Genesis: Status and Performance Analysis of the GNSS Instrument

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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/69/466).

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

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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

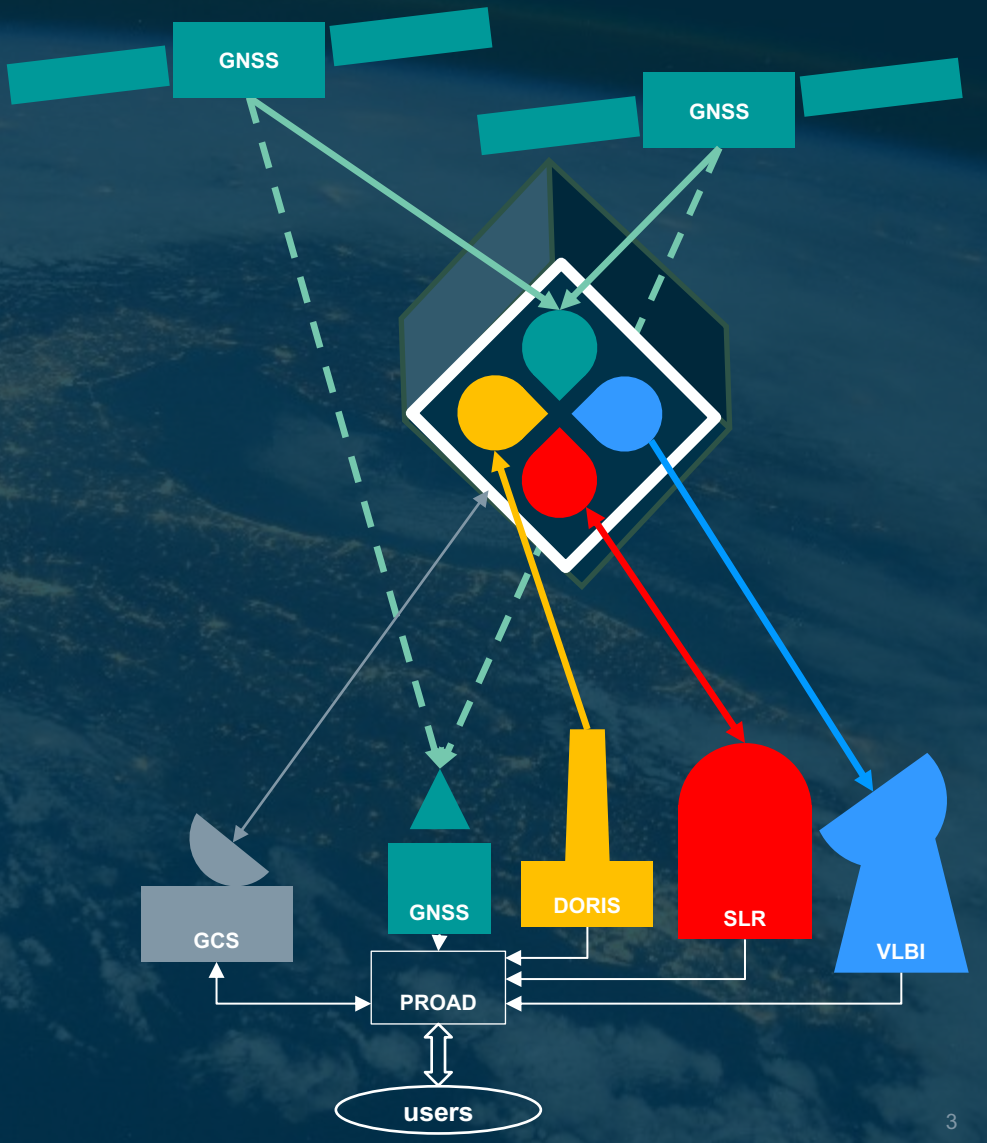
The General Assembly,

Targets:

