ESA Genesis WG1
ITRF & Combination of Techniques

Zuheir Altamimi

Florian Seitz

3rd Genesis Scientific Workshop, 12-13 March, 2026, Brussels, Belgium

WG1: Main activities over 2025

- Review and consolidation of mission requirements with focus on ITRF & Combination of Techniques

- Involvement and support in the mission development and satellite calibration process
  – studies and recommendation the ESA on Genesis orbital parameters in preparation of PDR
  – created new Sub-WG on Genesis System Aspects (Chair: M. Ziebart) (→ presentation)

- Development of strategies for multi-technique POD in preparation of Genesis
  – theoretical studies on combination concepts on NEQ/COL-Level
  – initiated Pilot Project on orbit combination jointly with IAG WG 1.1.1. (→ presentation)
  – forum for discussion of ongoing multi-technique combination projects, such as Genesis-D, Genesis-F, JPL activities, … (→ posters, presentation)

- Ongoing interaction with relevant international bodies, in particular IAG and IERS

3rd ESA Genesis Science Workshop: Agenda of WG1 Session

Oral presentations:

14:00 – 14:05 Introduction by the co-chairs

14:05 – 14:20 Ziebart M.: System Aspects Sub-Working Group (WG1-S)

14:20 – 14:35 Böhm J. et al.: Joint IAG/WG1 pilot project and tasks for the scientific community

14:35 – 14:50 Ait-Lakbir H. et al.: Current status of GENESIS-F activities: simulations, real data processing and perspectives

14:50 – 15:05 Merkowitz S.: Geodetic Reference Instrument Transponder for Small Satellites (GRITSS)

15:05 – 15:30 Discussion

Posters:

Heinkelmann R. et al.: GENESIS-D: a geodetic project from German organizations to support ESA‘s Genesis mission

Ries, P. et al.: Combining Geodetic Techniques at the Observation Level: Challenges and New Perspective for the Terrestrial Reference Frame

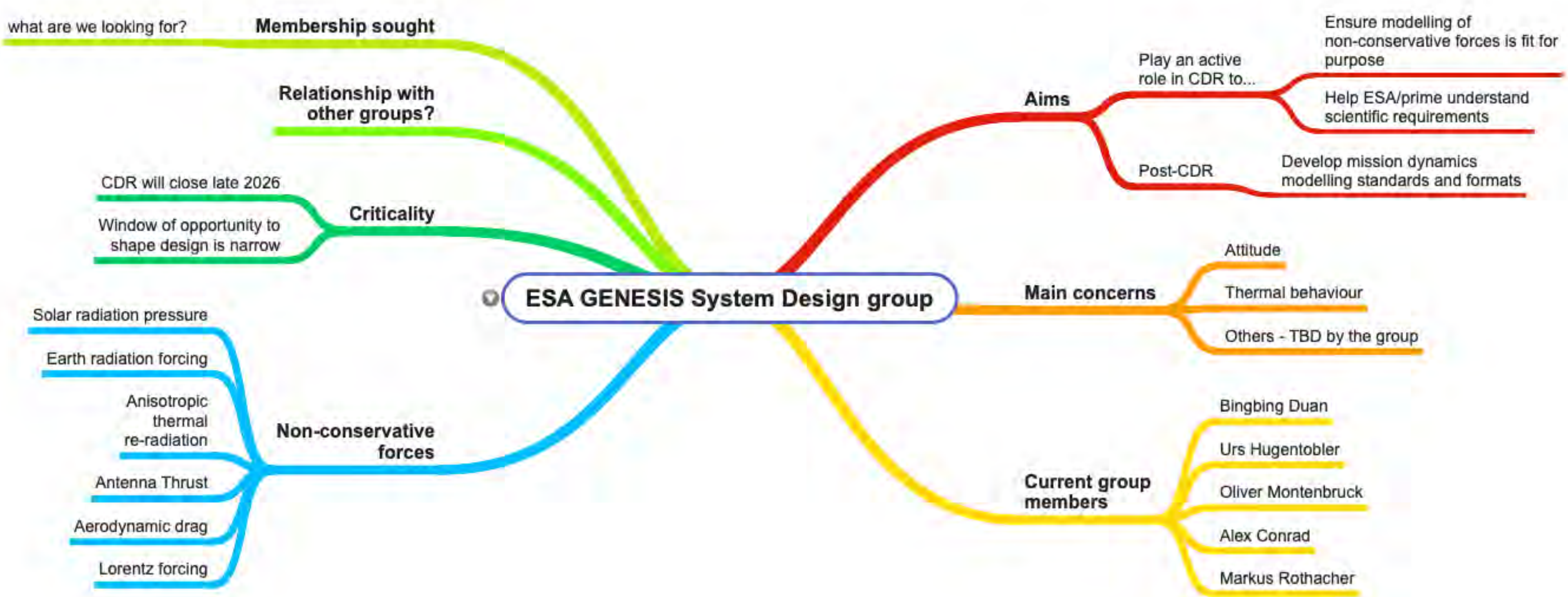
ESA GENESIS - Sub-Working Group on System Aspects (WG1-S)

Marek Ziebart
Professor of Space Geodesy
University College London

ESA GENESIS Science Workshop

13th March 2026

Overview


ESA GENESIS System Design group
Membership sought
what are we looking for?
Relationship with other groups?
Criticality
CDR will close late 2026
Window of opportunity to shape design is narrow
Non-conservative forces
Solar radiation pressure
Earth radiation forcing
Anisotropic thermal re-radiation
Antenna Thrust
Aerodynamic drag
Lorentz forcing
Aims
Play an active role in CDR to...
Ensure modelling of non-conservative forces is fit for purpose
Help ESA/prime understand scientific requirements
Post-CDR
Develop mission dynamics modelling standards and formats
Main concerns
Attitude
Thermal behaviour
Others - TBD by the group
Current group members
Bingbing Duan
Urs Hugentobler
Oliver Montenbruck
Alex Conrad
Markus Rothacher

ESA GENESIS:

- First mission integrating the four fundamental space-geodetic techniques
- Supports future realisations of the International Terrestrial Reference Frame (ITRF)
- Orbit determination accuracy requirement at the <u>millimetre</u> level
- *Spacecraft behaviour, therefore, becomes part of the geodetic measurement system*
- **But… ”not business as usual”**

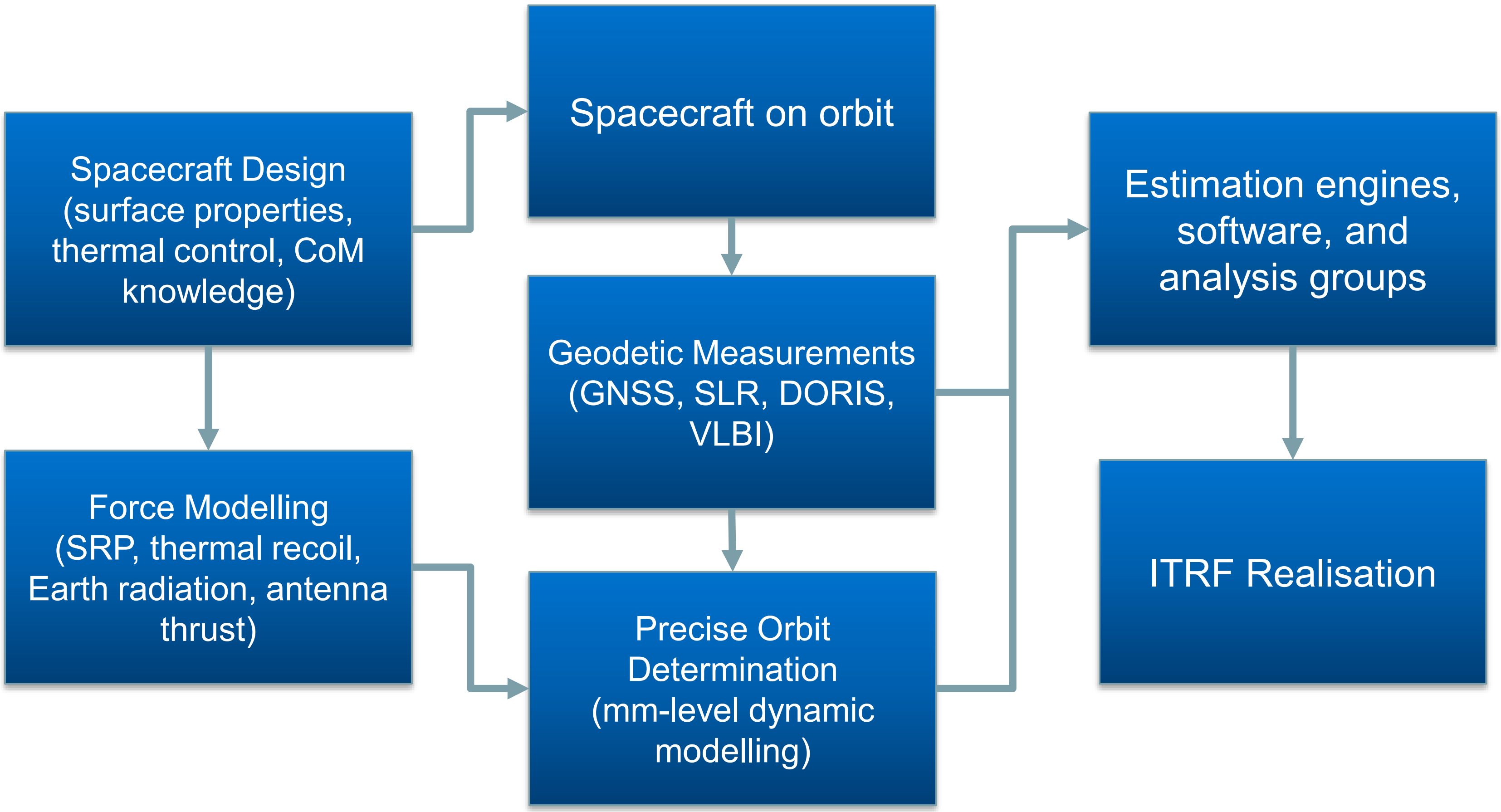
Mission Status

- ESA GENESIS mission fully funded
- Preliminary Design Review (PDR) completed
- Mission now entering Phase C
- System design consolidation underway
- After CDR, the spacecraft design will effectively be frozen

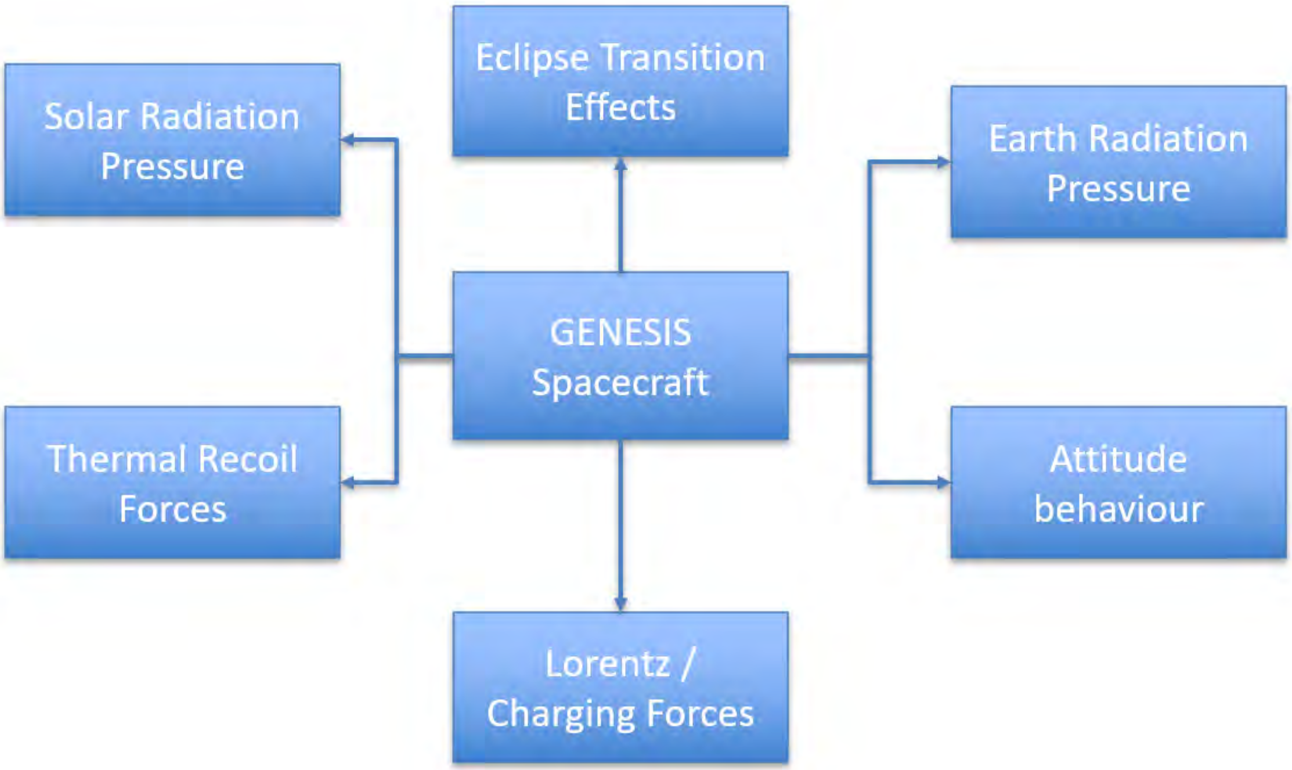
Why System Aspects Matter

- Millimetre-level orbit accuracy requires modelling of non-conservative forces
- Spacecraft centre-of-mass knowledge
- Spacecraft attitude knowledge
- Thermal radiation forces and eclipse transitions
- Possible surface charging and Lorentz forces

From Spacecraft Design to Reference Frame Accuracy



Non-Conservative Forces Acting on the GENESIS Spacecraft (and related factors)



Why is GENESIS dynamically challenging?

- Anisotropic thermal re-radiation forces
- Penumbra/umbra eclipse transitions
- Attitude knowledge and possible anomalies
- Surface property uncertainties
- Possible spacecraft charging and Lorentz interactions

Opportunity for the Scientific Community

- GENESIS mission structure allows scientific input before CDR
- Understanding of payload distribution and energy dissipation
- Thermal sensor placement
- External surface properties
- MLI configuration
- Centre-of-mass determination strategy
- Attitude knowledge requirements
- Telemetry rates and information

Role of the WG1-S Sub-Working Group

- Focal point for system aspects within WG1
- Interface between science team and spacecraft system design
- Support spacecraft system design consolidation
- Provide input to scientific orbit determination modelling

Key Activities

- Collate spacecraft information required for orbit modelling
- Develop spacecraft force models
- Perform modelling and sensitivity studies
- Identify design sensitivities
- Provide recommendations to ESA

Expertise We Are Looking For

- Space geodesy and astrodynamics
- Spacecraft design and thermal modelling
- Attitude determination and control
- Orbit determination and dynamic modelling
- Numerical modelling, coding and visualisation
- ESATAN modelling experience

Timeline and Urgency

- Phase C now underway
- System design consolidation during 2026
- Critical Design Review approaching
- Recommendations must be developed within the next few months

Group members so far:

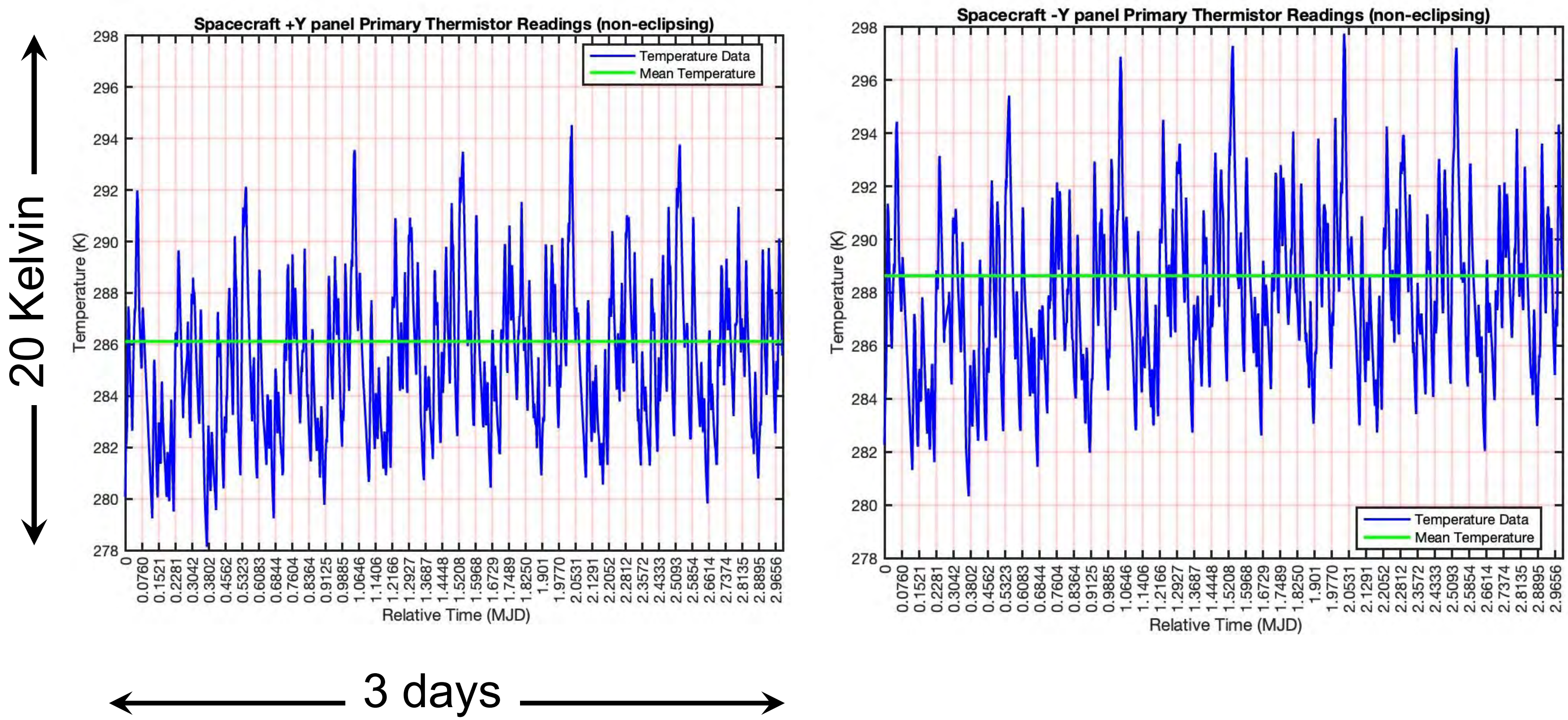
- Urs Hugentobler
- Oliver Montenbruck
- Markus Rothacher
- Bingbing Duan (TUM)
- Alex Conrad (JPL)
- Marek Ziebart

