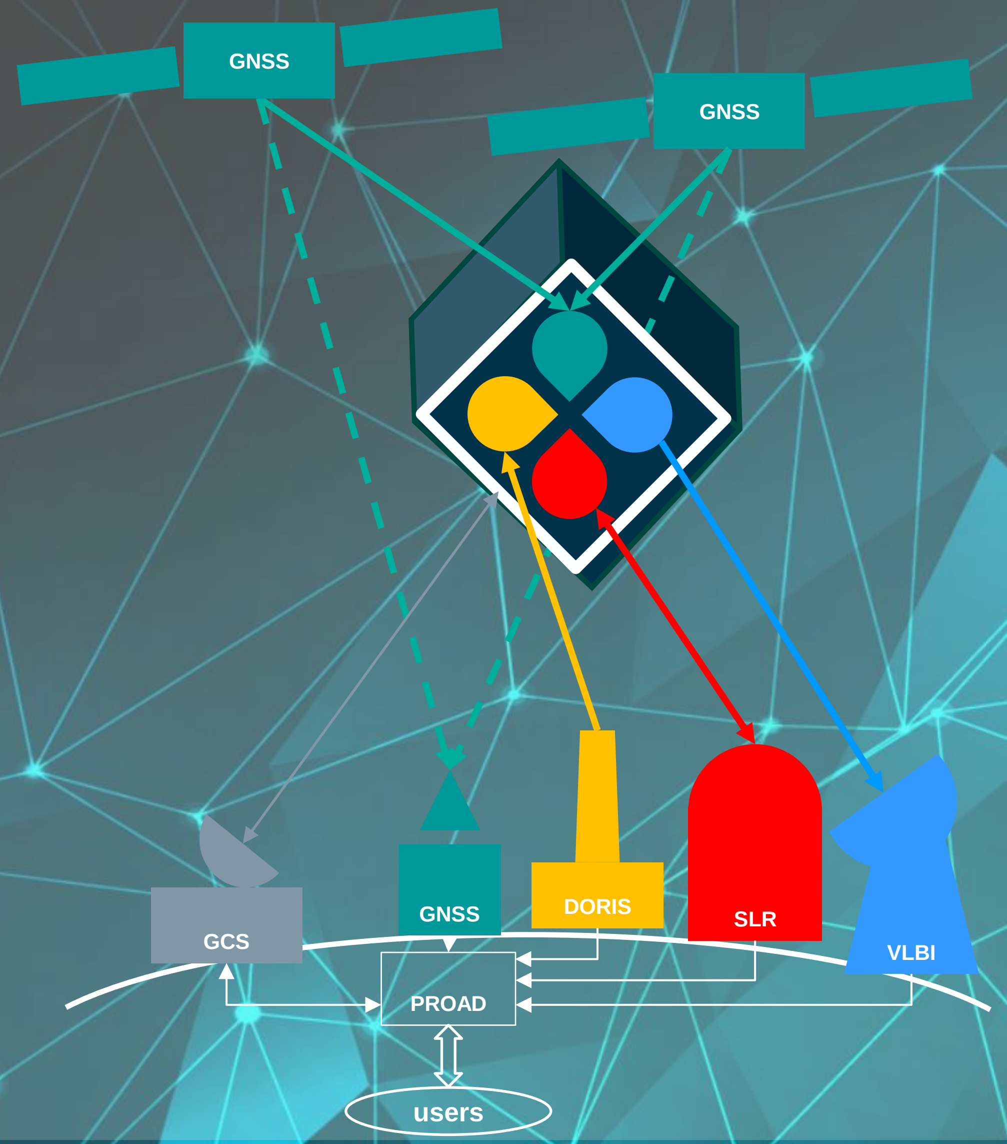
- ✓ Agreement reached with CNES (legacy DORIS DGXX-S instrument without USO)
- ✓ Preliminary performance assessment at Genesis orbit
- ✓ SRD-level requirements consolidated:
  - ✓ Velocity Measurements clarified, input frequency bands and levels updated

On-going:

- Receiver and Antenna procurement (by CNES)
- Consolidation of performance at Genesis orbit and with external USO
- Requirements flow-down, Equipment Qualification Status Review

Next Key Point:

- Satellite PDR: confirmation of DORIS performance



USO and Frequency Distribution Status

Achieved:

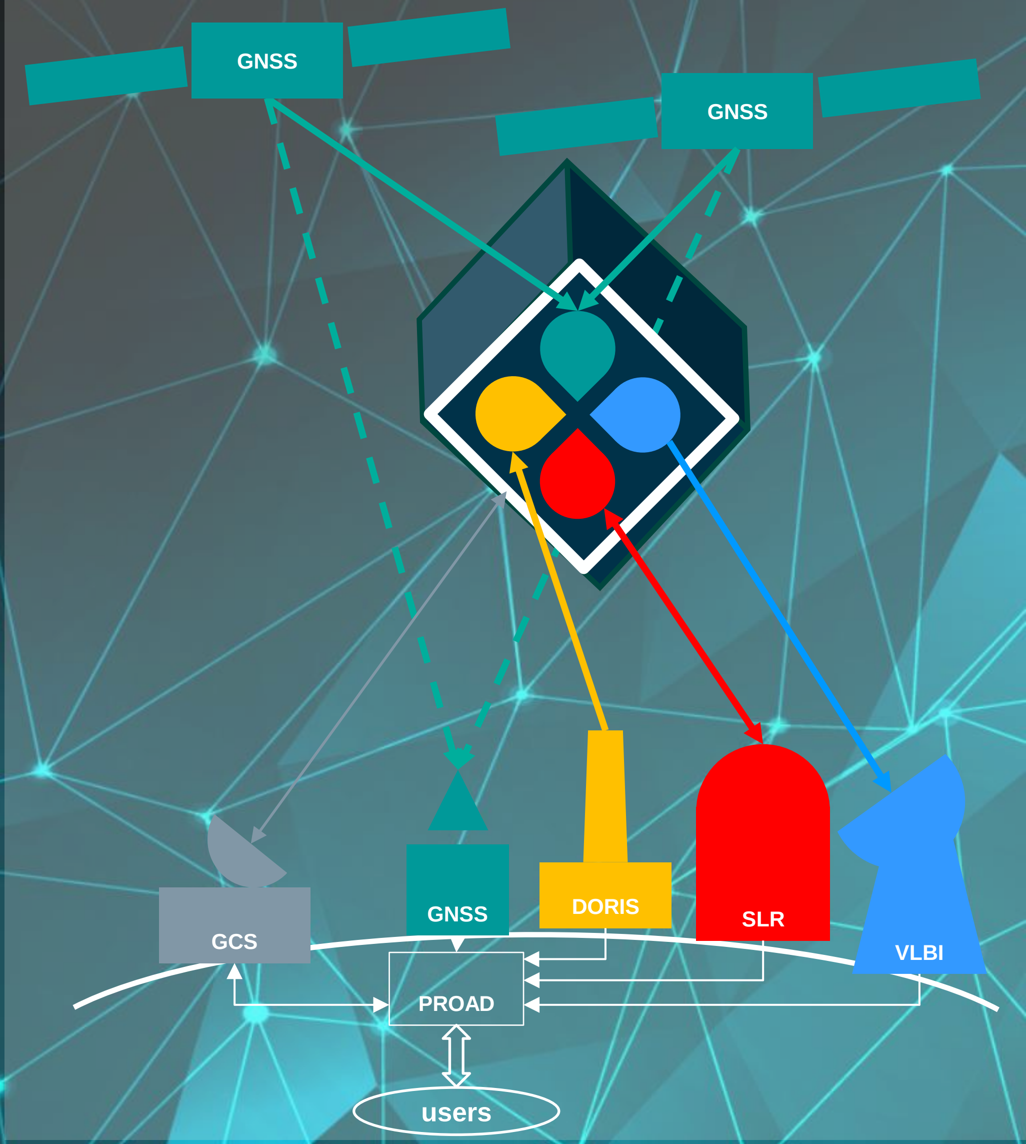
- ✓ USO supplier selected: Safran Timing Technologies (CH)
- ✓ SRD-level requirements consolidated
    - ✓ ADEV spec extended to 10000sec

On-going:

- Frequency/Time signals distribution definition and trade-offs
- Long-lead items procurement

Next Key Point:

- Satellite PDR: preliminary design for time/frequency signal distribution



Few words about calibration for Genesis

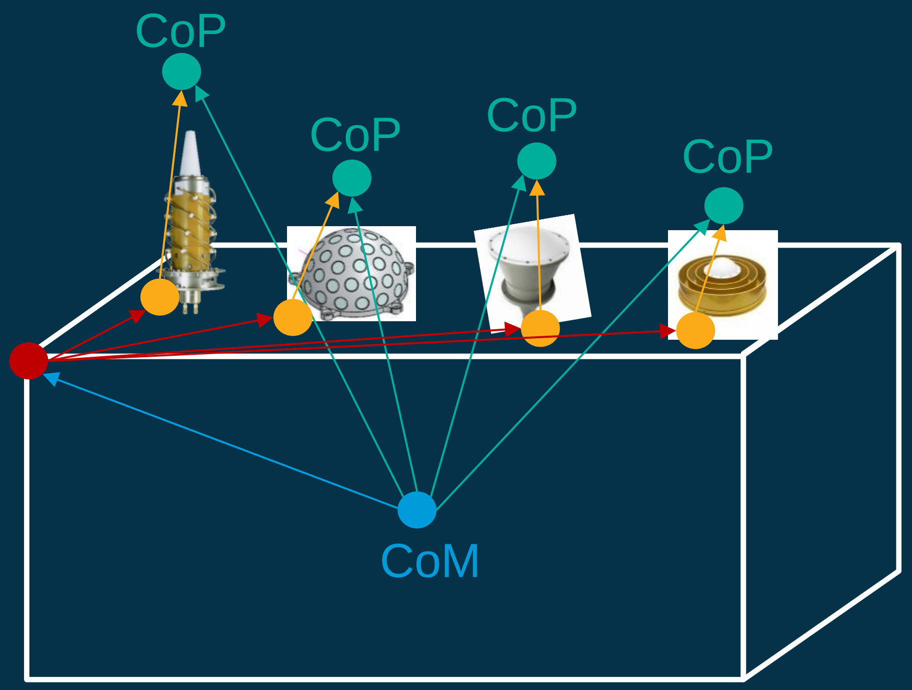
Calibration = characterization of the biases and their variations, within a given uncertainty, between:

- the satellite Centre of Mass
- the instruments Centre of Phase

Uncertainty ~1mm is challenging!

In practice, biases are broken down to refer to physically measurable points:

- Satellite Mechanical Reference Point
- Instruments/Antenna Reference Point



Approach to Calibration

CoM → Sat. Reference Point:

- Physical measurement at Satellite level in final configuration (no moving part, no consumable)

Sat. Reference Point → Instrument/Antenna Reference Points:

- Laser tracker measurements at Satellite level in final configuration

Instrument/Antenna Reference Points → Centre of Phase:

- Combination of measurement and analysis at instrument/satellite levels, no technique/facility identified yet

Phase skewing effects (thermo-elastic, thermal, EMC…)

- Combination of measurement and analysis at instrument/satellite levels, no technique/facility identified yet

A calibration campaign at satellite level in final configuration in anechoic chamber is confirmed.

Approach to Calibration

Instrument/Antenna Reference Points → Centre of Phase:

- Maximum reuse of techniques and heritage developed for GNSS (PCO/PCV) and SLR (Range Correction)
- Harmonise and adapt these techniques to DORIS and VLBI to guarantee consistency

Phase skewing effects:

- Define and validate a solid Satellite thermal model
- Extended characterization at instrument/satellite level, in particular during TVAC tests

More generally:

- Define optimum measurement/analysis combination approaches (incl. procedures and data processing)
- Conduct early validation and performance assessment

Support from the Scientific community is needed!

Goal: end-to-end calibration concept with preliminary performance budget assessment by Satellite PDR

Genesis Calibration Planning

2025
- Draft Concept

2026
- Final Concept

2027
- Implementation

2028
- In-orbit Calibration

To summarize…

Thanks to combined efforts from Scientific Community, ESA Member States, Industry and ESA, the **Genesis Mission has become a reality!**

This challenging mission will be a stepping stone towards **improved GNSS and navigation**, together with addressing **major scientific and societal goals**

Despite a challenging schedule, ESA, Industry and the Scientific community are fully committed to the **success of the Mission**

We are looking forward to updating the community on the progress of the mission

Genesis – AT THE FOUNDATION OF NAVIGATION