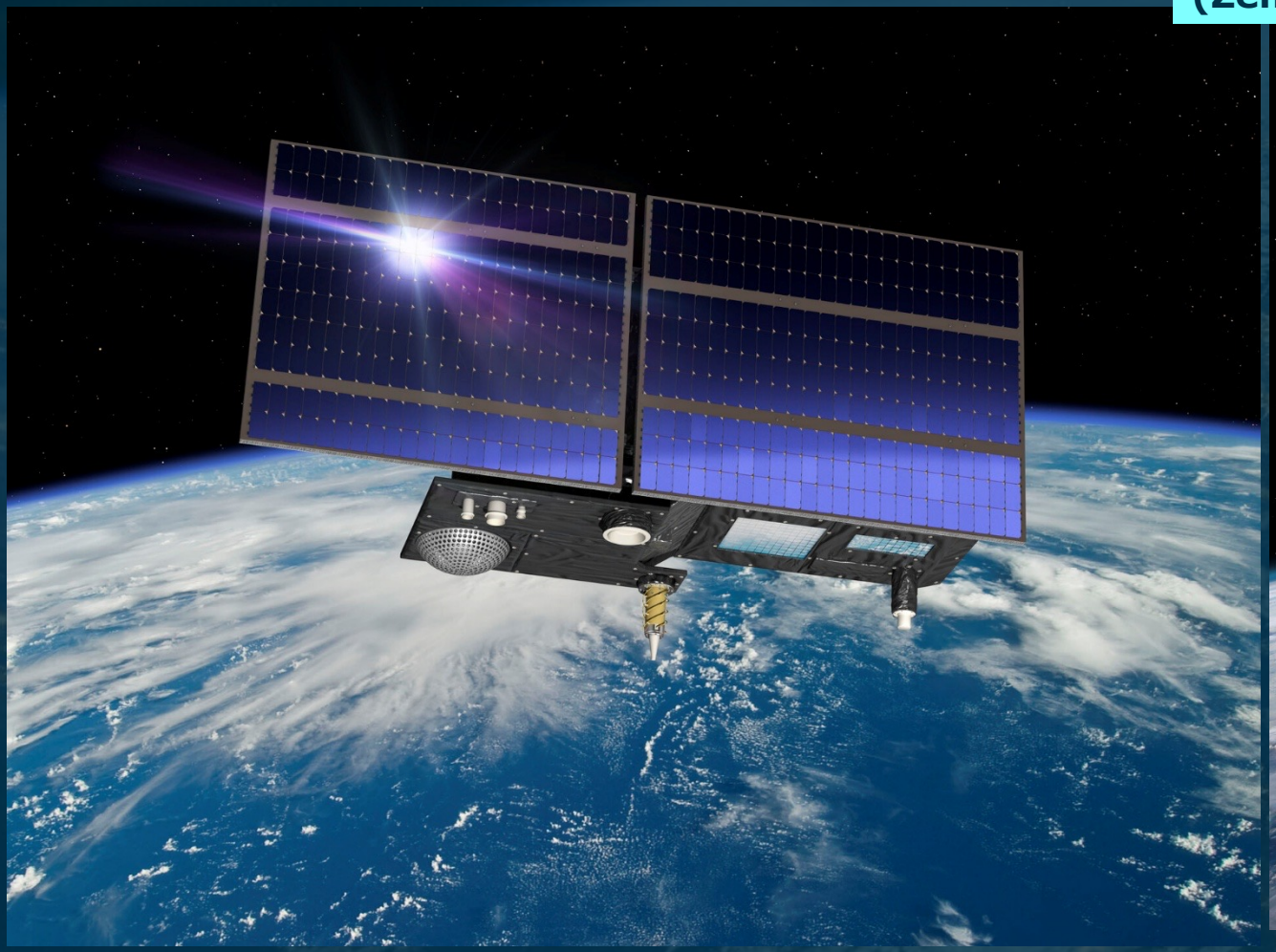
Accuracy: 1 mm
Stability: 0.1 mm per year