Closing Message

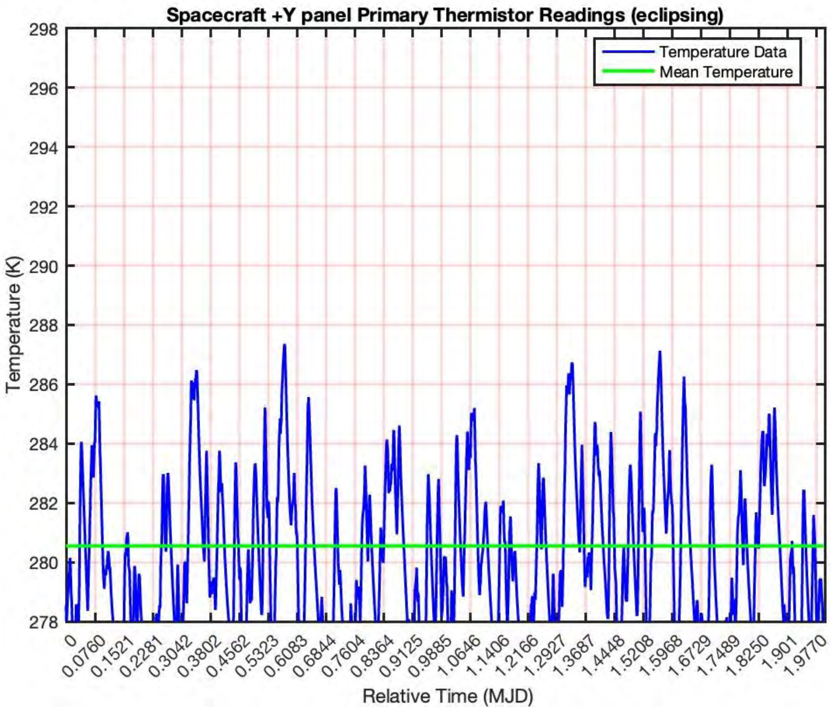
- GENESIS aims to deliver millimetre-level geodetic measurements
- The spacecraft must be treated as part of the measurement system
- WG1-S enables the scientific community to contribute to this critical design phase
- Join us? Email: m.ziebart@ucl.ac.uk (and please copy in Zuheir and Florian)

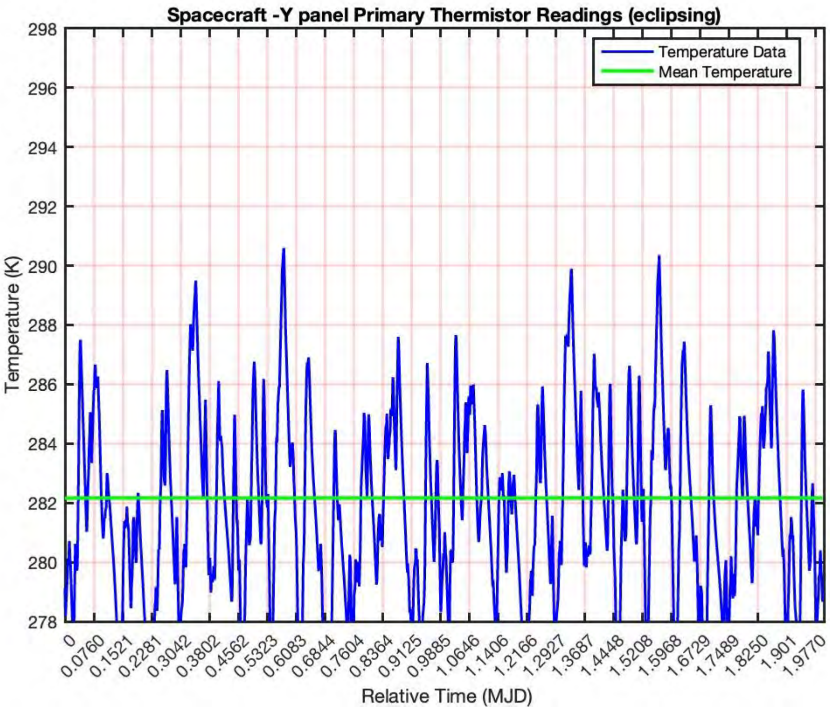
Back up slides: examples of thermal telemetry and quaternions analysis

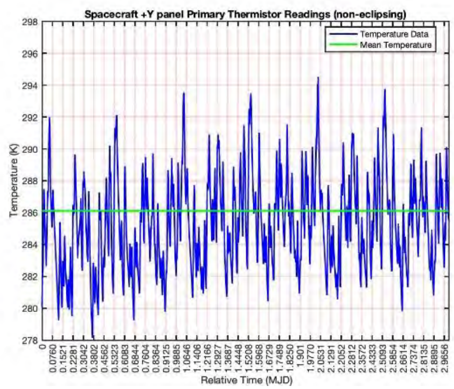
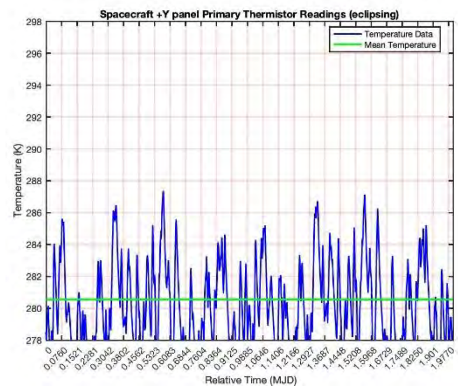
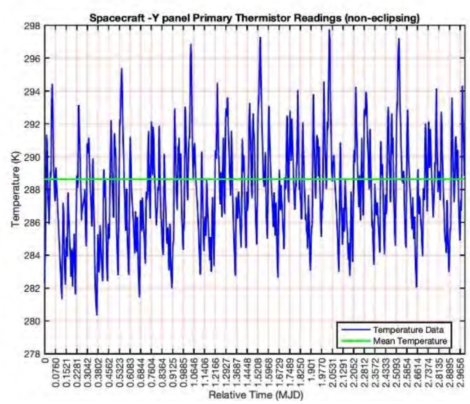
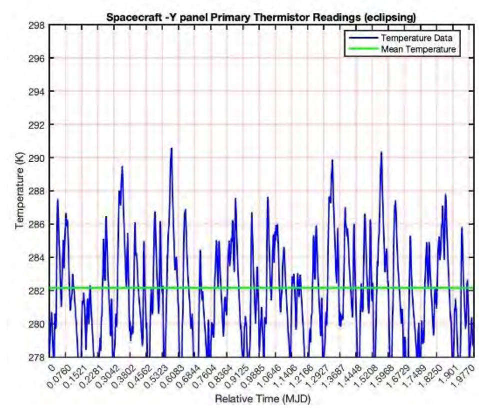
Polar LEO s/c +/- Y thermistor telemetry (non-eclipsing)



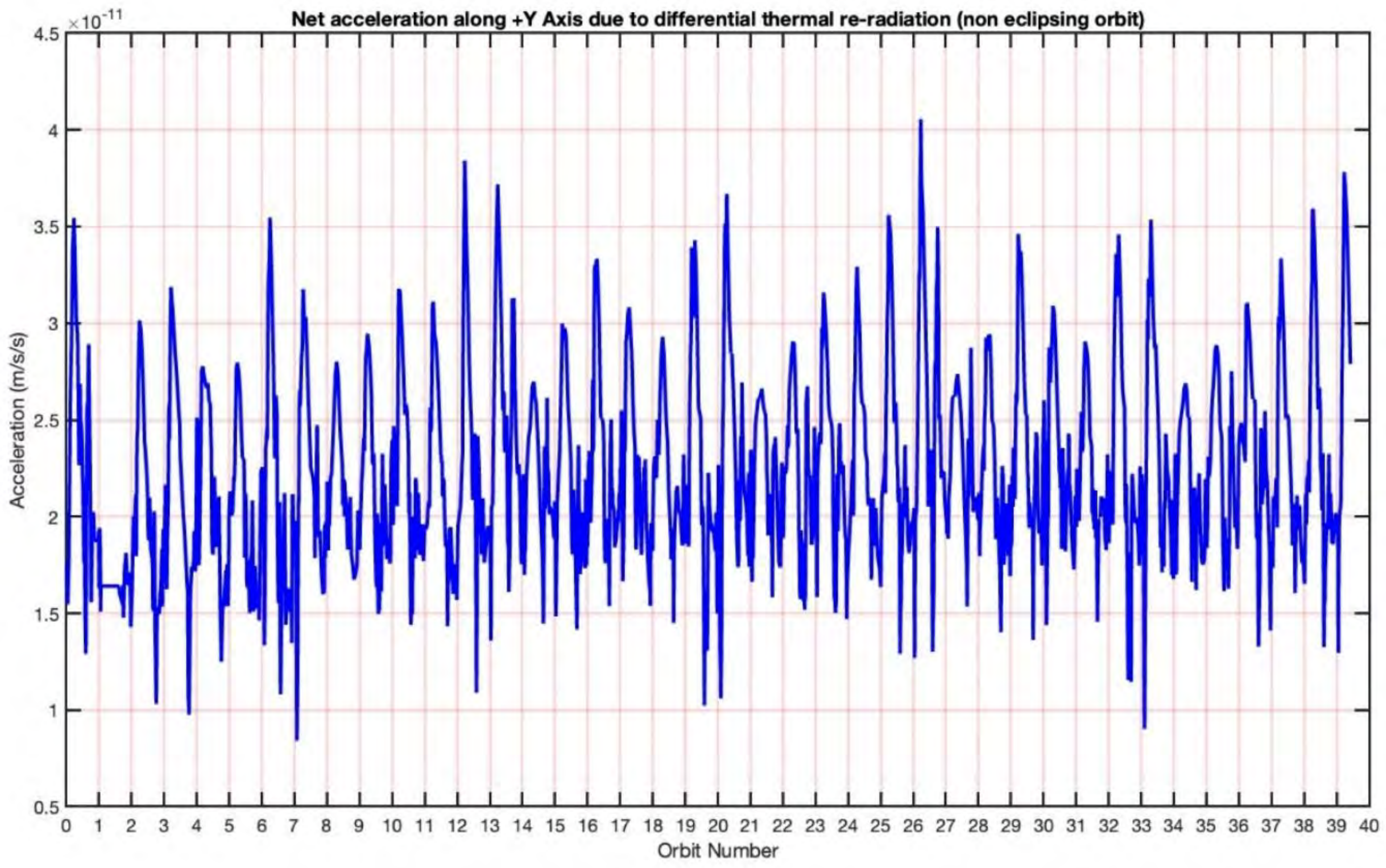
Polar LEO s/c +/- Y thermistor telemetry (eclipsing)





	Non-eclipsing	Eclipsing	
			+Y
			-Y

Thermal re-radiation net acceleration +Y (non-eclipsing)



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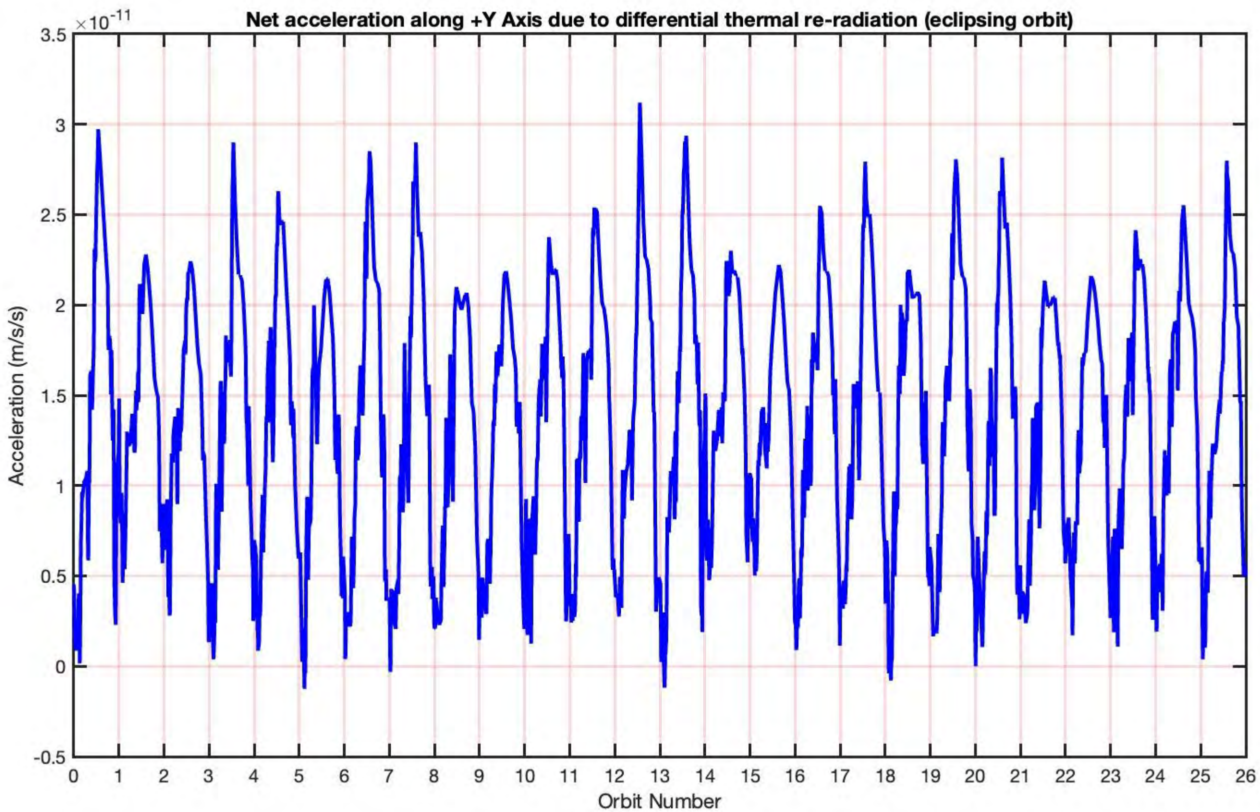
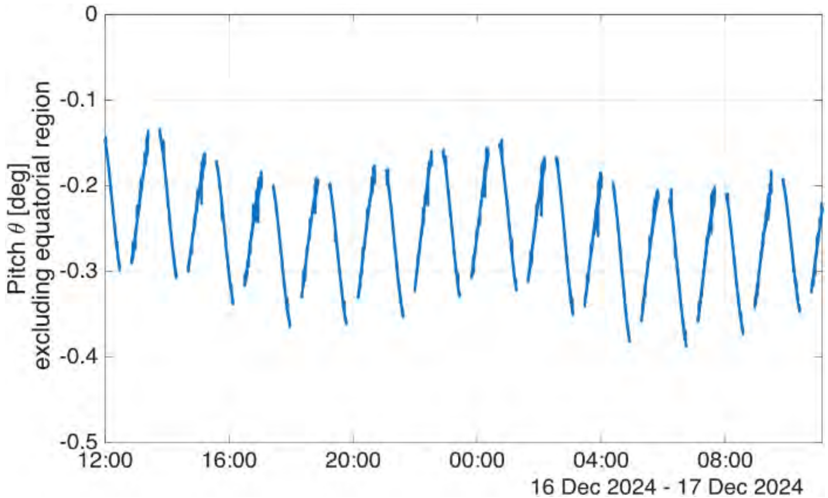
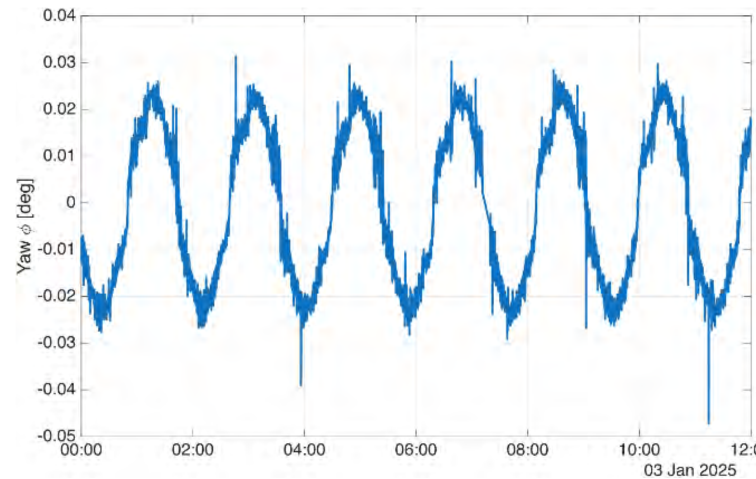
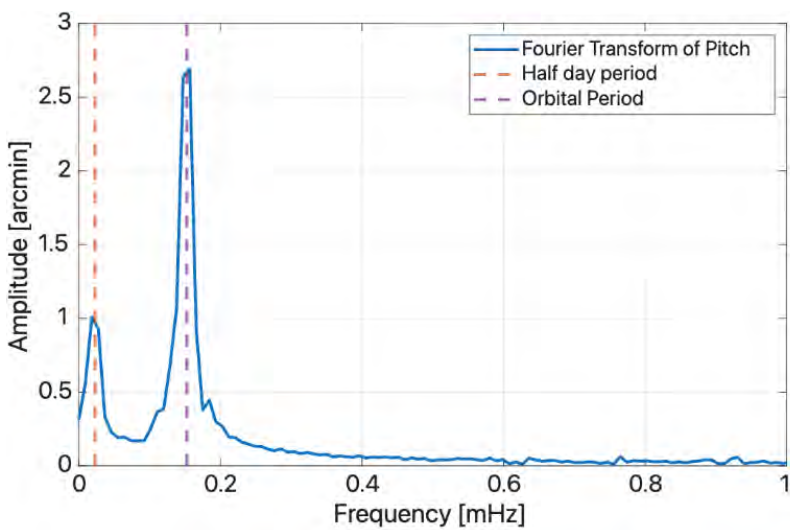
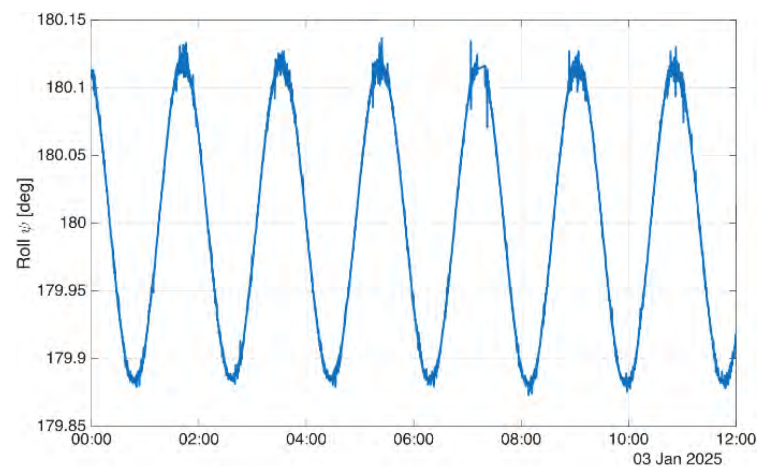


