Mission standing committee

ESA-GENESIS

23rd International Workshop of Laser Ranging
Kunming, China
October 23rd 2024

Mathis Blossfeld & Clément Courde

Agenda

1. Informations on the mission & the organization
2. Discussion regarding the SLR related requirements

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GENESIS Mission 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).

Targets:

Accuracy: 1 mm

Stability: 0.1 mm per year

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.

Overview of the GENESIS Mission

Scientific Involvement in GENESIS mission

- Participation to requirements consolidation in Phase A
- Support ESA in the follow up of the industrial activities, with emphasis on instrument and platform developments
- Analysis of mission performance and the mission contribution towards target ITRF improvement
- Preparation of the scientific data exploitation, covering any gaps in algorithms, tools or ground infrastructure required
- Preparation and execution of required ground-based campaigns (in particular VLBI, SLR)

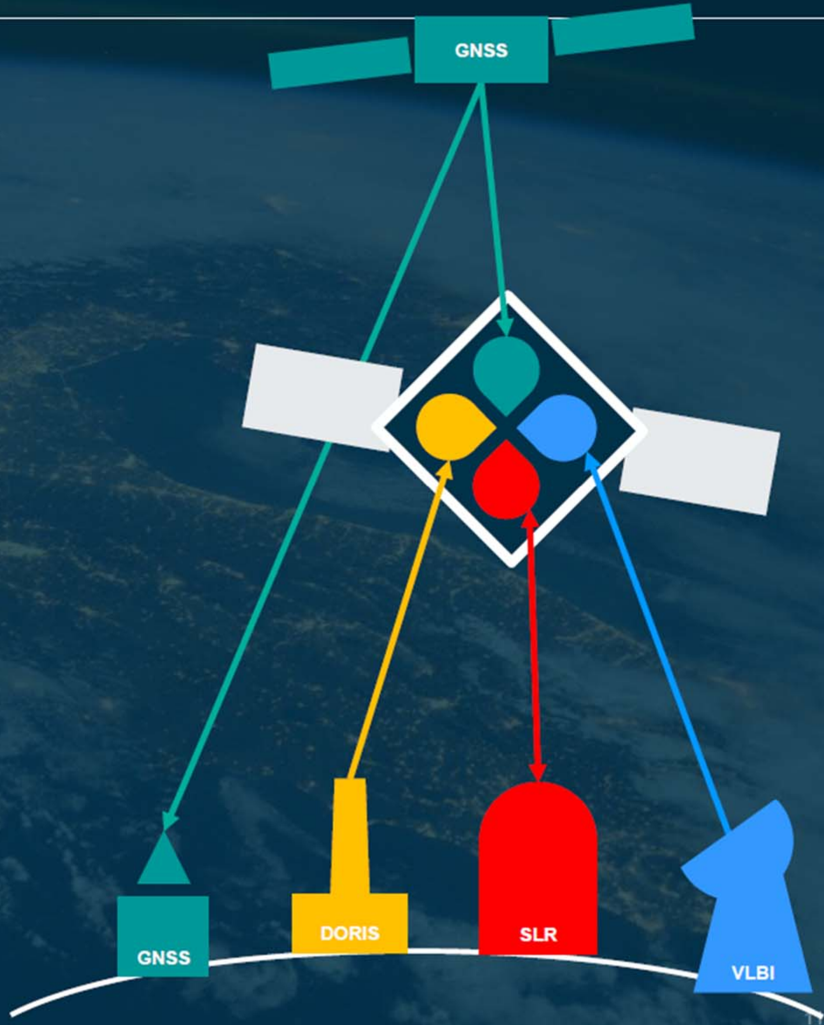
GENESIS Satellite and Payload Overview

Description

- Single satellite ~250-300kg, ~6000km alt. (MEO), ~95º inclination
- Platform: maximum reuse of qualified equipment
- Payload: 4 co-located instruments (GNSS, DORIS, SLR, VLBI)

Points of attention at satellite and payload level:

- Radiation environment: total dose and single events effects
- Radiofrequency and electromagnetic compatibility of VLBI
- Non-gravitational forces: mechanisms, geometry, materials...
- Spacecraft centre-of-mass and attitude law
- Synchronisation of active instruments to the on-board oscillator
- On-board instruments systematic biases and their calibrations: phase centres + group delays



GENESIS Mission Status

esa

Contract Signature and Kick Off of activities
March-April 2024

System Requirements Review (SRR)
Q3 2024

Preliminary Design Review (PDR)
2025

Critical Design Review (CDR)
2026

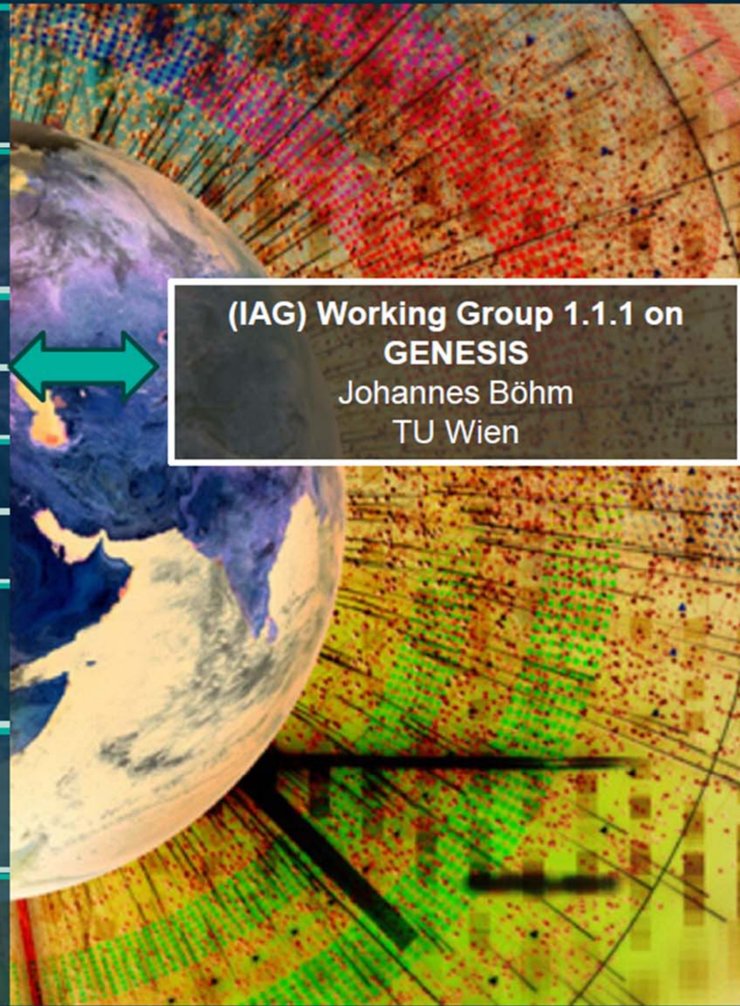
Qualification and Acceptance Review (QAR)
2027

esa genesis

LAUNCH 2028
2 years of Operations
Option for extension

GENESIS Science Management Board - Nominations

Coordinator	**Özgur Karatekin** Royal Observatory of Belgium – RoB
Co-Coordinator	**Francesco Vespe** ASI Space Geodesy Centre at Matera
WG1: ITRF & Combination of Techniques	**Zuheir Altamimi** Institut national de l'information géographique et forestière – IGN
	Florian Seitz Deutsches Geodätisches Forschungsinstitut-Technischen Universität München – DGFI
WG2: GNSS	**Rolf Dach** Universität Bern
	Benjamin Männel Deutsches GeoForschungsZentrum – GFZ
WG3: VLBI	**Rüdiger Haas** Chalmers Tekniska Högskola
WG4: DORIS	**Guilhem Moreaux** CLS-Collecte Localisation Satellites
WG5: Laser Ranging	**Clément Courde** Centre national de la recherche scientifique – Géoazur