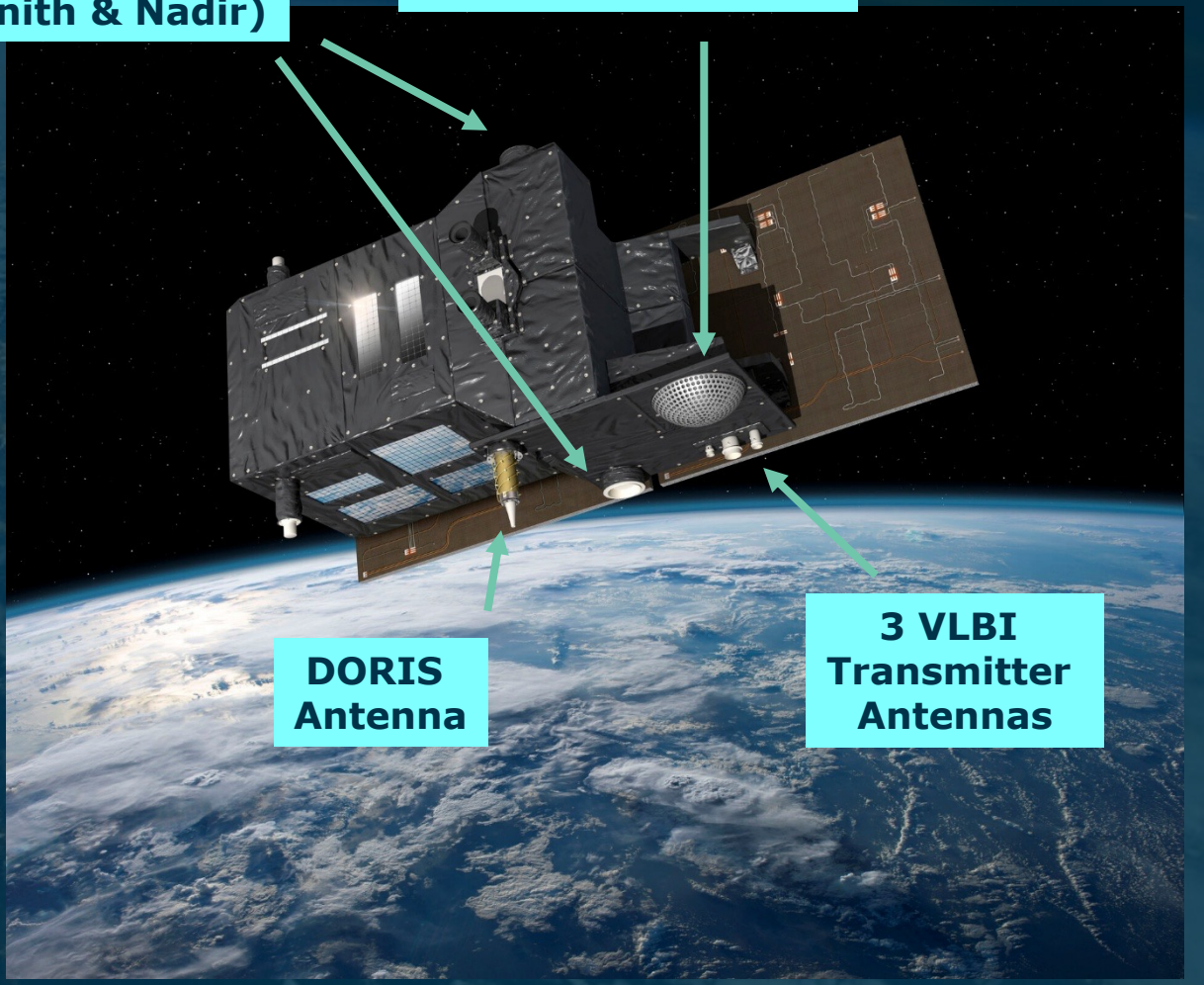
Genesis System PDR Overview

- Satellite
  - Mass: 406 kg
  - Power: 480 W (nominal)
  - Envelope: 1.85m X 1.33m X 3.39m
  - Attitude:
    - 3-axis stabilized, Nadir-pointing, yaw steering law
    - Pointing accuracy: < 1 degree
- Orbit:
  - 6000km altitude (low MEO)
  - 95.5º inclination
- Payload:
  - 4 co-located geodetic instruments
    - GNSS, DORIS, SLR, VLBI
  - Ultra-Stable Oscillator for synchronisation



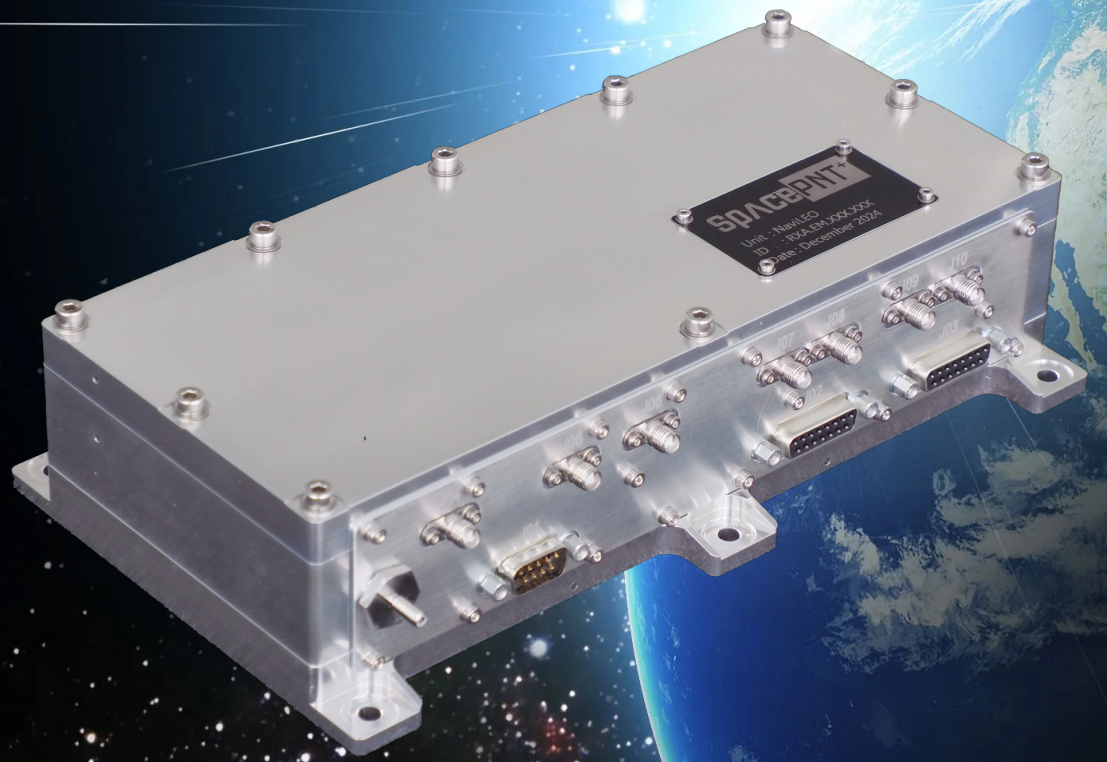
Genesis satellite configuration





Genesis status as per System PDR

SpacePNT+



Enabling Millimetre-Level Geodesy from Space: NaviMEO GNSS Receiver for the ESA Genesis Mission

Michele Scotti, Michael Karpf, Cyril Botteron, Mathieu Rico, Kévin Fischer, Baptiste Marechal,
Vasili Massaras, Daniel Guillod, Damien Desdoits

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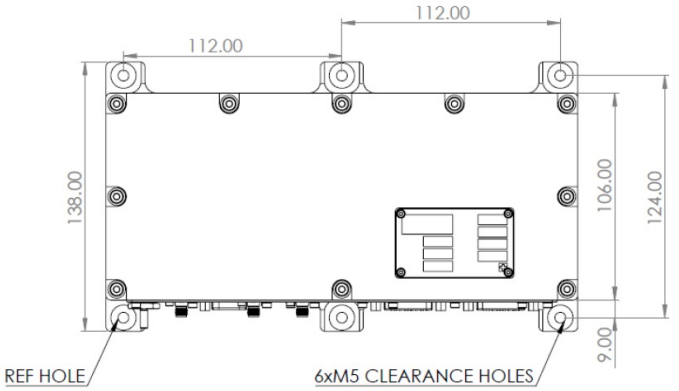
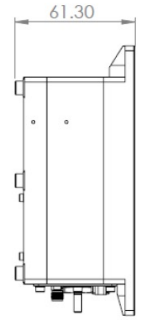
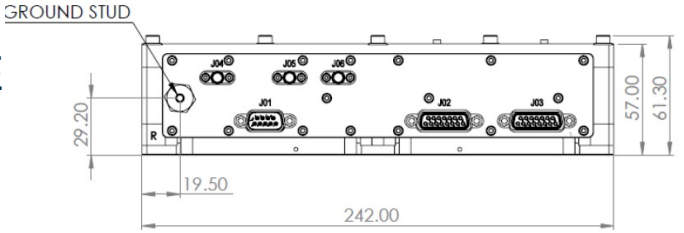
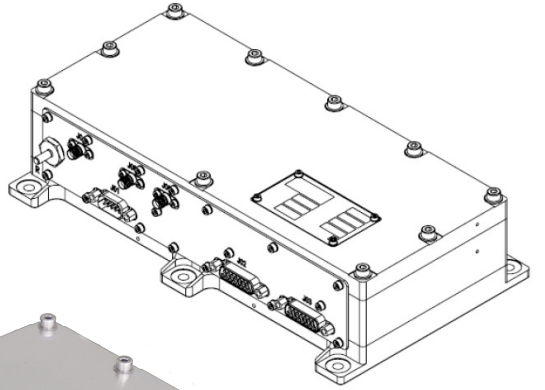
NaviMEO – Genesis specific features