Roll, pitch and yaw behaviours derived from telemetered quaternions

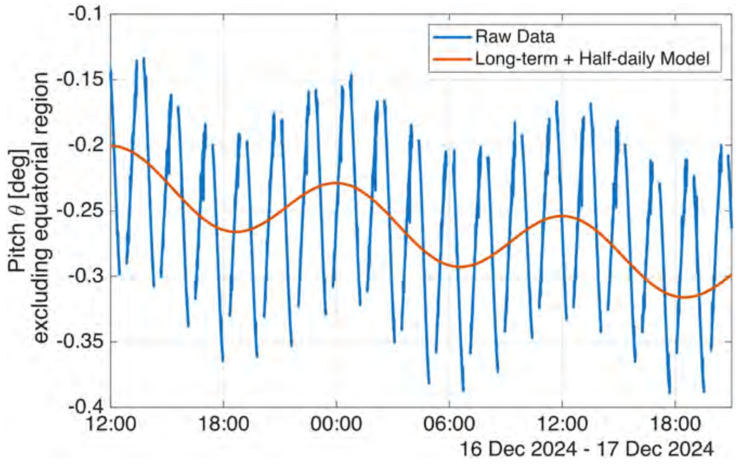


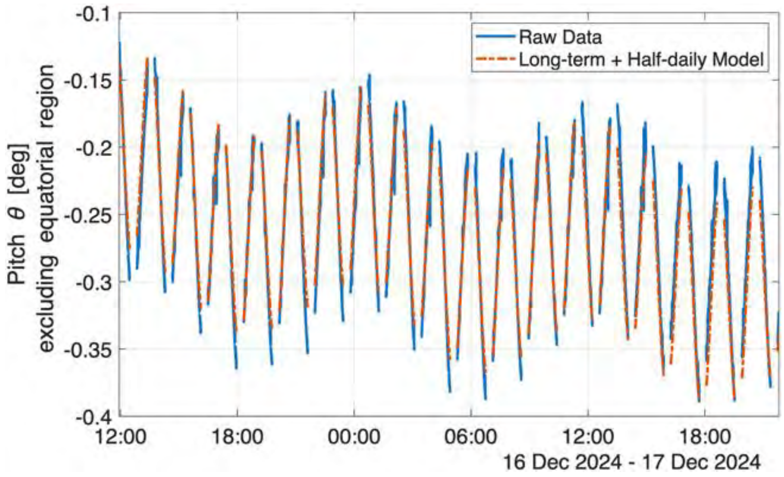






Attitude model analysis using quaternion data





ESA Genesis Science Workshop 2026

Joint IAG/WG1 pilot projects and tasks for the scientific community

Johannes Böhm, Helene Wolf, Zuheir Altamimi, Florian Seitz

March 13, 2026

IAG Working Group 1.1.1 on Genesis joint with GGOS and IERS

- Members from the geodetic community
  - overlapping with ESA Working Groups

- Open forum for discussions and investigations
- Stimulating new research enabling science
- Fostering the cooperation between the groups

IAG Working Group 1.1.1 on Genesis joint with GGOS and IERS

- Goals and objectives (1/2)
  - Identify possible scenarios for the utilization of Genesis for the improvement of the terrestrial reference frame.
  - Develop strategies for combination of solutions including Genesis.
  - Set up and implement a work plan with timeline to make the most promising scenarios possible once data is available.
  - Get an overview of possible contributions by the various groups to the analysis of Genesis observations.

IAG Working Group 1.1.1 on Genesis joint with GGOS and IERS

- Goals and objectives (2/2)
  - Help to set up co-operation between the groups to facilitate the best realization of the reference frame with Genesis.
  - Review and investigate existing co-locations in space between GNSS, DORIS, and SLR, as well as VLBI observations to satellites.
  - Formulate and raise questions to address open issues with the Genesis mission, both on a technique-specific level and the combination level.
  - Identify and investigate new scientific opportunities, which will become possible with Genesis.

We must be ready with the launch of Genesis!

- Software packages must be developed further (e.g., VLBI to satellites)
- We must test the analysis and combination scenarios for orbit estimation and the terrestrial reference frame determination
- Tests should rely on real observational data as much as possible
- Simulated data will be used in cases when real data is not available
- Three pilot projects have been initiated at the Frankfurt meeting in 2025

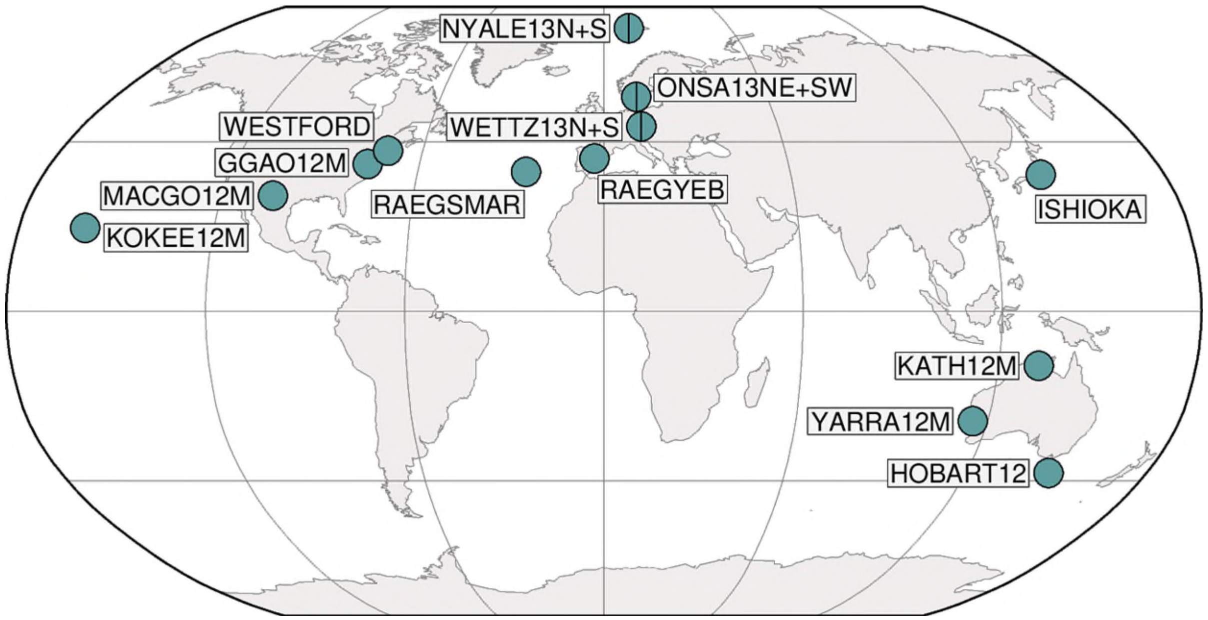
Pilot Project 1 – Sentinel 6A

(c) ESA

- Sentinel 6A
  - Altitude 1330 km
  - Inclination 66 degrees
- GNSS, SLR, and DORIS on board (real data available)
- Selected time span: August 4-10, 2025 (one week)
- High accuracy orbit provided by TU München (sp3 files)
- VLBI schedules are created for existing 16 station VGOS network
- Realistic and well defined VLBI observations are generated
  - Clear description of applied models imperative
- GNSS, SLR, and DORIS observations are available but could be simulated as well

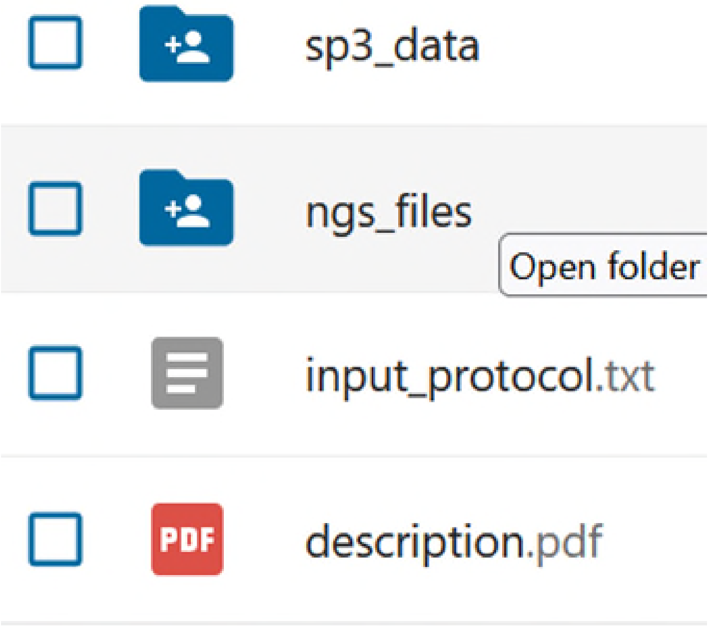
Pilot Project 1 – Sentinel 6A

- Comments on VLBI part
  - Altitude 1330 km rather low for VLBI $\Rightarrow$ only 5% of scans to Sentinel 6A
  - We need more analysis centers to verify models for satellite observations
    - There are real observations to GNSS satellites (accurate at the dm-level)
  - Attitude and phase center models still missing



Pilot Project 1 – Sentinel 6A

- https://colab.tuwien.ac.at/spaces/GW/overview
- Orbit data and VLBI observations made available to everybody
- DOI number to be given after consolidation phase



Pilot Project 1 – Sentinel 6A

- Analysis Scenarios
  - Combination at observation level (one design matrix)
    - Simulated VLBI observations to be used with care, but useful for feasibility studies
  - Combination at normal equation level
    - Station coordinates / terrestrial reference frame
    - Orbit parameters or kinematic positions of satellite
      - Test combination strategies proposed by Urs Hugentobler et al.
  - Comparison/combination at solution level

Pilot Project 2 – LAGEOS 1

(c) NASA

- LAGEOS 1
  - Altitude 5900 km (more VLBI observations)
  - Inclination 109.9 degrees
- Real SLR observations available
- Selected time span: August 4-10, 2025 (one week)
- High accuracy orbit to be provided by TU München (sp3 files)
- VLBI schedules are generated for existing 16 station VGOS network
- Realistic and well defined VLBI observations will be provided
- GNSS and DORIS observations to be simulated as well
- Analysis scenarios similar Sentinel 6A

Pilot Project 3 - Genesis

(c) ESA

- Genesis
  - Altitude 6000 km
  - Inclination 95.5 degrees
- Genesis Mission Reference Orbit has been defined
- https://gssc.esa.int/news/genesis-mission-reference-orbit/

Pilot Project 3 - Genesis

Dynamic Models		
Reference frame modelling		
Displacements of station coordinates	**Ocean loading**	EOT11a
	Atmospheric pressure	None
	Seasonal	None
Centre of mass corrections (geocentre motion)	**Ocean loading**	Yes
	Atmospheric pressure	No
	Seasonal	No
Reference system		IERS 2010 conventions with ERP set to 0
Satellite reference		
Mass		406kg
Gravity		
Gravity field (static)		EIGEN.GRGS.RL05.MEAN-FIELD with quadratic_mean_pole
Gravity field (time varying)		Drift/annual/semi-annual piece wise lineair terms up to degree/order 120
Solid Earth tides		Applied (IERS 2010)
Ocean tides		FES-2022 (80x80)
Atmospheric gravity		AOD1B RL06 (100x100)
Atmospheric tides		AODB RL06
Earth pole tide		IERS 2010
Ocean pole tide		IERS 2010
Third bodies		Sun, Moon, Planets DE405
Surface forces and empiricals		
Radiation Pressure model		Cannonball model (1.85m x 3.39m) for SRP
Earth radiation		Cannonball model (1.85m x 3.39m) for Albedo and Infra-red
Atmospheric density model		N/A
Radiation pressure coefficient		Fixed = 1

Pilot Project 3 - Genesis

(c) ESA

- Genesis
  - Altitude 6000 km
  - Inclination 95.5 degrees
- Genesis Mission Reference Orbit has been defined
- https://gssc.esa.int/news/genesis-mission-reference-orbit/

- Wishes for orbit in the past (e.g. August 4-10, 2025) with attitude model and realistic radiation pressure model

Pilot Project 3 - Genesis

- Realistic and well defined VLBI observations to be provided
- GNSS, SLR, and DORIS observations to be simulated as well (by DLR, TUM, CNES)
- Purpose
  - testing attitude model and phase center offsets in software packages and analysis
  - evaluate impact of calibration errors
  - orbit combination etc.

Pilot Projects

- Overview

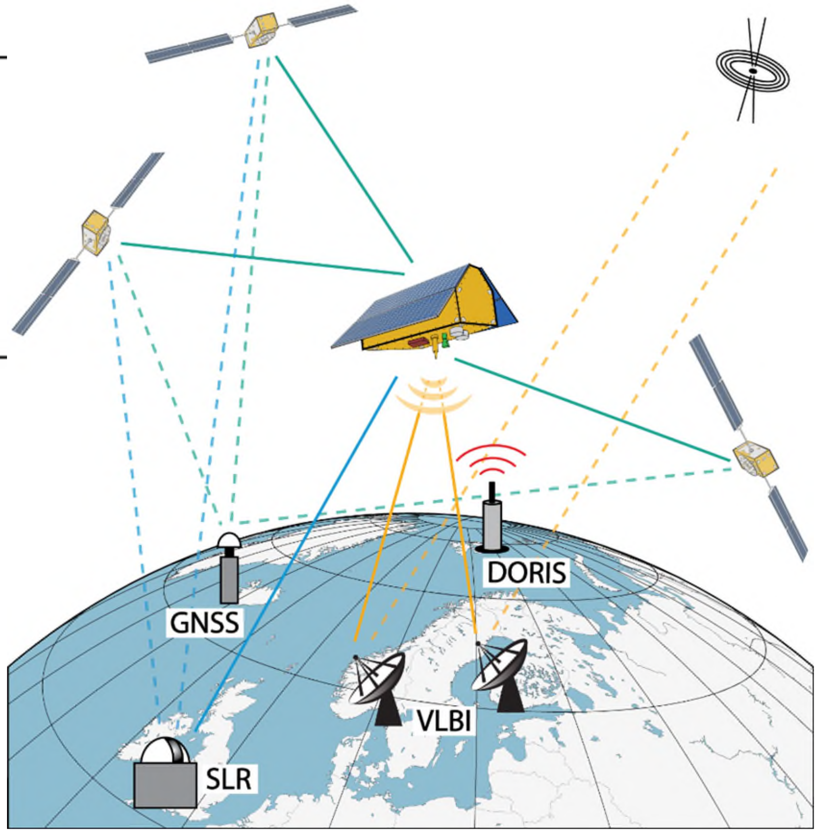
7-day orbit	VLBI	GNSS	SLR	DORIS
Sentinel 6A	simulated	real	real	real
LAGEOS 1	simulated	simulated	real	simulated
Genesis	simulated	simulated	simulated	simulated