(IAG) Working Group 1.1.1 on GENESIS
Johannes Böhm
TU Wien

→ THE EUROPEAN SPACE AGENCY

GENESIS SLR WG

Current members of GENESIS SLR WG

- Simone Dell'Agnello
- Robert Sherwood
- Michael Steindorfer
- Stephen Merkowitz
- Mike Pearlman
- Toshimichi Otsubo
- Johann Eckl
- Alexandre Belli
- José Carlos Rodriguez
- Randall Carman
- David Sarroco
- Mathis Blossfeld (Deputy)
- Matthew Wilkinson
- Dariusz Strugarek
- Pierre Exertier
- Julien Chabé
- Marco Cinelli
- Franck Reinquin
- Christian Schwatke
- Randall Ricklefs
- Claudia Carabajal
- Ole Johan Klingan
- Clément Courde (Chair)

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1. Informations on the mission & the organization
2. Discussion regarding the SLR related requirements

GENESIS SLR-related requirements

- **Payload SLR requirements:**
  PLD-SLR-010 Accommodation of Passive Laser Retroreflector
  The satellite shall be equipped with a passive Laser Retroreflector (LRR) which requires no power or active control.
- PLD-SLR-020 Compatibility with Existing Ground SLR Infrastructure
  The LRR shall be compatible with the International Laser Ranging Service (ILRS) stations and support ground station tracking anytime the satellite is nadir-pointing.
  In particular, the LRR shall not create the need for building mission specific SLR ground stations or additional hardware systems at current ILRS stations.
- PLD-SLR-030 Optical Link Budget
  LRR shall allow a sufficiently high optical link budget to allow the network of SLR ground stations to track GENESIS with sufficient efficiency.
  Note: Depending on the satellite orbit and the amount of energy desired at the station, the trade-off shall be made considering effective cross section, material quality of the array and choice of mirrors (Coated or non-coated), etc.

GENESIS SLR-related requirements

- **Payload SLR requirements:**
  PLD-SLR-040 LRR Cross Section
  LRR must have minimum effective cross section of 3 million square meters at apogee for laser wavelength of 532 nanometres
  Note: The minimum number has been derived assuming ~ 7500 km circular orbit. It corresponds to ~ 20% of the return rate from the ILRS standard target LAGEOS (6-8 km Orbit with 15M). As additional reference, cross-section in Galileo is 50M (IOV), 72 M2 (FOC) and 100M m2 (G2).
- PLD-SLR-050 FoV from Ground
  The satellite design shall accommodate the LRR so that in Earth Pointing Mode the field of view from ground is in the range of 90deg - 15deg above the horizon.
  Depending on the satellite orbit, it gives a mask on the satellite side FoV.

GENESIS SLR-related requirements

- **Payload SLR requirements:**
  PLD-SLR-060 Position Vector Knowledge
  The position vector of the LRR centre of phase relative to the internal satellite reference frame shall be known with accuracy better than 0.5 millimetres (1 sigma).
- PLD-SLR-070 Position Knowledge
  At instrument level the position of the LRR shall be known by mechanical design better than ±0.1 mm.
- PLD-SLR-080 Elimination of Mounting Errors
  The LRR mounting error shall be eliminated by alignment techniques once mounted on the satellite.
- PLD-SLR-090 Range Correction
  The range correction of the array shall be known at any given moment with an accuracy below 1 mm.
  This shall be valid for any given solar illumination condition, i.e. the thermal influence on the design parameters shall be minimal.