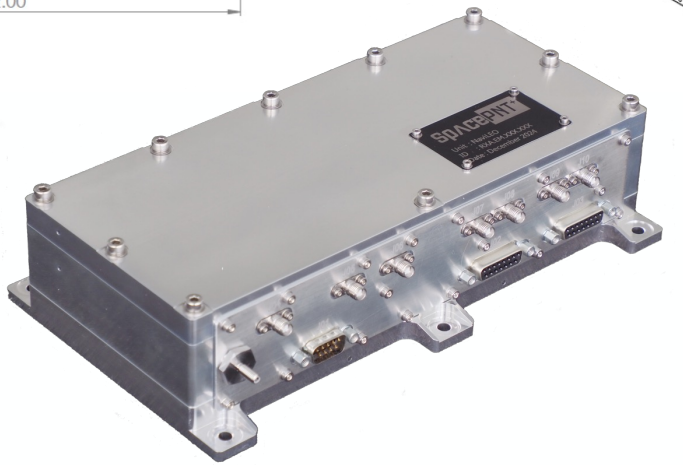
- Processed signals:
  - Galileo E1B, E1C, E5a-Q
  - GPS L1C/A, L2C(L)*, L5-Q
- Dual antenna input
- 64 channels (up to 21 satellites, 3 signals x sat)
- 10 MHz reference: input from USO
- RHA approach based on extensive TID and SEE test campaigns
- Acquisition and tracking engines
  - full digital/SW implementation
  - in-flight re-programmable
- KF dynamics model tailored for Genesis orbit
  - Used by platform











**GPS L2C(L) under implementation*

Genesis GNSS receiver testing

Ground Testing – Live Sky

- Real GNSS signals
- NaviMEO Hardware connected to ESA Geodetic Antenna
- GNSS products based on ESA ad-hoc products
- Tracking of the following signals:
  - Galileo E1B, E1C, E5a-Q
  - GPS L1C/A, L5-Q
- 24 hours arc processing
- Genesis receiver initialized at 10:00 - 14 hrs used

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On-board Testing – Space Simulation

- GNSS simulated signals via Spirent Simulator
- NaviMEO Hardware in the loop
- High-fidelity Genesis reference orbit
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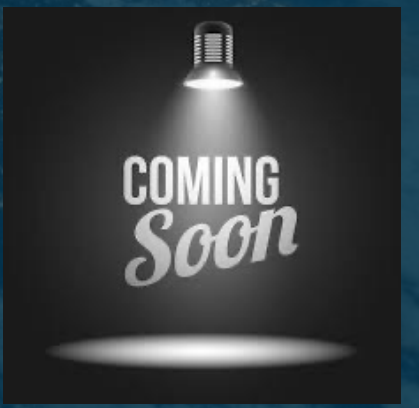
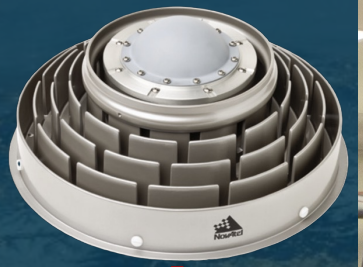
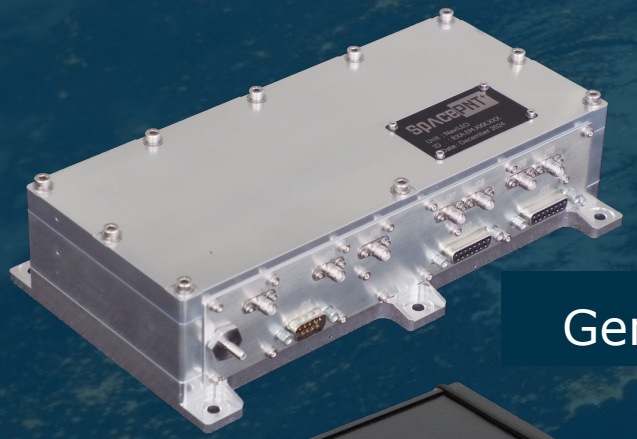