Tasks for the scientific community

- Links between Genesis and space geodetic techniques

	VLBI	GNSS	SLR	DORIS
Genesis to ground	+	–	+	+
Genesis to satellite	–	+	–	–
EOP/CRF	+	–	–	–
Genesis orbit	+	+	+	+
Earth center of mass	+	+	+	+
Same satellite clock	+[a]	+	–	+
Same atmosphere paths	+	-	+[b]	+

a) if PRN data; b) in the optical



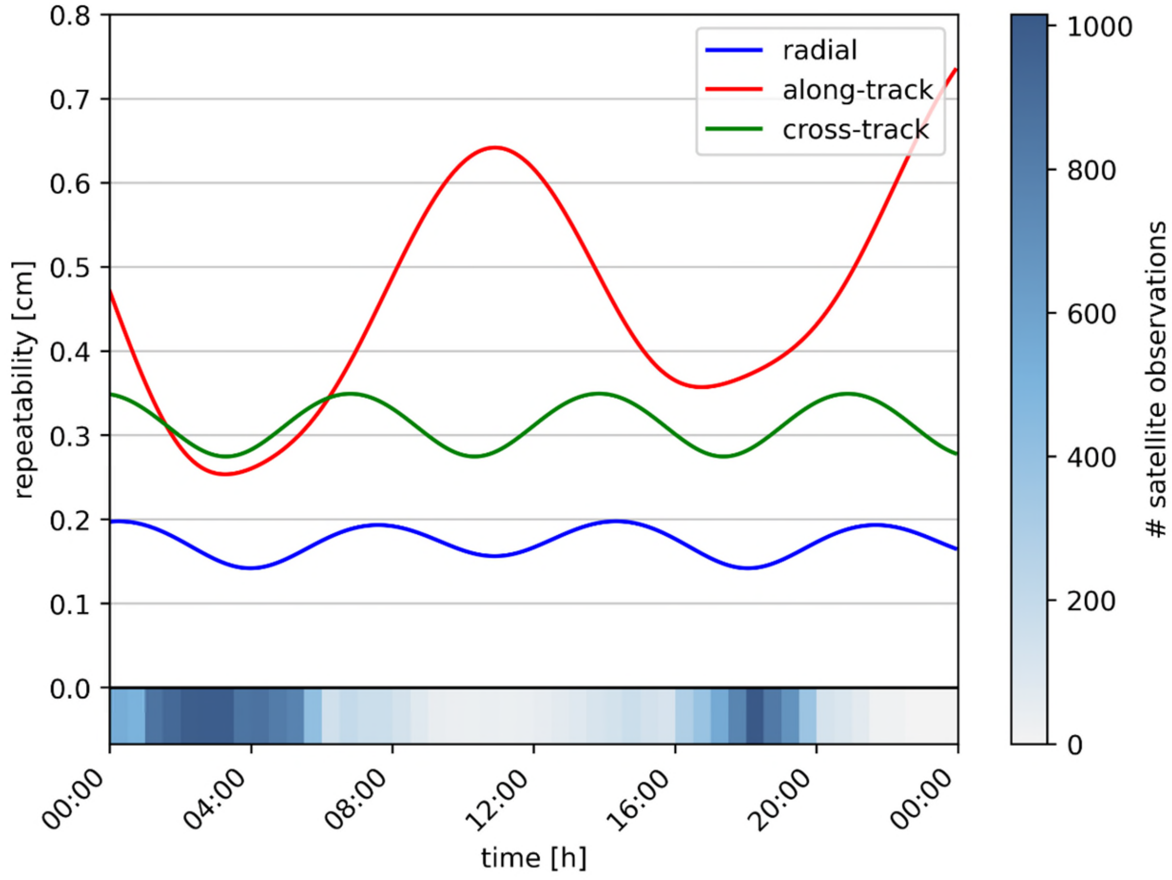
Selected topics and action items

- Orbit combination at normal equation level (Hugentobler et al.)
  - initial state vectors can only be combined if same force model is used
  - thus, transformation to orbit positions which are combined at the normal equation level
  - back-transformation to initial state vector
  - SINEX format including orbit information required

Selected topics and action items

- Orbit combination at normal equation level (Hugentobler et al.)
  - Tests with VieVS-VLBI successful to apply orbital parameters from Bernese

$$\frac{\partial \tau}{\partial p_i} = \frac{\partial \tau}{\partial r(t)} \cdot \frac{\partial r(t)}{\partial p_i}$$



Next steps

- Clear description is still missing what we would like to achieve with pilot projects
- For orbit combination at normal equation level more data has to be provided
  - SINEX files
  - partials with respect to orbital parameters?
- Data for Sentinel 6A is available
  - simulations for LAGEOS-1 and Genesis still missing
- More realistic Genesis orbit needed

- Details of pilot projects to be discussed and decided at IAG WG meeting during EGU General Assembly

Current status of GENESIS-F activities : simulations, real data processing and perspectives

Ait-Lakbir Hanane [1]

On behalf of GENESIS-F members, among whom
Altamimi Zuheir [4,5], Banos-Garcia Adrian [6], Capdeville Hugues [6], Chatzinikos Miltiadis [2], Collilieux Xavier [4,5], Couhert Alexandre [1,3], Coulot David [4,5], Delva Pacôme [2], Leroux Leonie [4,5], Loyer Sylvain [6], Marty Jean-Charles [1,3], Perosanz Felix [3], Pollet Arnaud [4,5], Reinquin Frank[1,3], Santamaria Alvaro [1,3], Saquet Eleonore [6]

[1] GET, Université de Toulouse, CNES, CNRS, IRD, UPS
[2] LTE (ex-SYRTE), Observatoire de Paris-PSL, CNRS, Sorbonne Université, LNE
[3] CNES
[4] Université Paris Cité, Institut de Physique du Globe de Paris, CNRS, IGN
[5] ENSG-Géomatique, IGN
[6] CLS

Acknowledgments: Some of these activities was financially supported by CNES as a contribution to the GENESIS-F project.

1. WHAT IS GENESIS-F ?

GENESIS-F

Observatoire de Paris

- IERS Combination center -> EOP/C04
- GENESIS orbit optimization
- GENESIS data simulations
- VLBI data processing and expertise

IPGP · Université Paris Cité · IGN · Géodata Paris · Université Gustave Eiffel

- IERS Combination center -> ITRF
- IDS Analysis centers
- IGS Combination Center
- EGRASP/GENESIS data simulations
- ITRF R&D and expertise

Université de Bordeaux

- VLBI data processing and expertise

Observatoire de la Côte d'Azur

- SLR expertise
- Metrology expertise

cnes

- GENESIS-F coordination
- GINS software management and expertise
- IAG Analysis Centers (IDS, IGS, ILRS)
- IDS Combination Center
- DORIS, GNSS, SLR data processing expertise

Géosciences Environnement Toulouse

- GENESIS data simulations and processing

CLS

- IAG Analysis Centers (IDS, IGS, ILRS)
- IDS Combination Center
- Multi-technique LEO POD and NEQ using GINS

2. ABOUT THE GINS SOFTWARE

- Developed at CNES since mid 1960's to **compute satellite orbits** around any body of the solar system (planet, moon, comet, asteroids…) and using measurements to **solve for physical parameters**
  - Station positions and velocities
  - Planet rotation parameters
  - Gravity field
  - Natural satellite ephemeris and orientation
  - Ocean tide, mean sea surface, thermospheric model corrections, Love numbers

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- Measurements **for simulation or real data processing** : **SLR**, LLR, **DORIS, GNSS, VLBI**, Inter satellite links, gravity tensor, altimetry (or LIDAR) , optical, interplanetary Doppler and Range, landmark

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- **Current usages**
  - **IAG products**
  - Gravity field
  - Interplanetary

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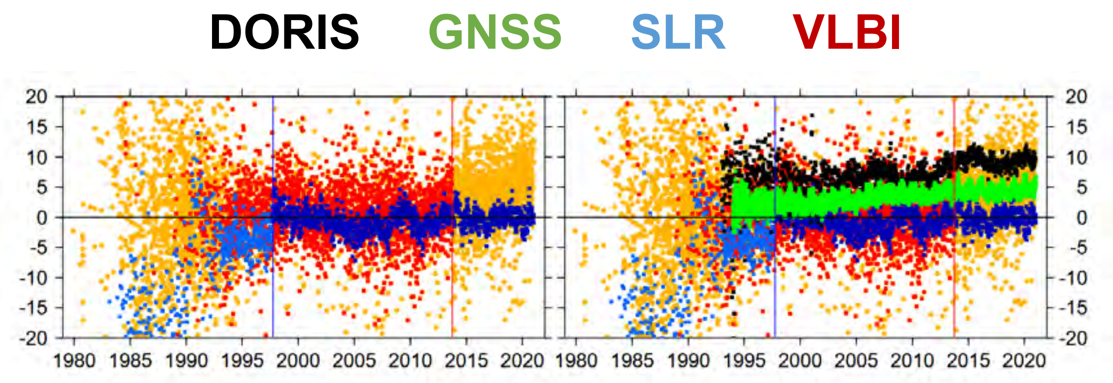
3. ONBOARD ANTENNA CALIBRATION ERROR PROPAGATION

Question : Can GENESIS serve as a reference to identify and correct inter-technique biases ?



From Altamimi et al, 2023
[Scale in mm wrt to ITRF2020, Fig. 9]

Inter-technique systematic biases

- Current realizations show significant discrepancies between the 4 techniques
- Example : bias in the scale factor
    - The DORIS-derived scale is biased by around 10 mm with respect to SLR/VLBI scales

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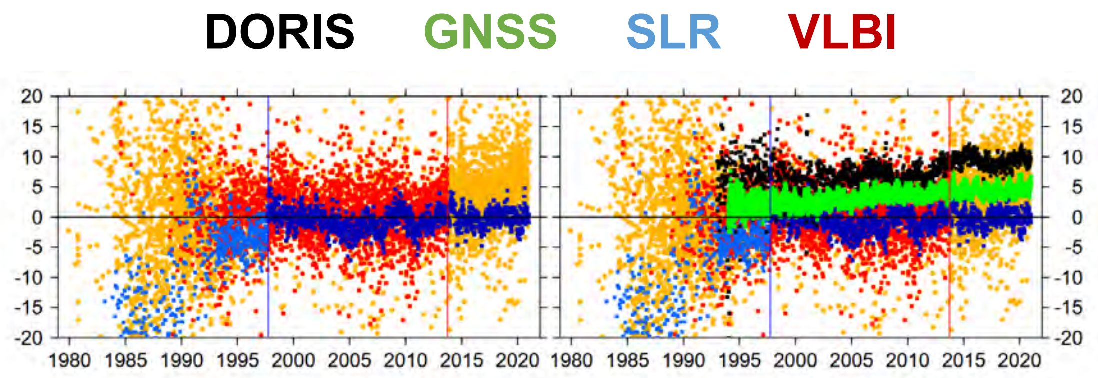
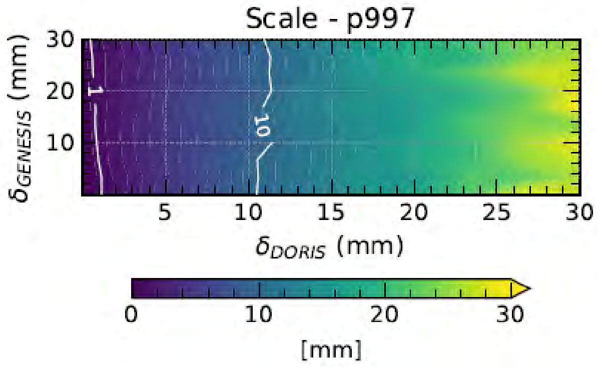


From Altamimi et al, 2023
[Scale in mm wrt to ITRF2020, Fig. 9]

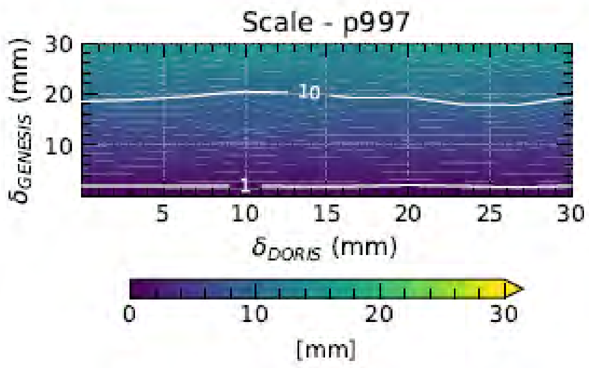
We can use the calibration accuracy of onboard GENESIS antennas as a reference to recompute the calibration errors on the other satellites
→ **Question of the sensitivity ?**

Sensitivity of DORIS scale factor to PCO calibration error

Without recalibration



With recalibration



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- Current realizations show significant discrepancies between the 4 techniques
- Example : bias in the scale factor
  - The DORIS-derived scale is biased by around 10 mm with respect to SLR/VLBI scales

3. ONBOARD ANTENNA CALIBRATION ERROR PROPAGATION

Two configurations are considered in terms of antenna calibration errors :

- **3D (RTN) case**
- **Radial-only case**

  → assuming that in-flight calibration is possible to properly correct the other directions (eg. with attitude maneuvers making possible to separate the geometrical error from dynamical and timing errors)

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Sensitivity of TRF parameters to GENESIS calibration (single-technique solutions)

Normalized values to produce a 1-mm effect on parameters

(in mm)	**Main contribution**	**TX**	**TY**	**TZ**	**Scale**
DORIS**	LEO constellation Possibility for GENESIS-based recalibration				**Radial : 1-2** RTN : 2
GNSS*, **	Both to GNSS and GENESIS Possibility for GENESIS-based recalibration	Radial : 7	Radial : 7	Radial : 2-3 **RTN : 1**	Radial : 2-3 **RTN : 1**
SLR	GENESIS	RTN : 10-15	RTN : 10-15	**RTN : 1**	**Radial : 1-2** **RTN : 1-2**
VLBI***	GENESIS	RTN : 7	RTN : 10	Radial : 2 **RTN : 1**	Radial : 4 RTN : 2

* Errors on the 2 GNSS antennas are considered independent

** Assuming recalibration with GENESIS as a reference to improve the technique contribution

*** Neglecting the spatial resolution error caused by PCO errors during the construction of the broadband delays

3. ONBOARD ANTENNA CALIBRATION ERROR PROPAGATION

Question : What is the impact of GENESIS calibration on a GENESIS-tied multi-technique TRF solution ?

Principle: Exploration of 6-dim space ($\delta_{DORIS}, \delta_{SLR}, \delta_{GNSS}$; $\delta_{DG}, \delta_{LG}, \delta_{VG}$) → error propagation to combined TRF parameters

External calibration
- DORIS LEO,
- SLR spherical,
- GNSS MEO

GENESIS-related calibration
w.r.t. GNSS calibration (considered perfect)

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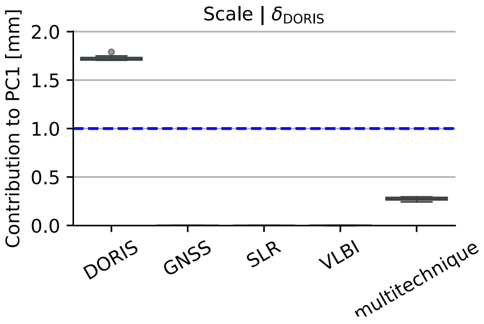
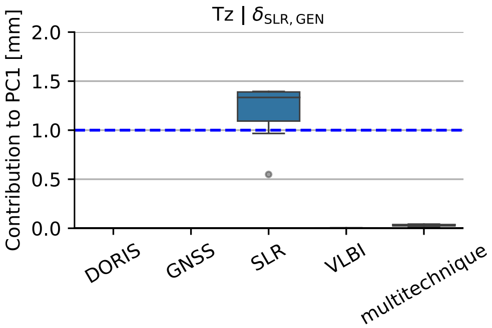
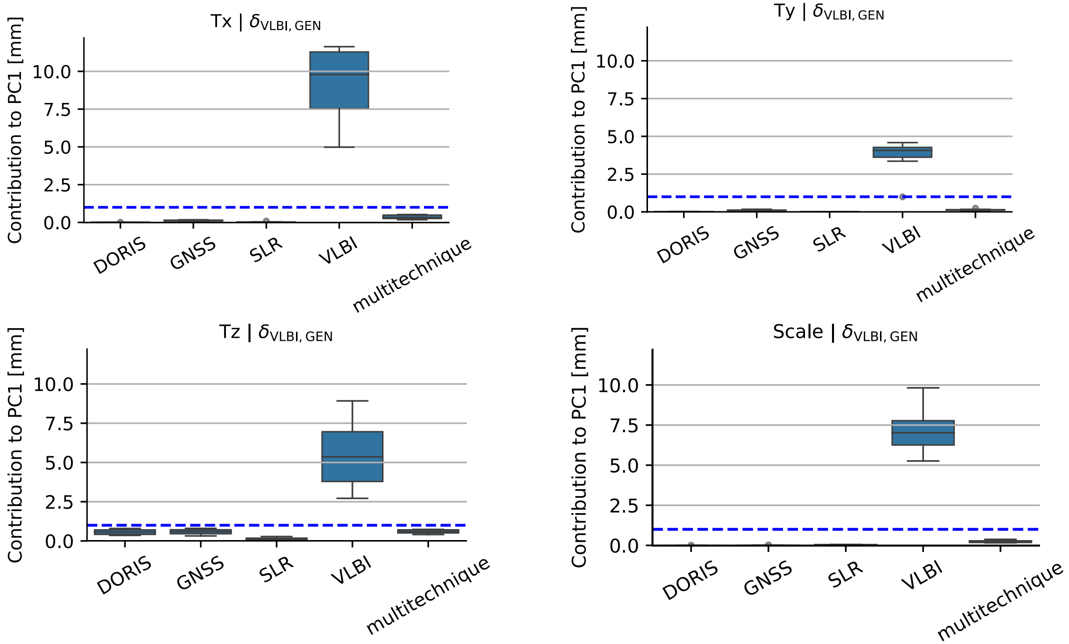
Preliminary results with only radial error on inter-technique consistency



Impact of DORIS LEO missions





Impact of GENESIS-related calibration

4. MULTI-TECHNIQUE PROCESSING OF SENTINEL-6A, SENTINEL-3A/B DATA

Current activities by CNES/CLS IDS (DORIS), IGS (GNSS) and ILRS (SLR) Analysis Centers

The idea is to:

1. Be prepared for the processing of future GENESIS observations.
2. Assess the benefits of the inclusion of LEO satellites into the classical IGS/ILRS solutions.
3. Assess the benefits of a multi-technique space mission (space tie) to TRF realizations.

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→ **Joint processing** of GNSS, DORIS and SLR observations using GINS software :

technique-specific processing with the same models, initial state vector, arc length, software, etc. and perform a combination of the resulting normal equations.

