Genesis

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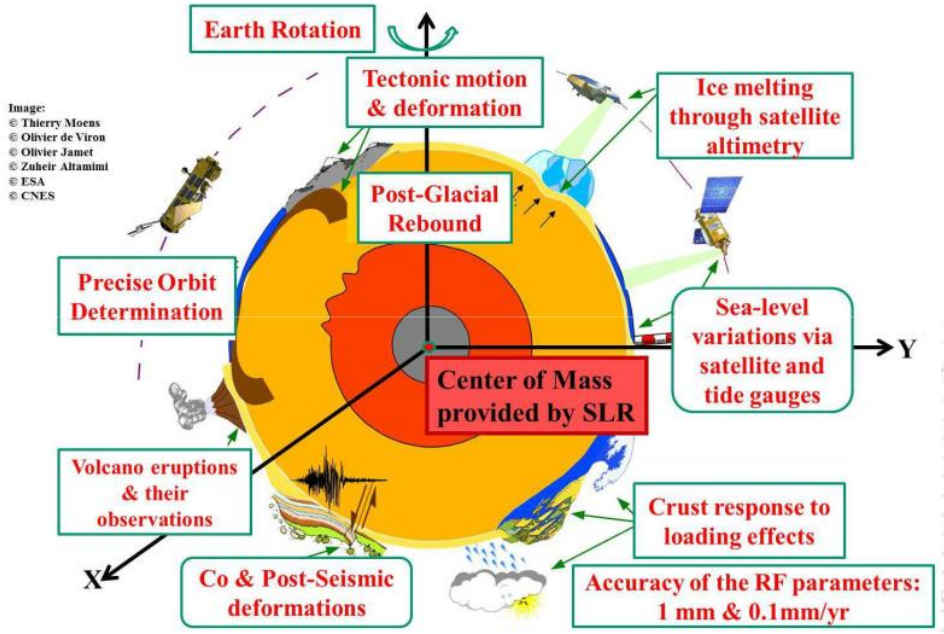
2025/01/21