GNSS receiver Ground Testing – Live Sky

Configuration at ESA/ESTEC, the Netherlands

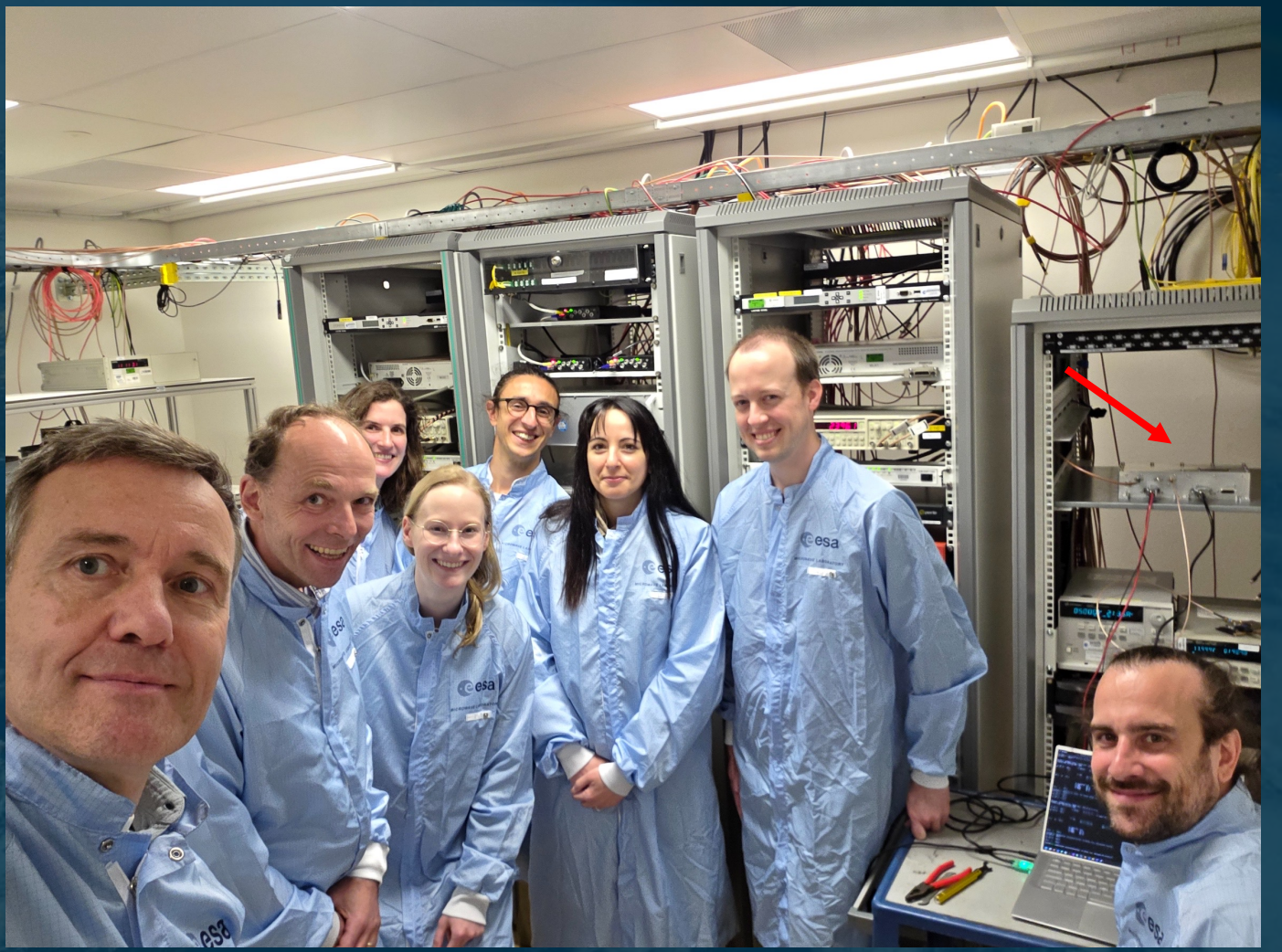
Novatel GNSS-750





Genesis Rx

Septentrio Rx



The ESA and SpacePNT teams

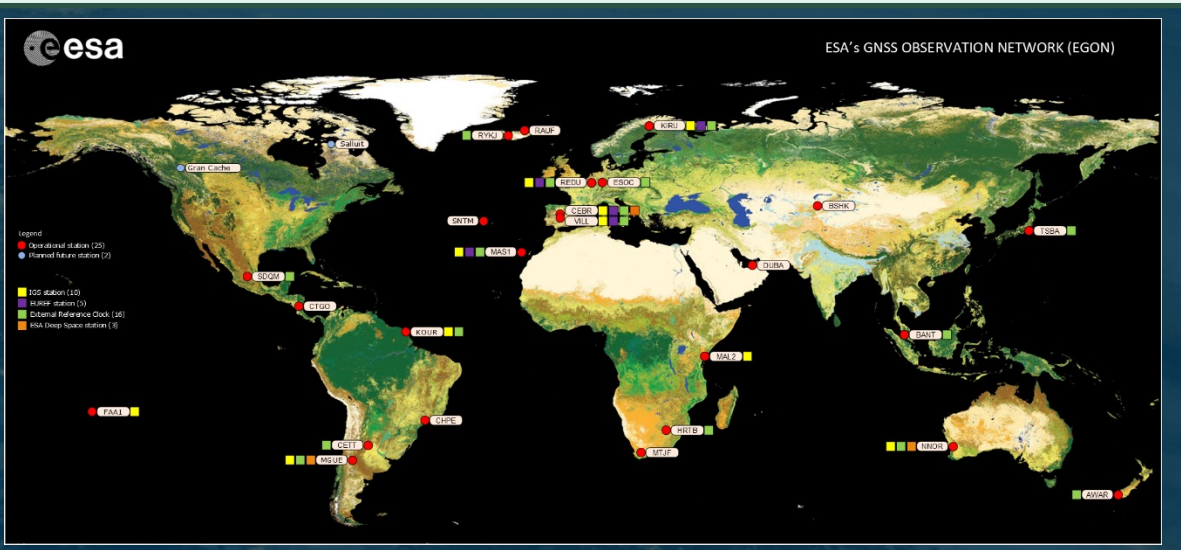
GNSS receiver Ground Testing – Live Sky

Data processing in IGS-like network approach with ~150 stations, Galileo (E1B,E1C,E5a-Q) & GPS (L1C/A,L5-Q) (similar testing conducted also with PPP-AR)