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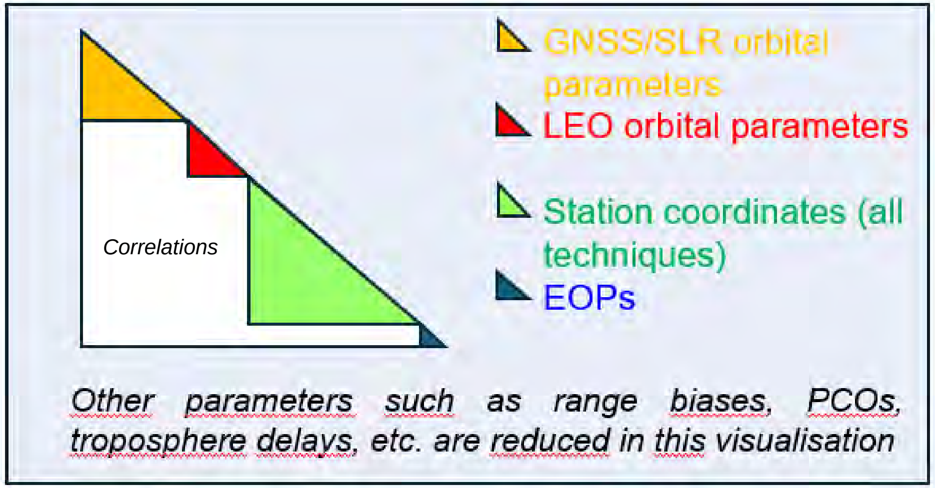

Advantages:

- Real « space tie »
- Correlations between station coordinates of different techniques available thanks to LEO observations
  → No need for constraints
- All techniques should benefit from each other's strengths

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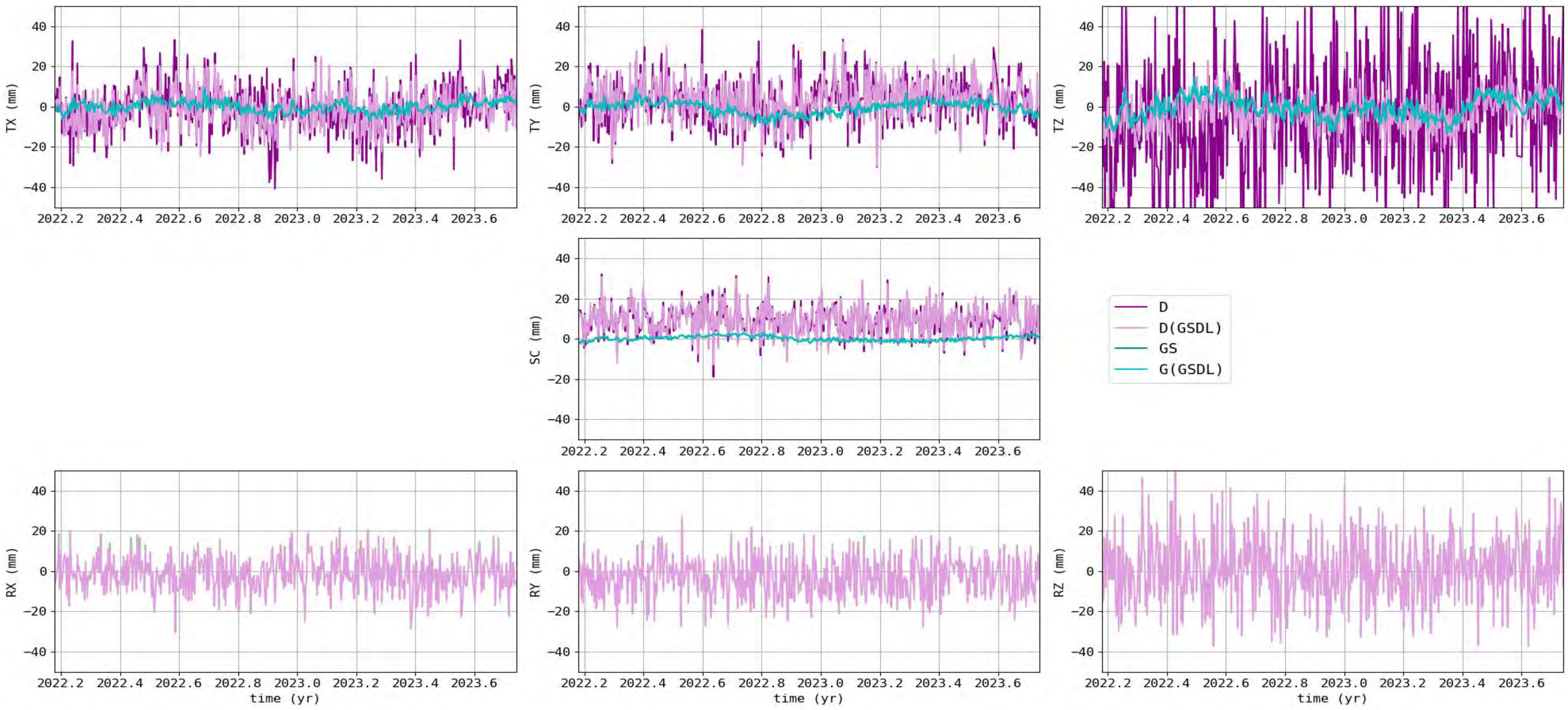

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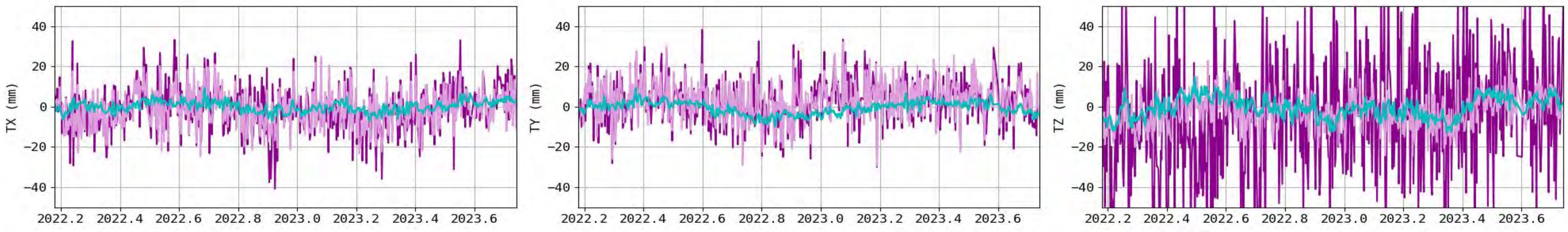

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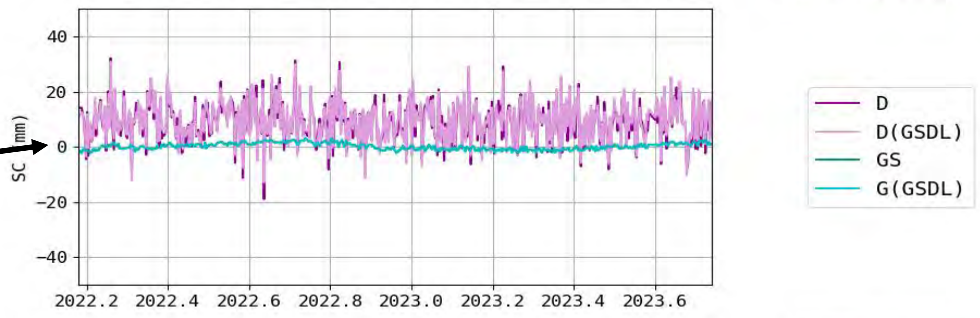
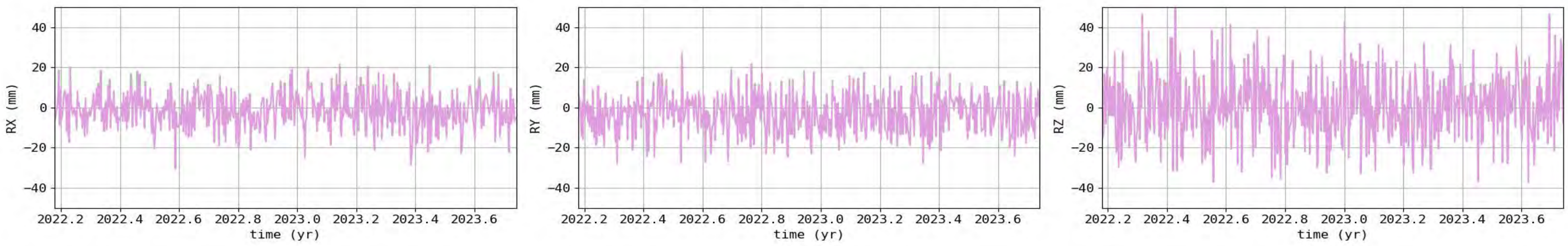
- **1 cm bias in the scale between DORIS and GNSS**, individually or combined





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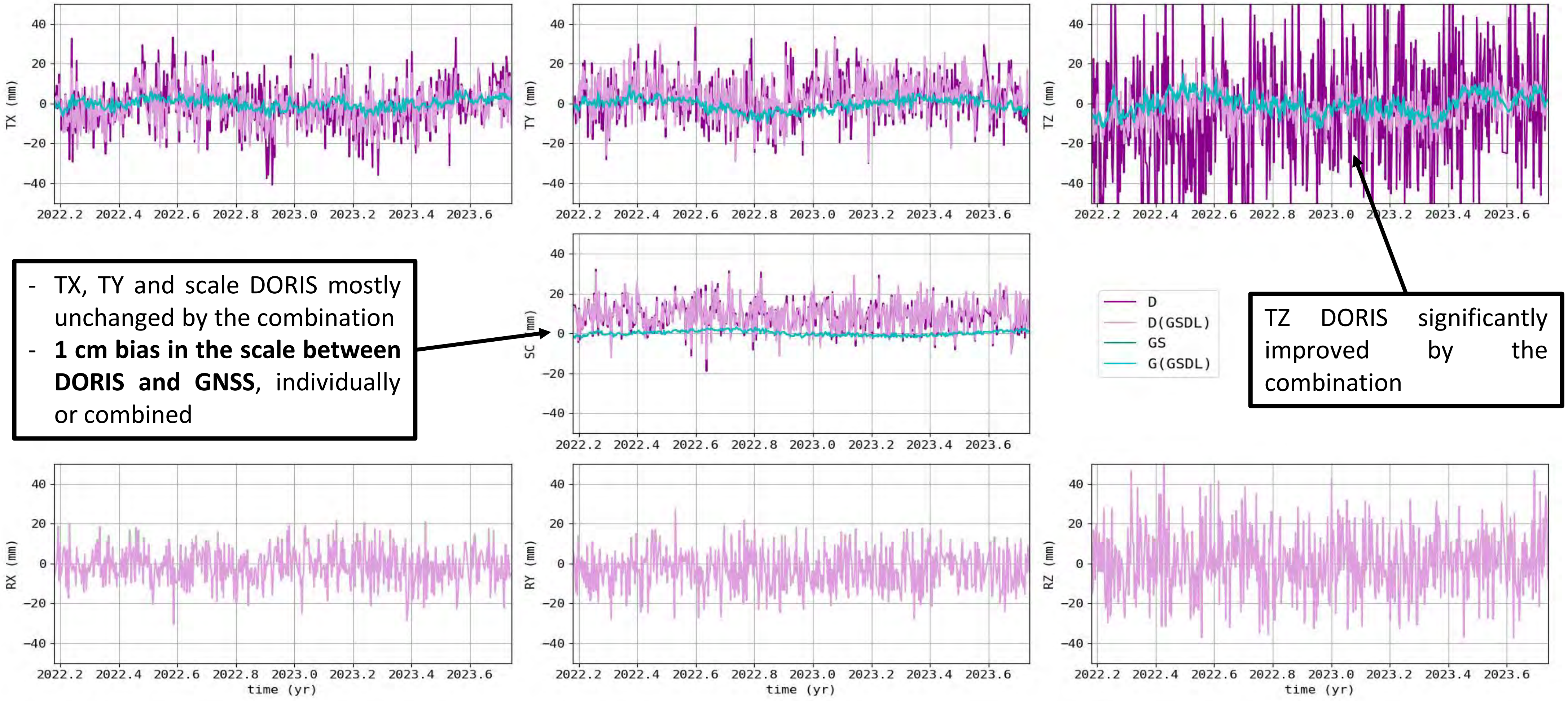

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TZ DORIS significantly improved by the combination

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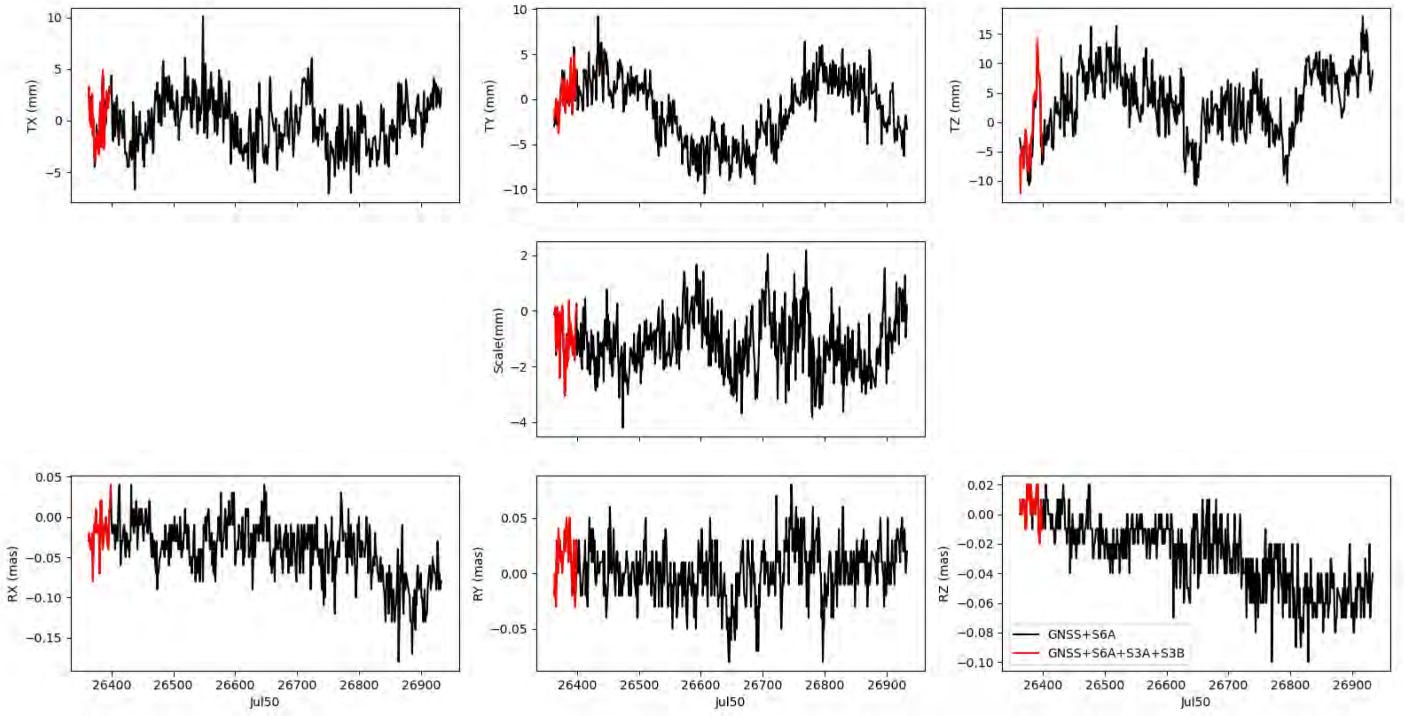
Current activities by CNES/CLS IDS (DORIS), IGS (GNSS) and ILRS (SLR) Analysis Centers

- **New LEOs/space ties** : S6A, S3A and S3B
  → First tests show positive results !

First combination results with 3 space ties



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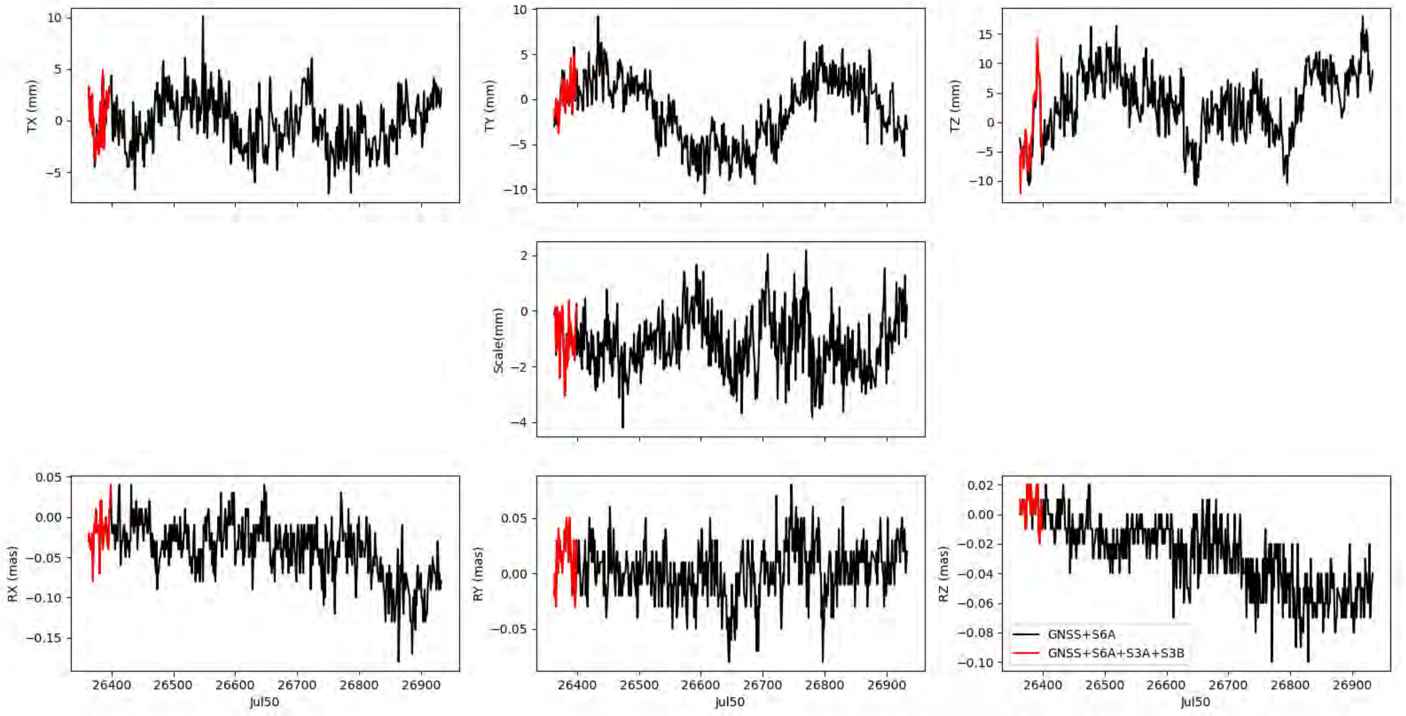
- **New LEOs/space ties** : S6A, S3A and S3B
  → First tests show positive results !