Discussion regarding the SLR related requirements

- Issue raised by Mathis=> Requirement : The satellite shall be tracked by means of the SLR generating an average of 1000 normal points per week. => seems difficult to obtain & requirement for the ILRS network, not really for the contractor
- Based on the last year, the tracking statistics for the geodetic spheres read
- LAGEOS-1: ~ 1024 obs/week
- LAGEOS-2: ~ 910 obs/week
- Etalon-1: ~ 113 obs/week
- Etalon-2: ~ 106 obs/week
- LARES: ~ 1206 obs/week
- LARES-2: ~ 902 obs/week
- Stella: ~ 679 obs/week
- Starlette: ~ 1411 obs/week
- Ajisai: ~ 2253 obs/week
- Larets: ~ 292 obs/week

Discussion regarding the SLR related requirements

- Issue raised by Mathis+ Christian => Requirement : It shall be possible to uniquely identify the SLR data format, generation time, and covered time period from the data filename

the "covered time period" is currently not a standard part of the file naming convention applied within the ILRS: So this requirement might be necessary to be changed.

Discussion regarding the SLR related requirements

- Issue raised by Rob & José & Mathis => OCS

Requirement : LRR must have minimum effective cross section of 3 million square meters at apogee for laser wavelength of 532 nanometres
Note: The minimum number has been derived assuming ~ 7500 km circular orbit. It corresponds to ~ 20% of the return rate from the ILRS standard target LAGEOS (6-8 km Orbit with 15M).

Other related requirement : Optical Link Budget
LRR shall allow a sufficiently high optical link budget to allow the network of SLR ground stations to track GENESIS with sufficient efficiency.
Note: Depending on the satellite orbit and the amount of energy desired at the station, the trade-off shall be made considering effective cross section, material quality of the array and choice of mirrors (Coated or non-coated), etc.

Discussion regarding the SLR related requirements

- **Rob & José comments:**
- **for new designs**, in particular for a mission like Genesis, every **effort should be made to ensure that the observability of the satellite** is maximised, thus increasing the number of participating stations, the volume of data collected, and the observation geometry. In short: to ensure mission success.
- Therefore, aiming for a 20% of LAGEOS OCS is not simply lacking in ambition, but frankly worrying. We are of the opinion that as a minimum the LRA should match the optical cross section of LAGEOS. We are aware of **the disparity of LAGEOS OCS values** available, **with 7–15 M m^2** found in the literature. Meanwhile, the **optical cross section of LARES-2** is reported to be **2.7 M m^2** (Ciufolini et al, 2023). However, these **two sets of values do not match the actual experience of the stations of the network**, which find a similar success tracking LAGEOS, LAGEOS-2 and LARES-2. It is not the case that LARES-2 has 60% less response than LAGEOS (2.7 vs 7 M m^2), let alone 80% less response (2.7 vs 15 M m^2). We **ignore the reasons for this apparent inconsistency**. **What matters is that the performance of the Genesis LRA—however it is estimated— should be at least that of LAGEOS**, and *most preferably* above it.

Discussion regarding the SLR related requirements

- **Rob & José comments :**
- It must be noted that in this respect **we cannot count on future upgrades in the capabilities of the ILRS ground segment**. First of all, the time to launch is not so distant as to expect major developments in the network. Secondly, if anything, *less* capable systems may be deployed, in terms of sensitivity. The reason is the drive to achieve less costly station designs that would enable a greater densification of the network. If successful, these designs will most likely consist of smaller telescopes and high repetition, low power lasers, which will not offer any greater sensitivity than the current generation of systems.

Discussion regarding the SLR related requirements

Comments from Simone :

No reason to doubt about LARES-2 OCS ~2.7 Mm2

LARES-2 have a quite good range correction (2mm) with similar success tracking LAGEOS, LAGEOS-2 and LARES-2.

And going for much higher than 3 M m2 would jeopardize the target error because of the increased size ?