Overview of Preprocessing

Receiver	Mel. Wub.	PC-LC
Genesis	**0.747**	**2.893**
Septentrio	0.260	0.997

linear combinations RMS, given in meters



- Galileo E1B is tracked by the Genesis receiver but very rarely by IGS network
- Both linear combinations show 3 times higher levels for the Genesis receiver when compared to Septentrio
- Melbourne Wubbena RMS of 0.747m is considered quite high, particularly for integer ambiguity resolution of ambiguities with a wavelength of 0.86m

GNSS receiver Ground Testing – Live Sky

Overview of ambiguity-float data processing – global solution

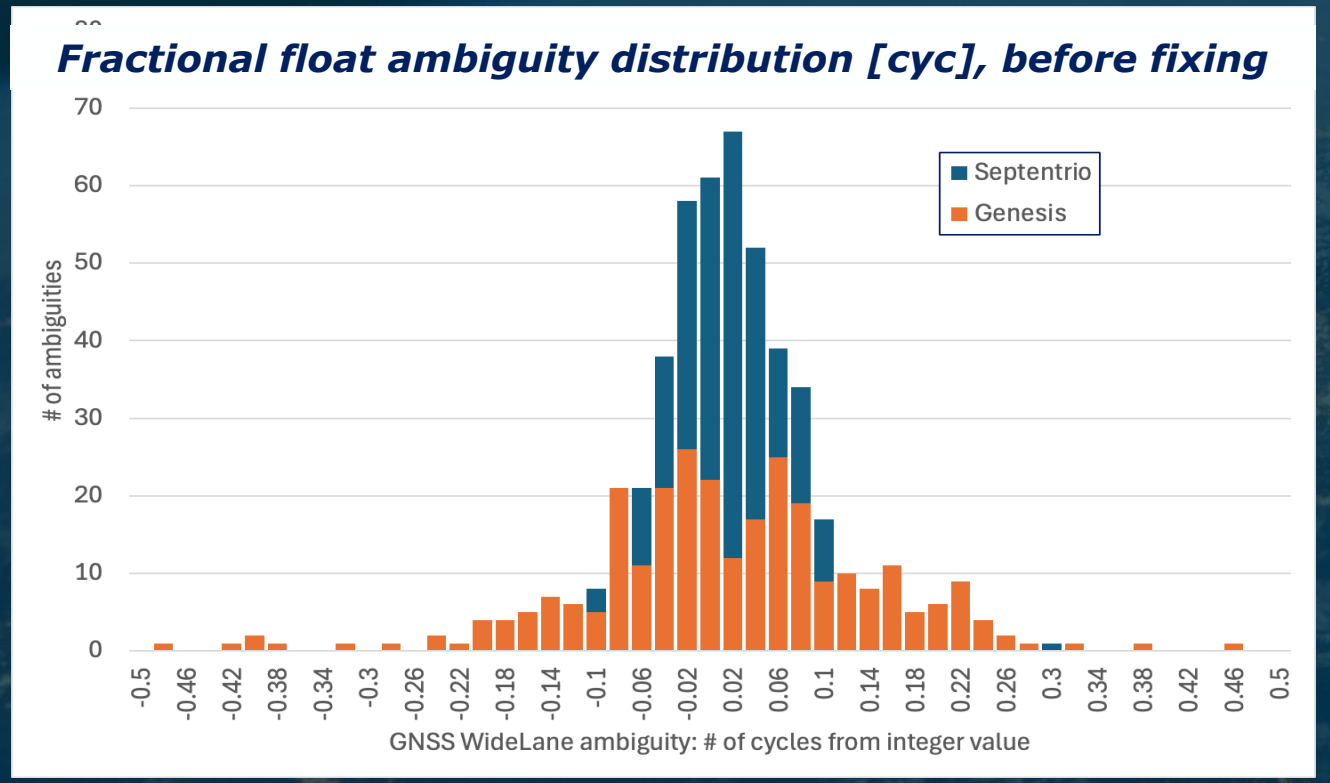
Receiver	Obs.	Obs. accepted	Obs. rejected	Phase Residuals RMS (mm)	Code Residuals RMS (m)
Genesis	**GPS**	890	47	**9.074**	1.495
	Gal	1352	74	**9.356**	1.465
Septentrio	**GPS**	1520	1	9.972	0.693
	Gal	2346	0	10.751	0.564

For the Genesis receveiver:

- The float solution confirms the **higher noise of the pseudo range** observations of Genesis Receiver
- The **carrier phase residuals RMS looks fine**.
- The **number of rejections is a bit high** but comes mainly, if not only, from the pseudo range observations

GNSS receiver Ground Testing – Live Sky

Overview of ambiguity fixing process



Receiver	# amb.	# fixed amb.	% fixed amb.
Genesis	43	42	**97.7 %**
Septentrio	76	76	100 %

- The **Genesis Widelane float ambiguity distribution looks quite flat**, (larger code noise)
- Despite the "flatter" histogram distribution, **almost all ambiguities are fixed in the process**

→ The important question: are the ambiguities successfully fixed?