- Study of **tropospheric ties** between GNSS and DORIS
  → Beginning of an internship

- **New SLR solutions** (7-day arc for Lageos + 1 jour for LEOs)
  → Improves the robustness of the solution, but a degradation is still seen in the combination with GNSS.

- **Sinex available** via ftp
  → EOPs
  → station coordinates D+G+L
  → PCOs of the LEO instruments
  → range biases for SLR stations.

First combination results with 3 space ties



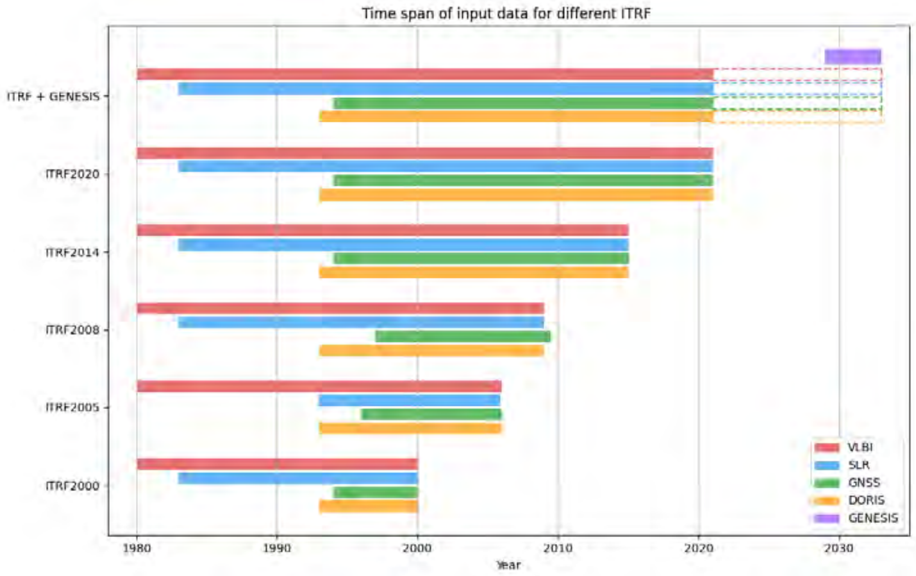
Please do not hesitate to contact them (Adrian, Sylvain) !

5. HOW TO INTEGRATE GENESIS DATA INTO THE COMPUTATION OF THE INTERNATIONAL TERRESTRIAL REFERENCE FRAME (ITRF)

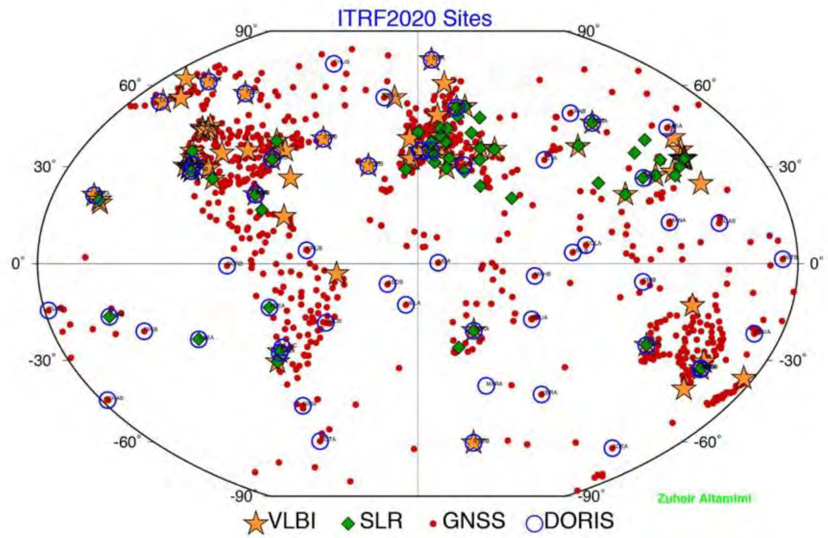
Current PhD by Léonie Leroux (IGN/IPGP)

Under the guidance of Xavier Collilieux, David Coulot, Hanane Ait-Lakbir, Arnaud Pollet and Zuheir Altamimi

Objective of the GENESIS mission : to contribute to improving the ITRF by combining the four space geodetic techniques on a single satellite (space tie) and mitigating their systematic errors



Integration of the GENESIS observations into the ITRF data history



Main questions :

- How to built an ITRF-like solution using GENESIS observations ? How to evaluate a GENESIS solution ?
- How to integrate a GENESIS solution into the ITRF computation and manage the data history ?

6. CONVENTIONS REQUIRING POTENTIAL UPDATES?

Question : Are the current conventions sufficient to meet the 1 mm-accuracy for the ITRF ?

Earth's GM (degree 0) : The large uncertainty of **2.0 ppb** for GM (398600.4415±0.0008 $km^3.s^{-2}$) corresponds to:

- **~20 times** the full Earth Radiation Pressure (ERP) acceleration on the LAGEOS satellites
- **8 mm offset** in the absolute radial position at the GENESIS altitude (2 cm for Galileo)

→ Need to reassess its values within **0.25 ppb** to realize the ITRF with a 1-mm accuracy in the ITRF realization

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Geocenter motion (degree 1)

- Self-consistent treatment of tidal variations in the center of mass of the whole Earth system (CM) but **not yet the case for non-tidal fluid mass redistributions**.
- A consensus model for daily to **interannual geocenter changes** does not exist.

→ Reconciling the conflict between the **linear+seasonal CM model** of the ITRF2020 origin and the non-linear nature of the geocenter motion is critical for improving future TRFs (effects > 2mm)

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Pole tide correction (degree 2 order 1)

- Need of consistent a priori geophysical model such as pole tide w.r.t. GIA corrections.

→ The GIA secular contribution to the pole tide should be the subtracted **mean pole** (effects on drifts > 0.1mm/y)

CONCLUSIONS AND PERSPECTIVES (WORK IN PROGRESS)

- Multi-technique processing capabilities
  - Software: GINS
  - Strategies : Solution/NEQ/observation levels
  - Experts : from data to their processing and geodetic solutions (ITRF, EOP, ICRF)

- Current activities to be prepared for GENESIS with real and simulated data

- Scientific engagement for GENESIS : GSET WGs, IAG

Geodetic Reference Instrument Transponder for Small Satellites (GRITSS)

S. M. Merkowitz

NASA Goddard Space Flight Center

March 12, 2026

The Geodetic Measurement System

VLBI
- Orientation of ITRF with respect to ICRF
- ITRF Scale

SLR
- Origin of ITRF (Earth's CM)
- ITRF Scale
- Position spacecraft in ITRF ("Orbits")

GNSS
- Precise monitoring of Polar Motion and Rotation Rate
- Position spacecraft in ITRF ("Orbits")
- Position instruments on Land and Sea (Tide Gauges and Buoys, Geodetic Instruments)

DORIS
- Position spacecraft in ITRF ("Orbits")
- Enhances global distribution of ITRF Station positions and velocities

Technique Connectivity (Station Co-Location)

Fully Define ITRF

VTS: ITRF Performance Improvement

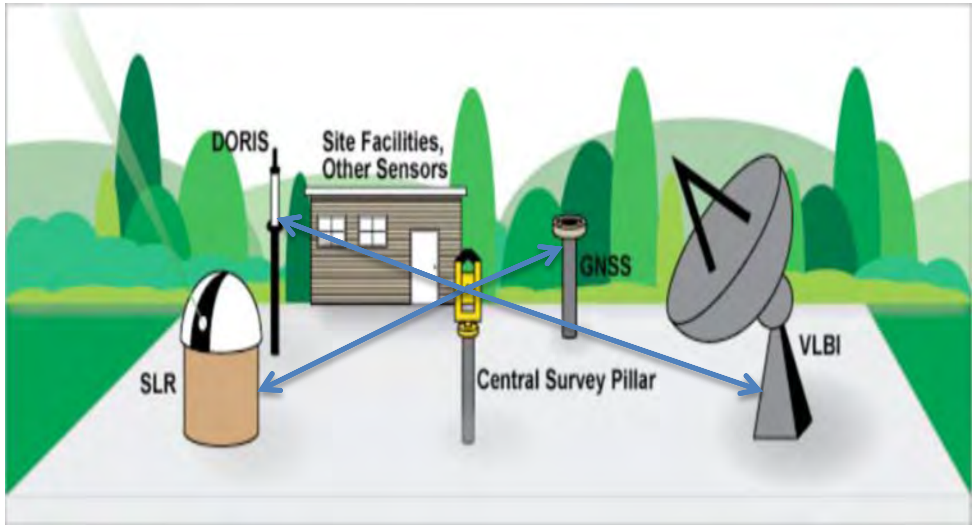
Origin, Scale, Orientation

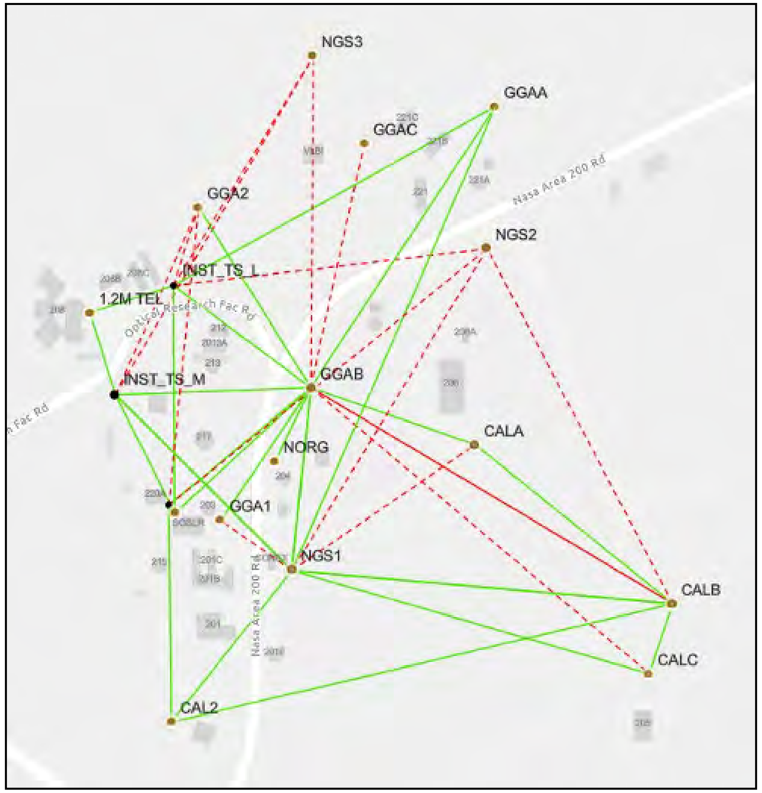
Low-Density Global Distribution

High-Density Global Distribution

Traditional Local Tie Surveys

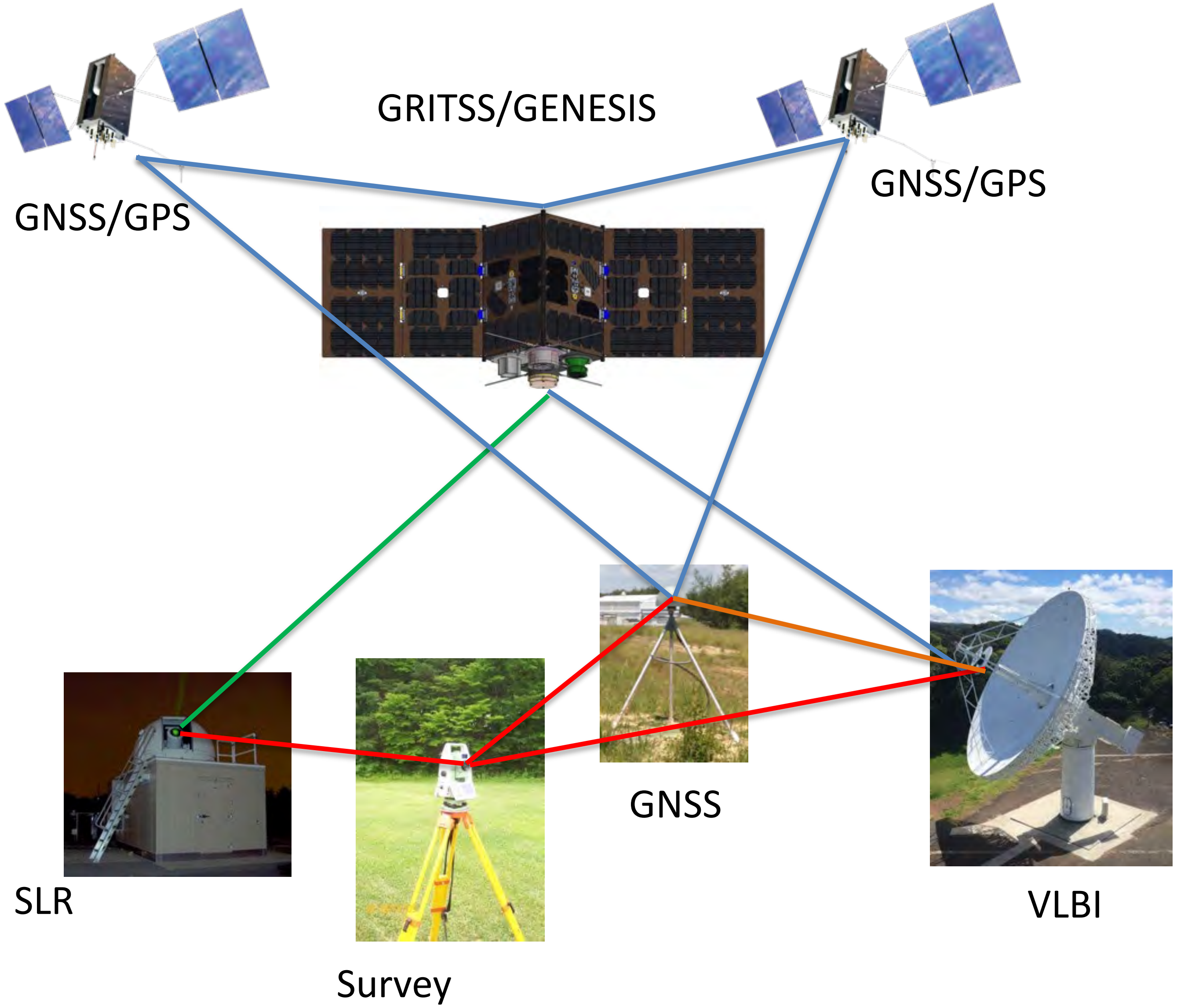
- Survey of site ground control network, site reference, optical access points, and supplemental targets to estimate the measurement points of space geodesy instruments.
- The actual instrument measurement point is often not accessible to survey techniques and must be estimated, introducing errors in the local tie.
- Surveys are only performed periodically further introducing the possibility of errors.





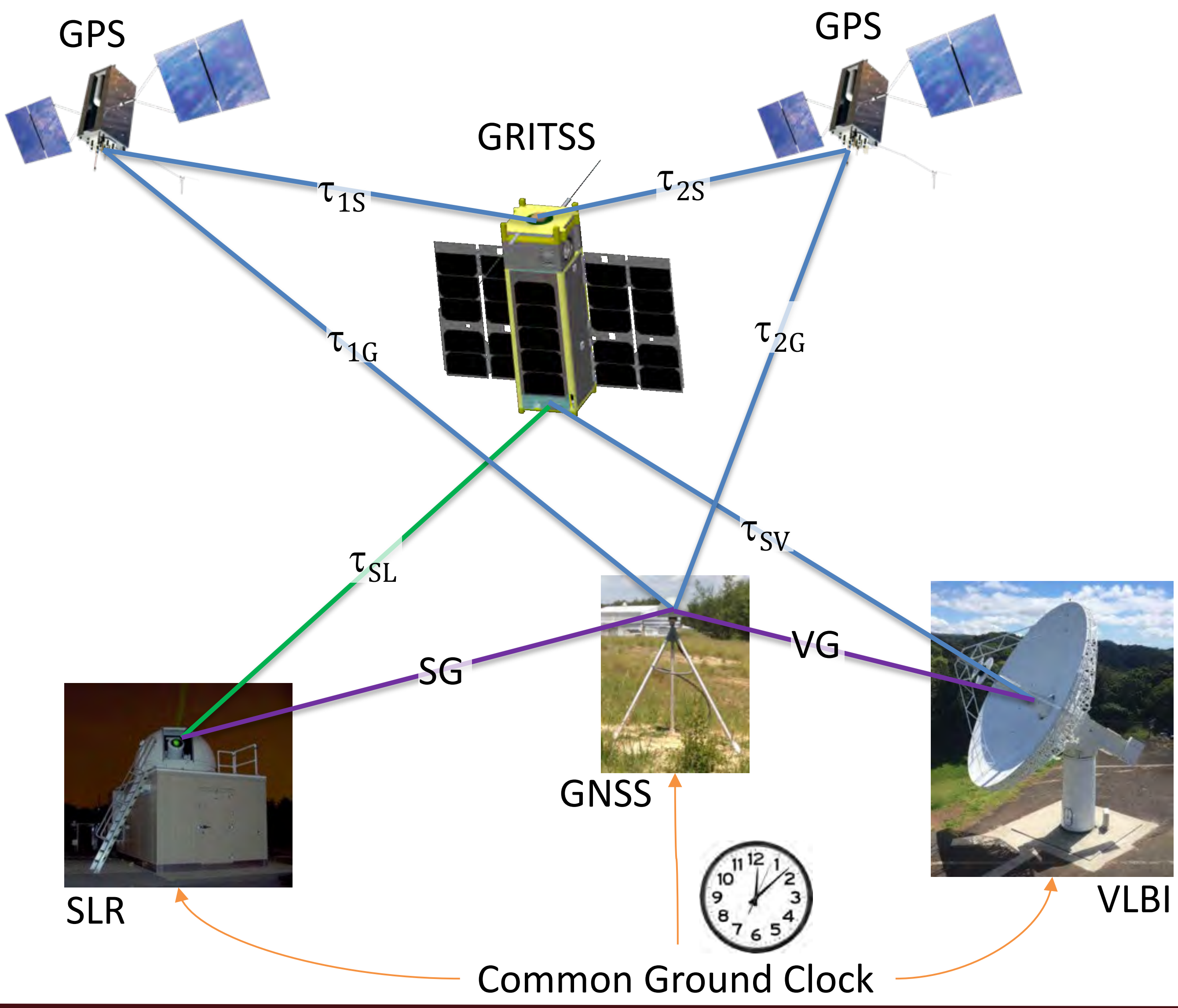
Geodetic Colocation In Space

Observations of a common space-based reference has the potential for reducing the uncertainty in the local-ties to the mm level thus improving the ITRF combination.