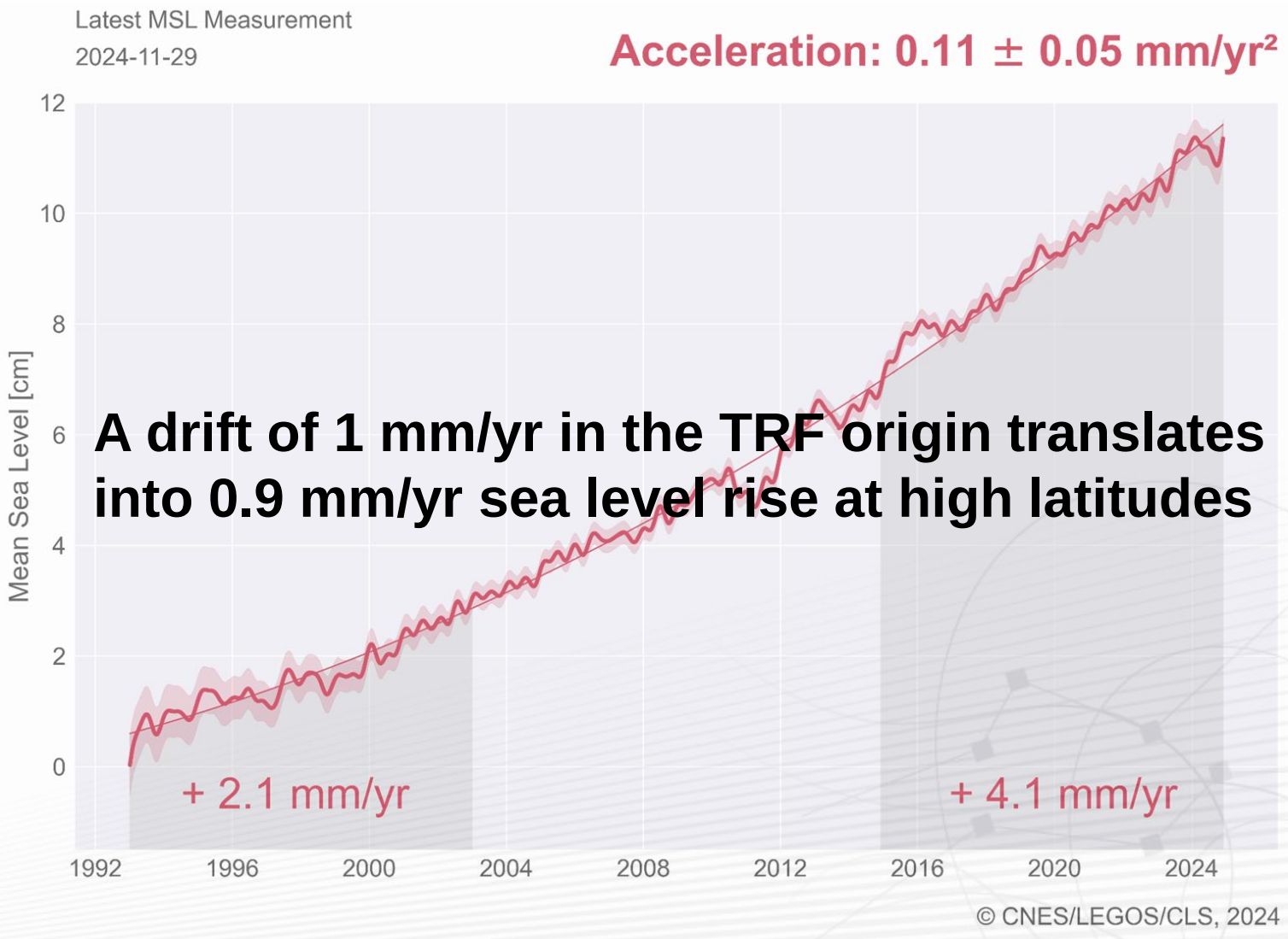
Context

Knowledge of Terrestrial Reference Frame (TRF) is fundamental for observing/determining

- plate tectonic,
- post-seismic deformations,
- regional subsidence,
- water cycle,
- impacts of climate change,
- sea level rise,
- precise orbits of Earth satellites,
- navigation and positioning,
- infrastructure development,
- …



TRF & Mean Sea Level Change



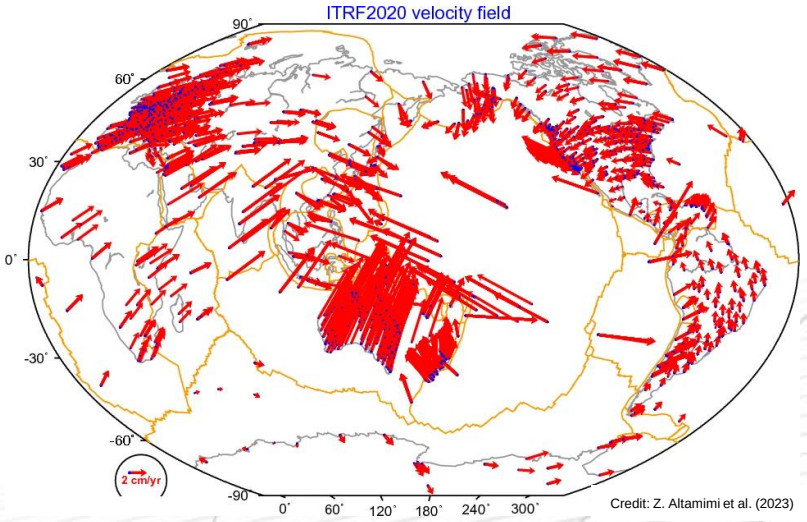
A drift of 1 mm/yr in the TRF origin translates into 0.9 mm/yr sea level rise at high latitudes

The International Terrestrial Reference Frame

Thus, the International Terrestrial Reference Frame (ITRF) has been defined and is realized/maintained by the International Earth Rotation and Reference Systems Service (IERS).