GNSS receiver Ground Testing – Live Sky

Overview of ambiguity Fixed data processing – global solution

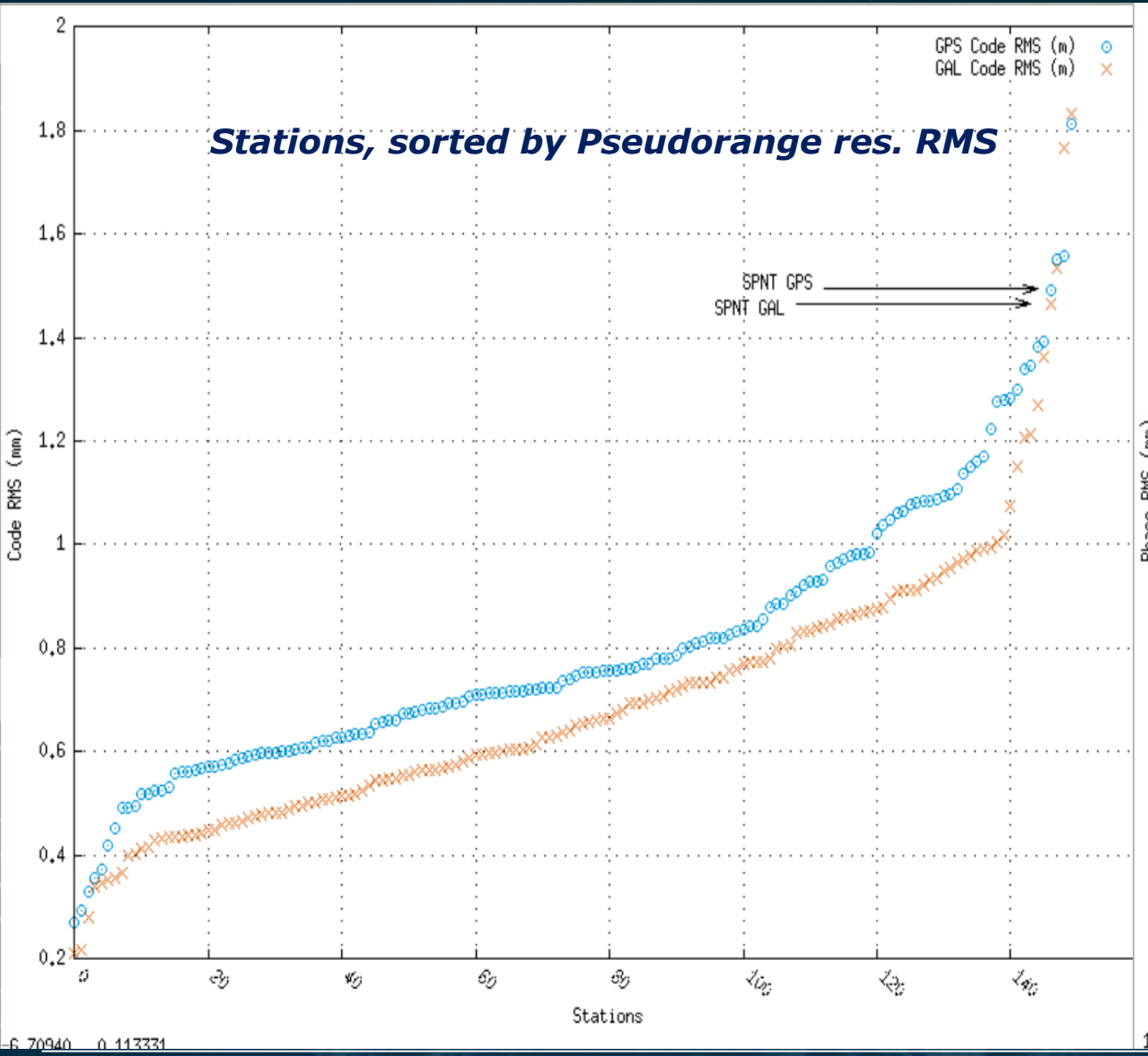
Receiver	Obs.	Obs. accepted	Obs. rejected	Phase Residuals RMS (mm)	Code Residuals RMS (m)
Genesis	**GPS**	887	3	**9.633**	1.493
	Gal	1352	0	**9.520**	1.466
Septentrio	**GPS**	1520	0	11.253	0.695
	Gal	2345	1	11.424	0.563