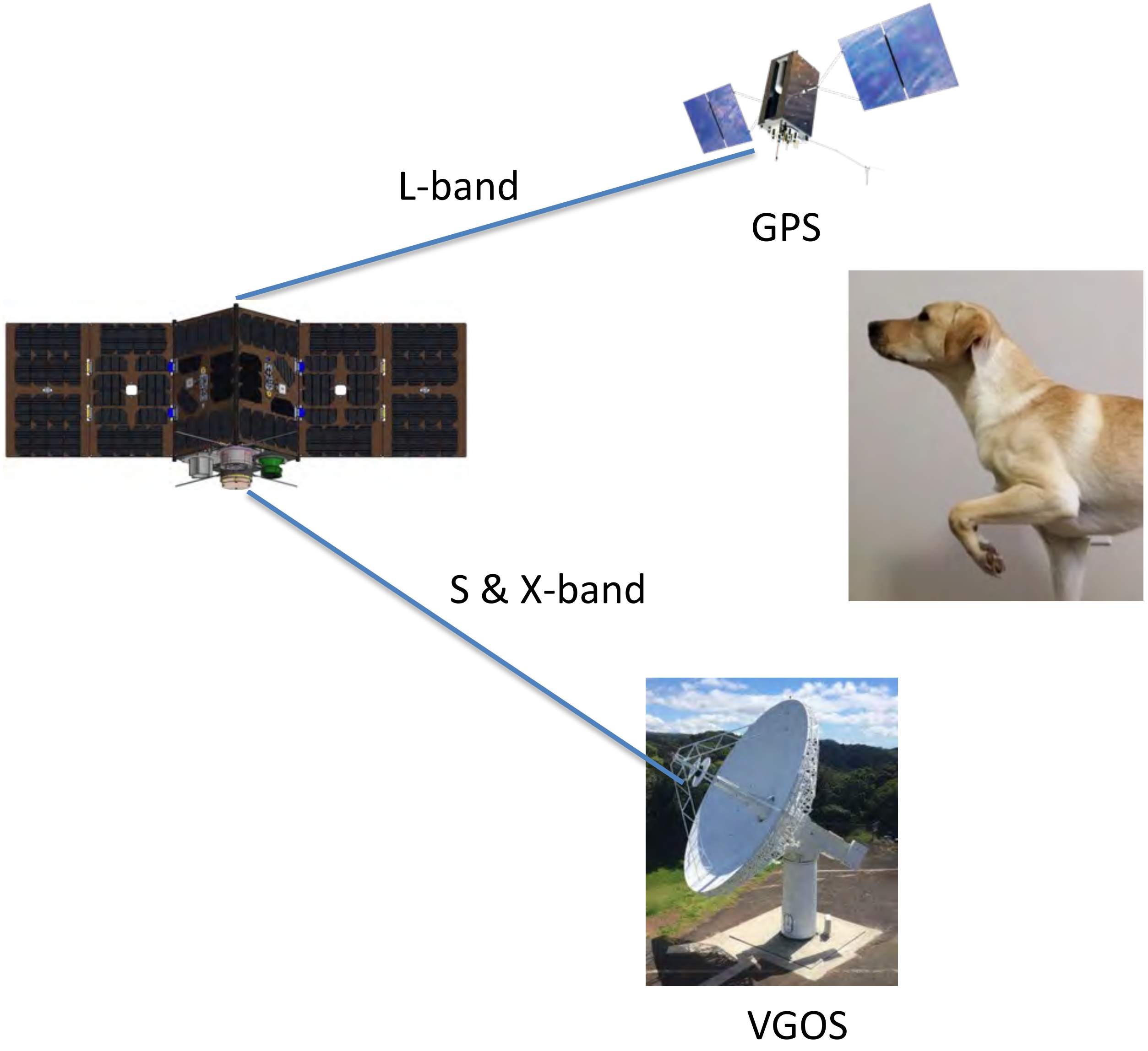
The GRITSS Observables

- τ_{SV} observable is a clock bias term that is obtained through differencing of space/VLBI GPS clock biases
- Differencing allows direct suppression of common clock terms.
- Fitting τ_{SV} to model given CubeSat Precision Orbit Determination yields VLBI position



The GRITSS Dog-Leg

GRITSS upconverts and transponds GPS signals to individual VGOS ground stations.

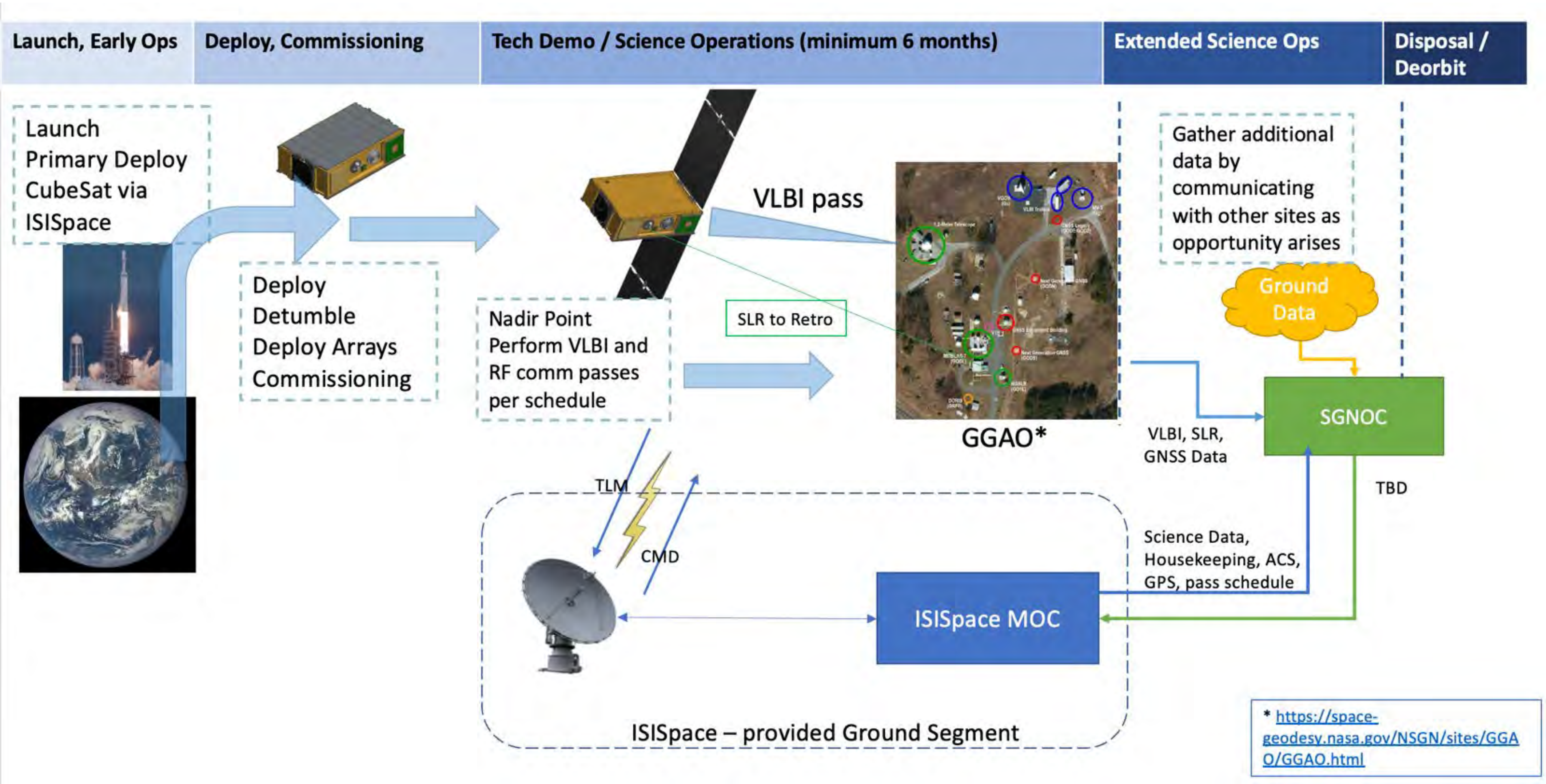


The GRITSS Demonstration Mission

- A NASA Earth Science and Technology Office sub-class D technology demonstration mission
- Jointly developed by the University of Massachusetts, Lowell and NASA GSFC
- 12UXL CubeSat, launch, and operations services provided by ISISpace in the Netherlands.
- Nominal operations: 1 year (extendable)
- Orbit: 590km sun synchronous
- Only broadcasts GRITSS signals over VGOS stations as spacecraft power permits
- Spacecraft kept nadir pointing throughout orbit to enable global SLR tracking

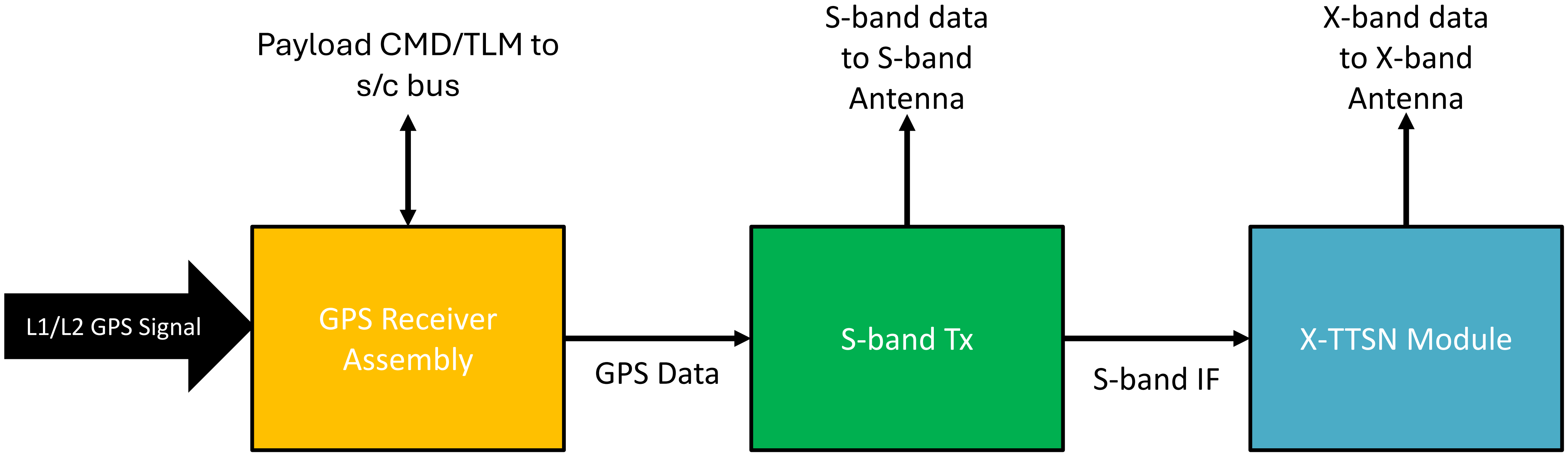
Initially targeting US NASA VGOS stations and will invite other VGOS stations to participate after successful first phase

Concept of Operations



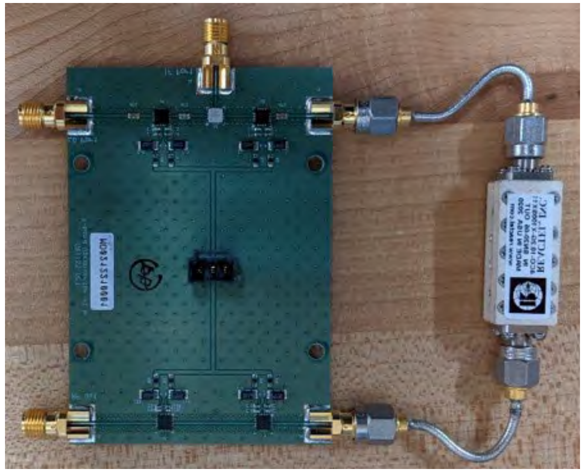
GRITSS Instrument Subsystems

- GPS Receiver Assembly
- Ultra-Stable Oscillator (USO)
- X-band Transmitter and Timing extenSionN (X-TTSN) Module - 10.2 GHz
- S-band Transmitter - 3.2 GHz
- Antennas (L1/L2 GPS, X-band, and S-band)
- Laser Retroreflector



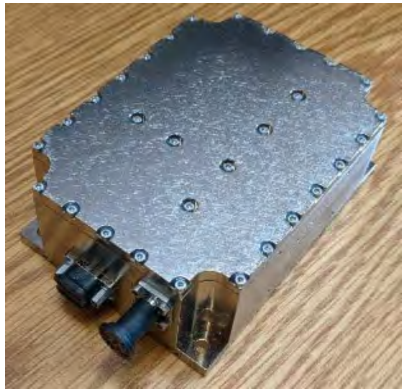
Completed Technology Readiness Level 5 Development

S-band Transmitter



X-band Transmitter

GPS Receiver Assembly

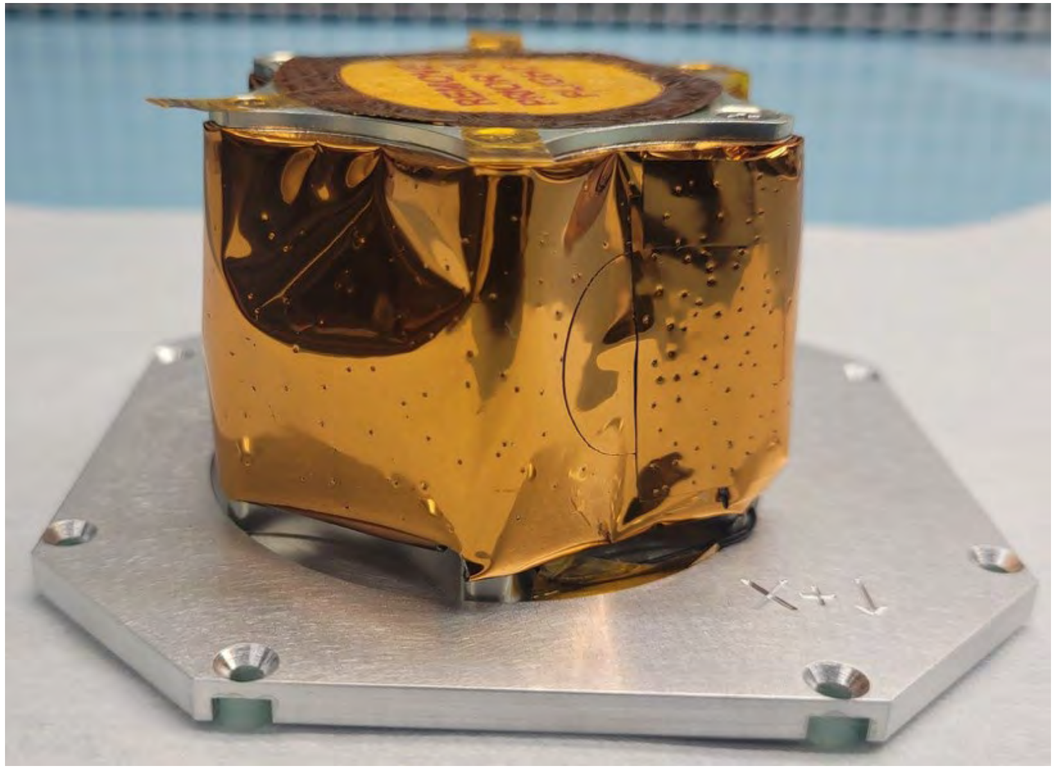


Wenzel USO

Laser Retroreflector

Single 1.6 inch diameter cube corner with measured dihedral angles offsets of 1.7, 1.4, and 1.5 arcsec.

Mounted to the nadir deck that will be kept nadir pointing most of the time.