The origin of the ITRF is at the center of mass of the entire Earth including the oceans and atmosphere.

The ITRF is currently provided by precisely determined coordinates and velocities of physical points on the Earth's surface.



Credit: Z. Altamimi et al. (2023)

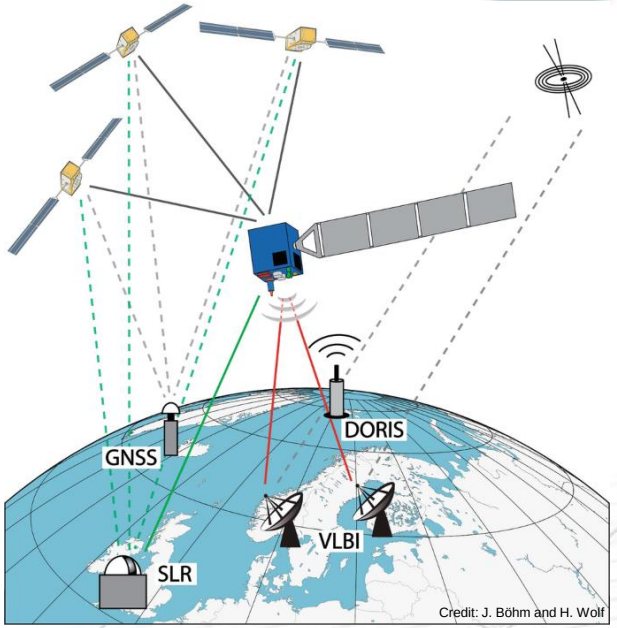
Since the creation of IERS in 1988, fifteen ITRF versions were published, starting with the ITRF88 and ending with ITRF2020-u2023 (released in 2024/12).

Current ITRF Realization

The computation of the ITRF is based on a rigorous combination of different TRF solutions estimated by observations from the four space geodetic techniques:

- ✓ Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS),
- ✓ Global Navigation Satellite Systems (GNSS),
- ✓ Satellite Laser Ranging (SLR),
- ✓ Very Long Baseline Interferometry (VLBI).

+ terrestrial local tie measurements conducted at co-location sites (where two or more geodetic instruments operate) to connect the techniques.