Discussion regarding the SLR related requirements

- Issue raised by Rob & José & Mathis => OCS

Presentation of Mathis, Monday 21st

Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

Genesis optical cross-section and simulation studies

Mathis Bloßfeld[1], José Rodríguez Pérez[2], Matthew Willkinson[3], Robert Sherwood[3], Tomasz Kur[4], Krzysztof Sośnica[4], Joanna Najder[4]

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[4] Wrocław University of Environmental and Life Sciences, Poland

Discussion regarding the SLR related requirements

- Issue raised by Rob & José & Mathis => OCS

Presentation of Mathis, Monday 21st

Conclusions

Real data analysis

- If the OCS requirement for Genesis is not changed (at least to LA-1 OCS; RRA design on Genesis already fixed?)
  - many SLR stations won't be able to sufficiently track Genesis at low elevations → degradation of height and range bias determination?
  - for nearly half of the SLR network it seems to be very difficult to obtain daytime NPs of Genesis

Simulations

- 6000 km altitude and inclinations between 70° and 110° result in smallest mean formal error for z geocenter
- Eccentric orbit at low altitude is most beneficial for gravity field recovery

Take-home message

- **Most of the state-of-the-art studies simulate 100% or 'realistic' tracking scenarios but do not consider planned OCS for Genesis**
- **Genesis OCS must be changed, otherwise simulations lead to non-optimal conclusions!**

Discussion regarding the SLR related requirements

- Requirement : FoV from Ground requires a field of view of 90-15 degrees above the horizon.

- Comments from Rob & José : If the retroreflector design allows it, and no other constraints are in place, **it would be beneficial to increase this to 10 degrees, or preferably to 5 degrees above the horizon.** Observations made at low satellite elevations **allow for a better separation between the estimated range biases and station positions**, and may also have **applications for tropospheric model testing**. The SLR products derived from observations to Genesis would be stronger with the better observation geometry afforded by low elevation tracking.
-

Discussion regarding the SLR related requirements

- Regarding OCS + FoV :

Question:

1. **Regarding the pb of tracking at low elevation : Is it a pb to reach the mm accuracy objective of GENESIS ? ILRS agreement to say Yes?**
2. **Regarding the capability to obtain daytime NPs: If half of the SLR network can't obtain daytime NPs on Genesis, does it compromise the objectives of GENESIS ?**
3. **What minimal OCS should we have to reach the GENESIS objective with the core station of the ILRS network ?**
4. **What FoV should we have to ensure that the core stations of the ILRS network can be able to track at low elevation ?**

Discussion regarding the SLR related requirements

- Issue raised by ESA :

Requirement: The LRR mounting error shall be eliminated by alignment techniques once mounted on the satellite.

“We still need to confirm if this is applicable and, if yes, to which level the mounting error shall be eliminated.

Industry's current understanding is that it is sufficient to know the error, but they see no need for correction.”

How to measure/quantify the LRR mounting error ?

What level should be asked ?

Discussion regarding the SLR related requirements

- Other issue raised by Simone & Toshi : CTE effects

=> Type of material & shape ?

Discussion regarding the SLR related requirements

- Requirement:Position Vector Knowledge requires a 0.5 mm (1 sigma) accuracy in the knowledge of the LRA phase centre in the body frame of the satellite.

- Rob & José comments : We question whether this is a sufficiently stringent requirement. If the target accuracy for the products is about 1 mm, a 2- and 3-sigma error here would already compromise said target. Hence, 1 mm at 3-sigma appears to be the bare minimum for this requirement. Ideally more, as the uncertainty in the knowledge of the reference positions of the different payloads (LRA, VLBI, GNSS, DORIS) will be compounded.

- This applies also to the requirement on the Range Correction (The range correction of the array shall be known at any given moment with an accuracy below 1 mm.This shall be valid for any given solar illumination condition, i.e. the thermal influence on the design parameters shall be minimal.)

Discussion regarding the SLR related requirements

- Comments from Rob & José :
- In connection with this, we note that although the primary operational wavelength of the most part of the ILRS network is 532 nm, several stations operate at 1064 nm, and more should be expected in the future. A secondary requirement for the LRA design should include reasonable performance at this wavelength, i.e. a drastic drop in cross section in the infrared should be avoided to ensure that all stations are able to participate.

- +comments from Michael Haefner : compatible also with ~800 nm + 400 nm for Ti:Saph laser

Discussion regarding the SLR related requirements

- Comments from Michael Steindorfer : possibility to mount a secondary retroreflector for space debris tracking after the active lifetime of the satellite.

Thanks for your contribution