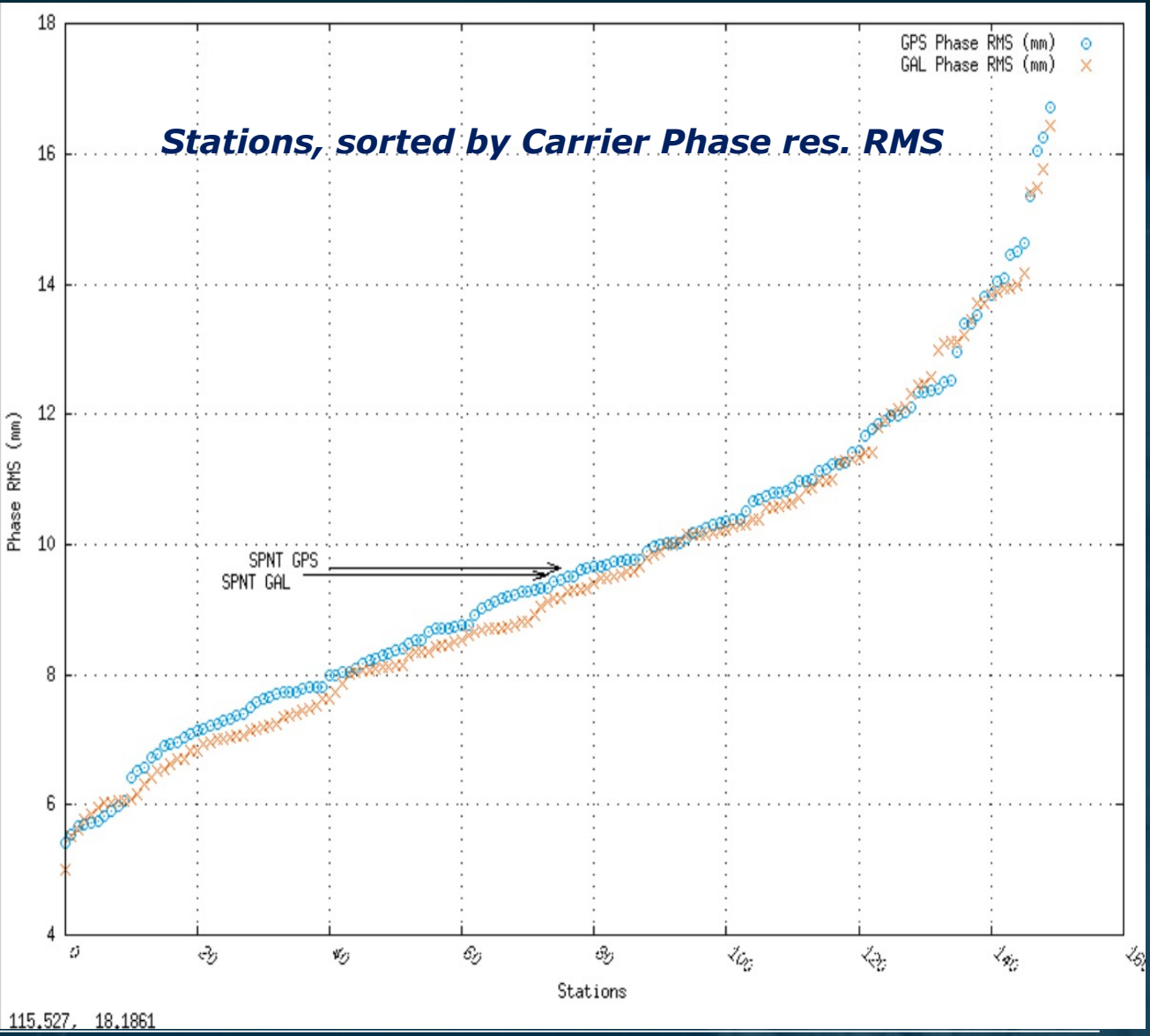
For the Genesis receiver:

- The pseudo range residuals RMS of the pseudo range observations hardly changes which is as expected
- The carrier phase residuals RMS increases slightly (expected) and even performs better for Genesis
- **The integer ambiguity resolution is confirmed to be successful** and, in this case, close to 100% which is excellent

The PPP-AR results showed consistent results

Pseudorange and Phase Residuals RMS, sorted by size among the Network (~150 stations)





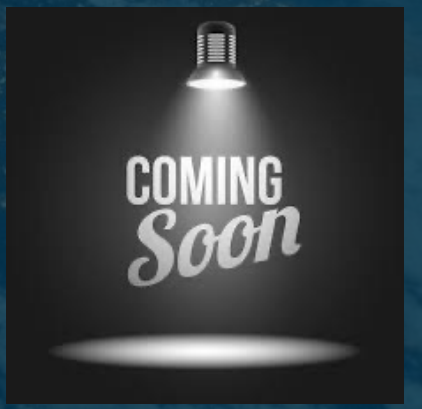
On-board Testing – Space Simulation

Space Simulations setup

- Hardware in the Loop testing is currently ongoing
- The Navigation Support Office at ESA/ESOC is responsible for the provision of the reference orbits and input products
- SpacePNT responsible for the setup of the Spirent Simulator and the Genesis Receiver

Status Overview

- Currently investigating inconsistencies in the data processing, most probably linked to misalignment of simulator and processing configuration
- Outcome of the on-board assessment will be shared with the community soon.



Conclusions

Based on the live sky testing

- Galileo E1B and E1C:
  - **E1C is recommended**, as E1B is rarely tracked by the IGS Network
  - **Lower tracking of E1C** compared to E1B needs investigations
- **Pseudo Range observations is rather noisier** compared to other receivers, including space receivers (e.g., Beyond Gravity PODRIX receivers on board the Copernicus Sentinel missions).
  - Expected lower noise of the Galileo observations compared to GPS – investigation ongoing
  - Tracking loop parameters are being fine-tuned, focusing on Genesis orbit
- **Carrier phase performance is very good** – fundamental for POD
- Despite the higher noise in the Pseudo range **integer ambiguity resolution is successful,** with >97% success rate in the global solution

Next steps

- Addressing of the key-points identified in the Live Sky test
- Finalization & Assessment of Space scenario testing
- Finalize implementation and testing of the GPS L2 observables

Once these elements are resolved, a dataset covering the live sky and the hardware in the loop testing will be distributed to the Genesis Science Exploitation Team for further investigations and assessment.

Genesis Reference Orbit and Attitude as of System Preliminary Design Review
available on the GSSC web portal

Please take a look at our Genesis Poster for more info on the mission.

Thank you, the Genesis team!