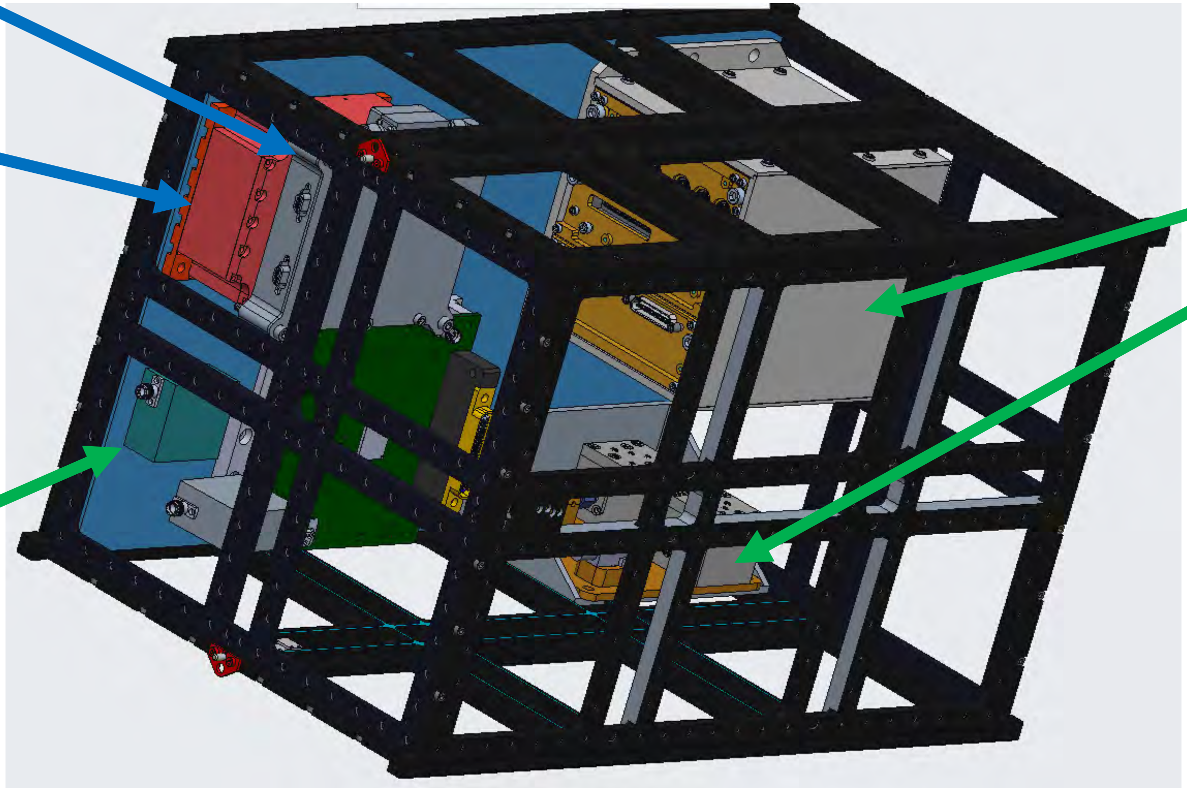


Designed and built by KBR

GRITSS Instrument Fits Within 6U Volume

X-TTSN Module

USO



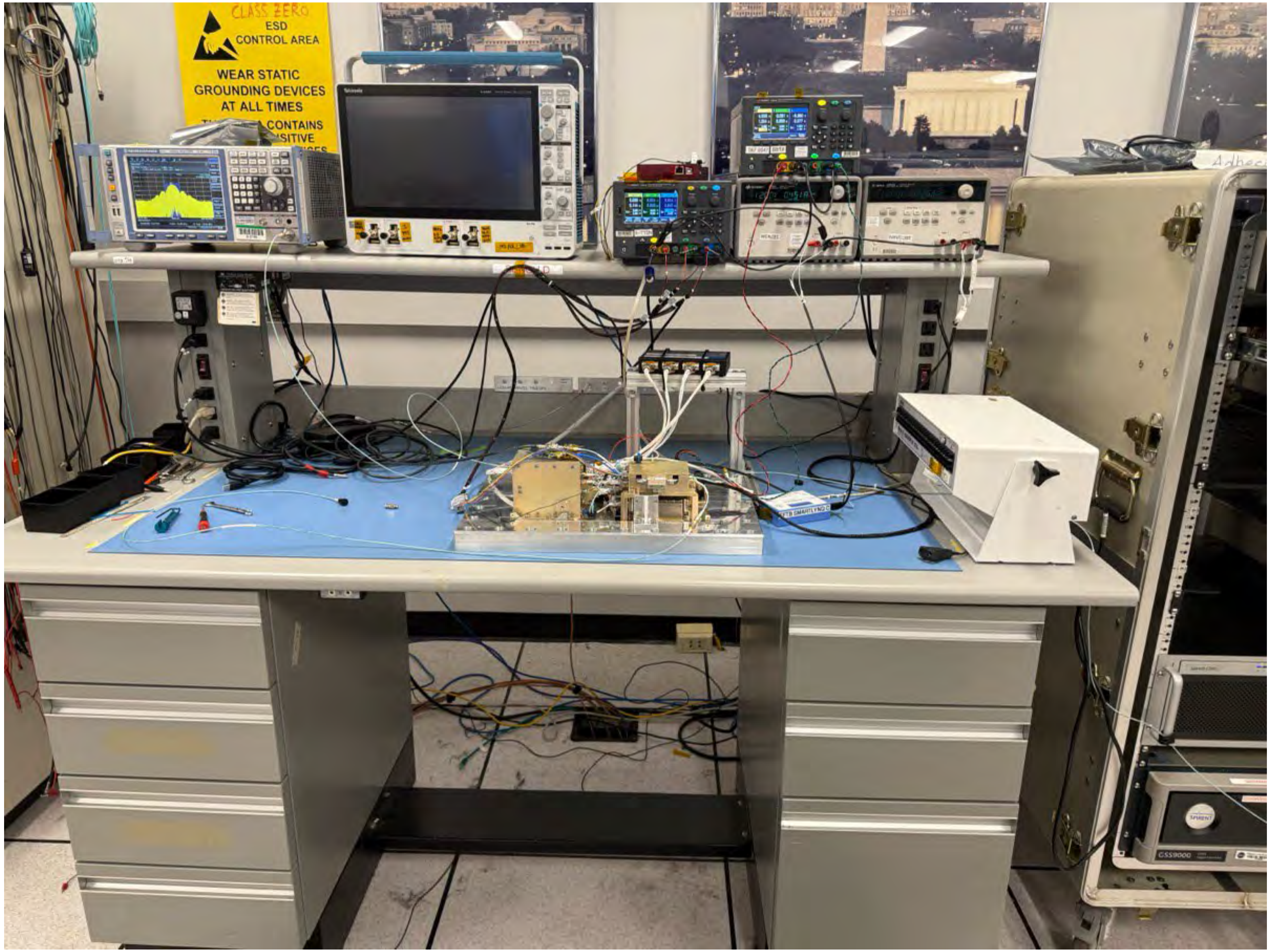
S-band Tx

GPS Receiver Assembly

- NavCube3-mini
- Low-Noise Amplifier (LNA)

Instrument Size:
20 cm × 11 cm × 34 cm

GRITSS Flight Instrument



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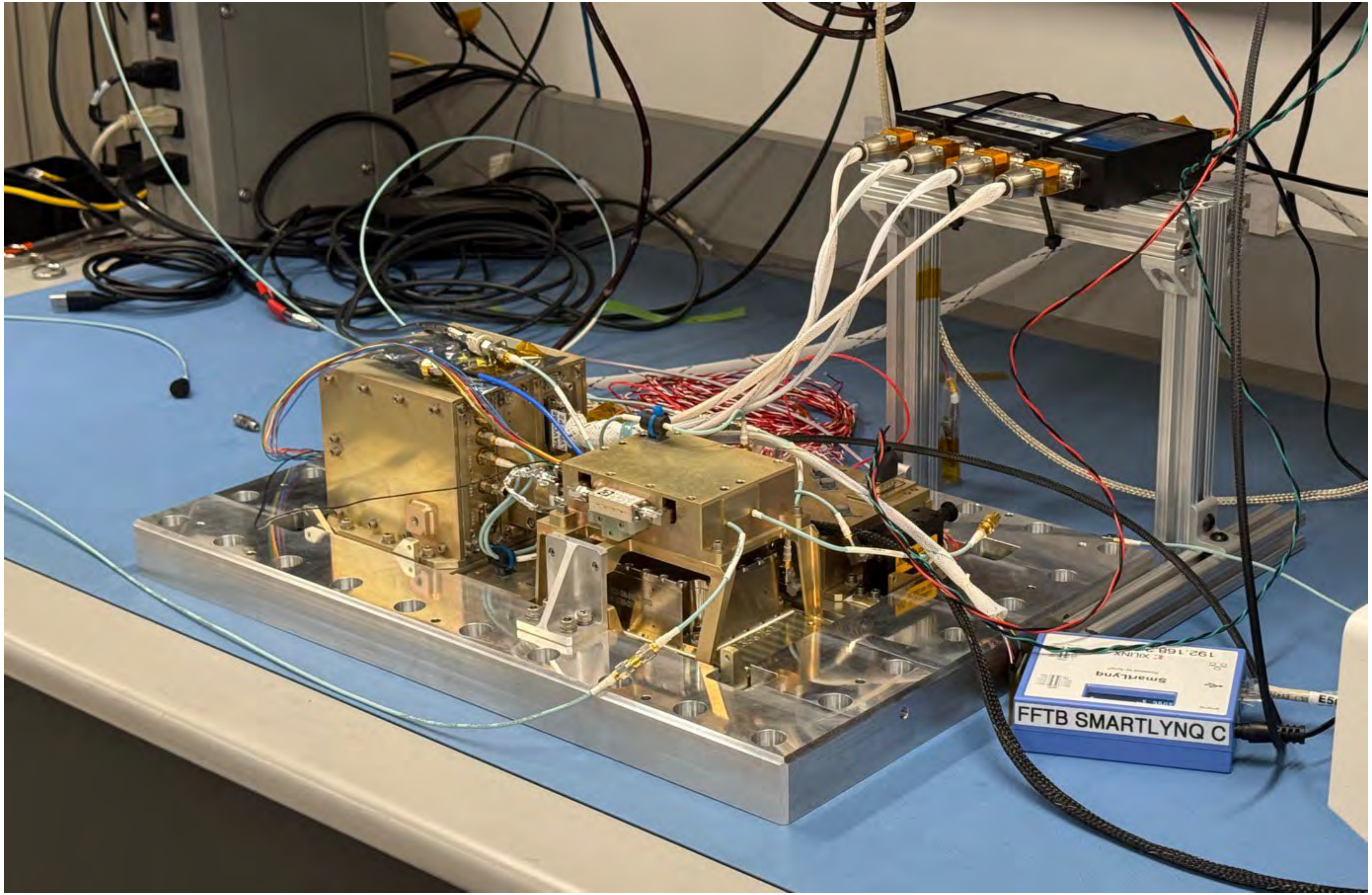
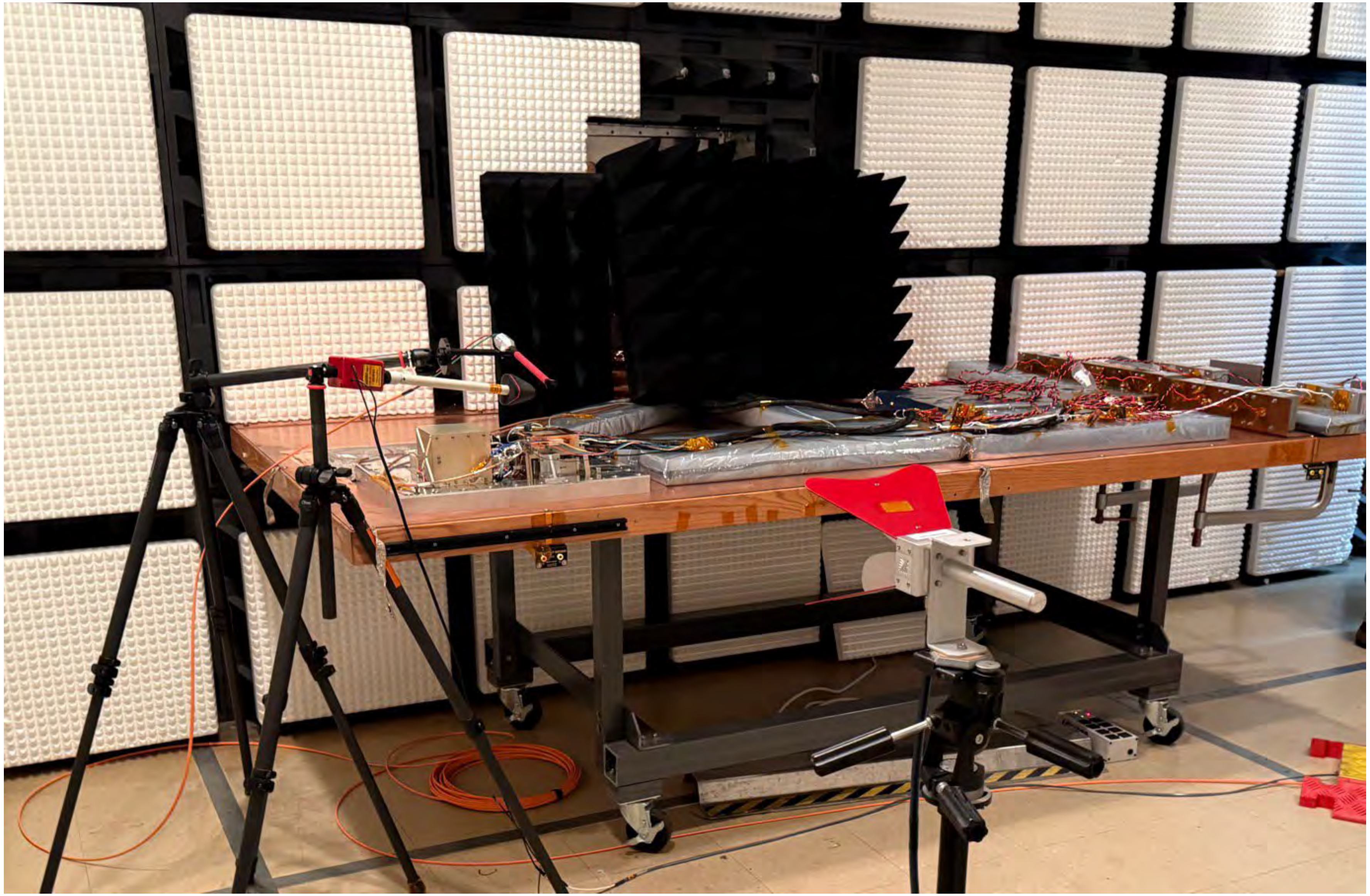
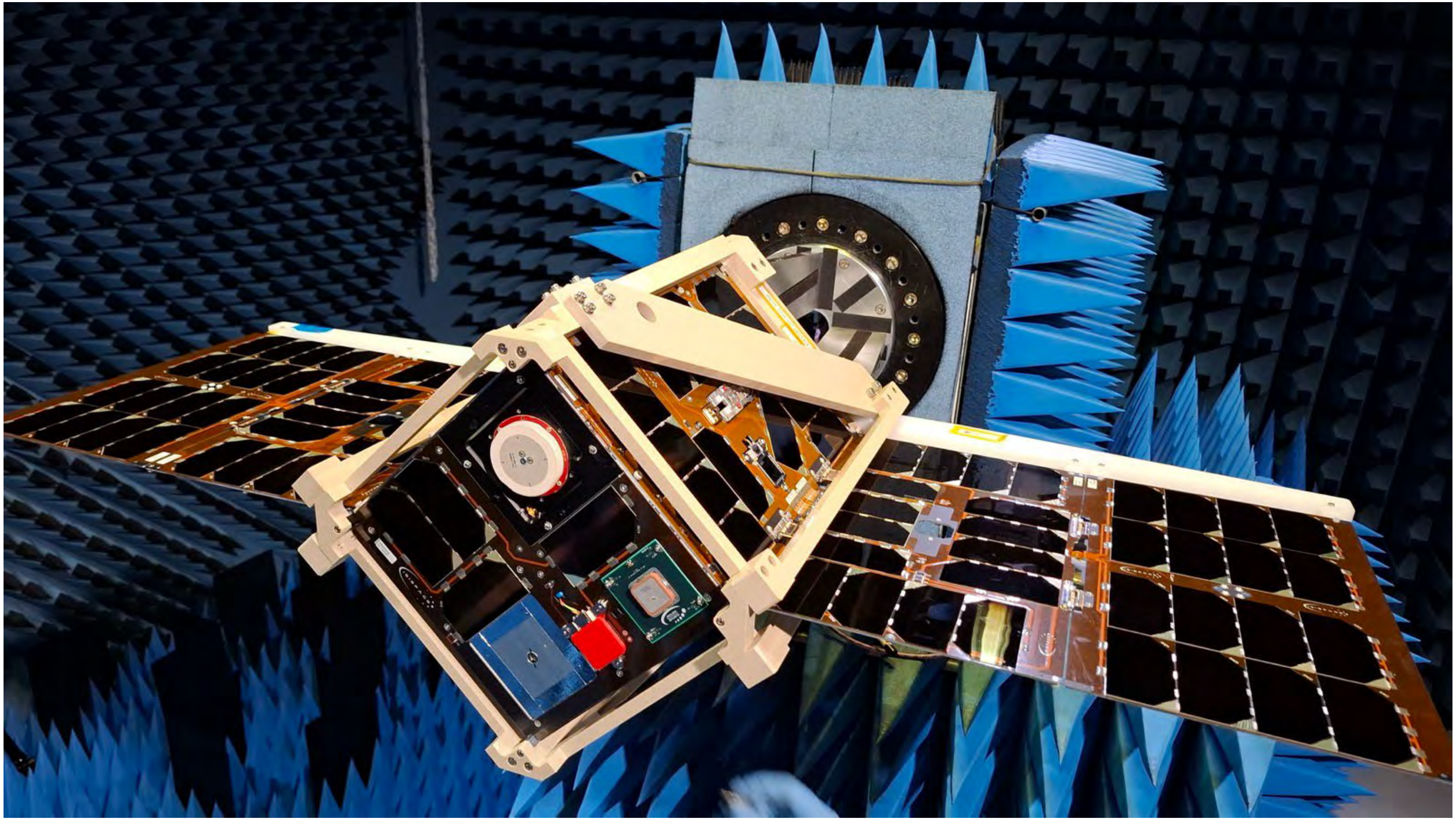


Instrument EMI Testing at GSFC



Integration with Spacecraft at ISISpace

Antenna Characterization at ESTEC



Summary

- GRITSS will demonstrate a space-tie using the novel approach of transponding the GPS signals to a VGOS antenna enabling it to be in Low Earth Orbit with view of only one VGOS station at a time.
- Instrument is fully integrated with the spacecraft and in the last stages of testing.
- 🚀 Scheduled to launch on SpaceX Transporter-17 in June 2026.

WG1: Points for discussion & further development:

1. **Genesis Mission Design / System Aspects:**
   - Calibration issues: Further studies on accuracy requirements / impacts of insufficient calibration
   - Investigations on possible interference between instruments
   - Further aspects & requests?
2. **Pilot Projects:**
   - Simulated Genesis orbit: Requests to ESA?
   - Procedure / Milestones / Schedule
3. **Genesis data**
   - Requests from the scientific community (processing level, formats,…)
   - Processing chain of Genesis data within/across IAG-Services
4. **Interrelation between Genesis & GRITTS data analysis**