Current ITRF Realization

Analysis Centers

Combination Center

IERS Production Center

IDS

Weekly DORIS Solutions

IGS INTERNATIONAL GNSS SERVICE

Daily GNSS Solutions

International Laser Ranging Service

Weekly SLR Solutions

IVS

Session-wise VLBI Solutions

Weekly IDS Combined Solutions

Daily IGS Combined Solutions

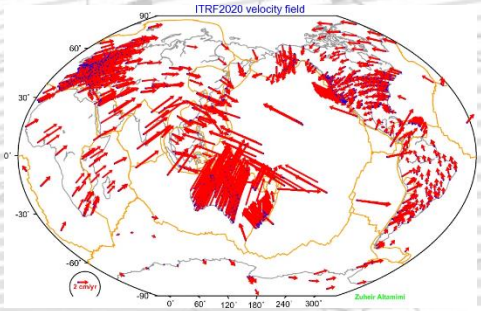
Weekly ILRS Combined Solutions

Session-wise IVS Combined Solutions

Terrestrial local ties

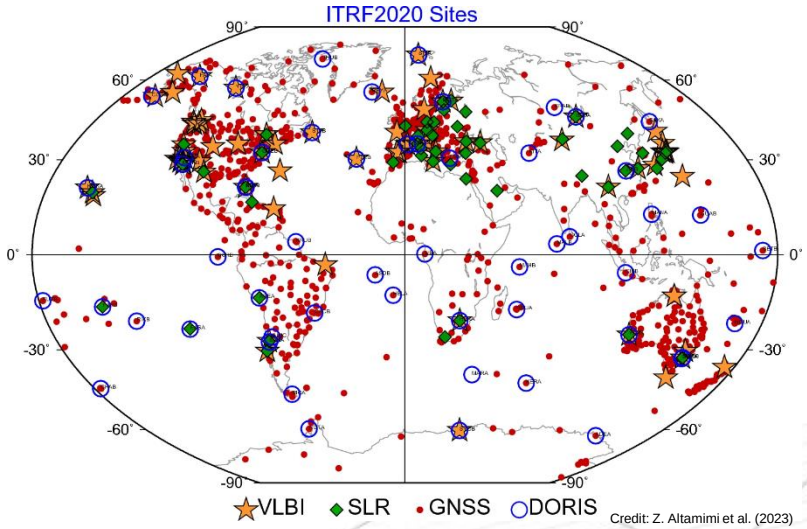
Inter-Technique Cumulative Solution
DORIS + GNSS + SLR + VLBI

ITRF



ITRF2020 Network and Tie Residuals

- ✓ **Number and geographical distribution of geodetic sites**
  - Poor/uneven distribution of the VLBI and SLR sites.
  - Few sites in Africa and Russia.
  - Very few (4) sites with the four techniques.

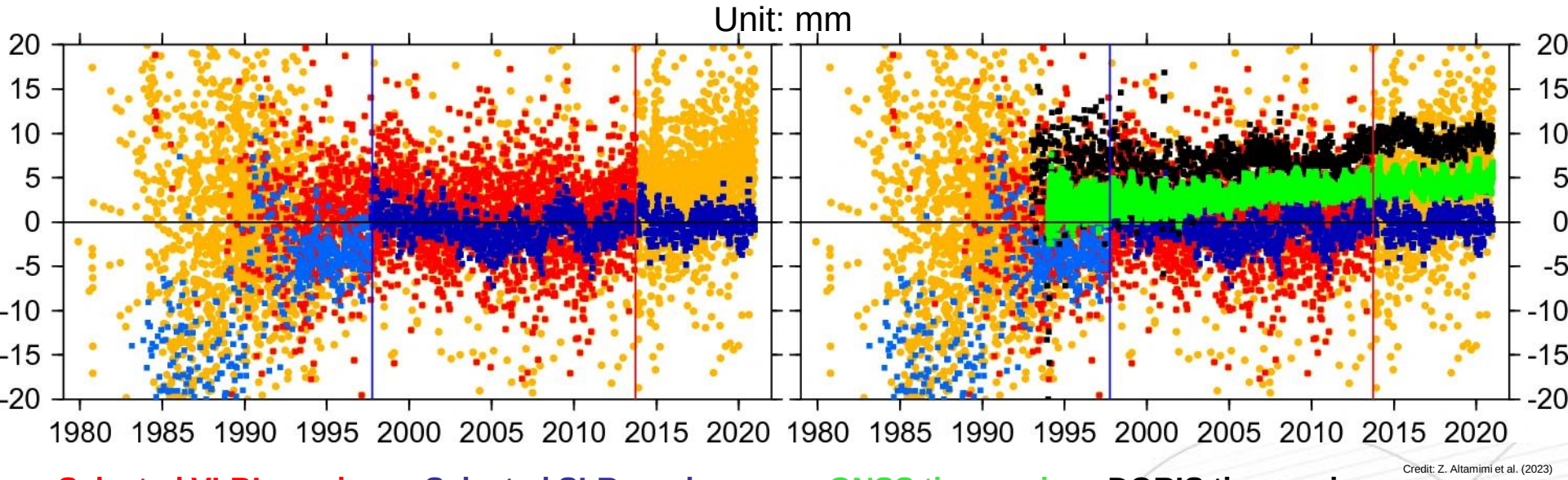


- ✓ **Tie Discrepancies** (=measured ties–coord. differences)

More than 50% of the tie discrepancies > 5 mm mainly due to technique systematic errors.

	# ties	% > 5mm
GNSS – VLBI	**77**	**50**
GNSS – SLR	**53**	**64**
GNSS – DORIS	**123**	**68**

ITRF2020 Scale



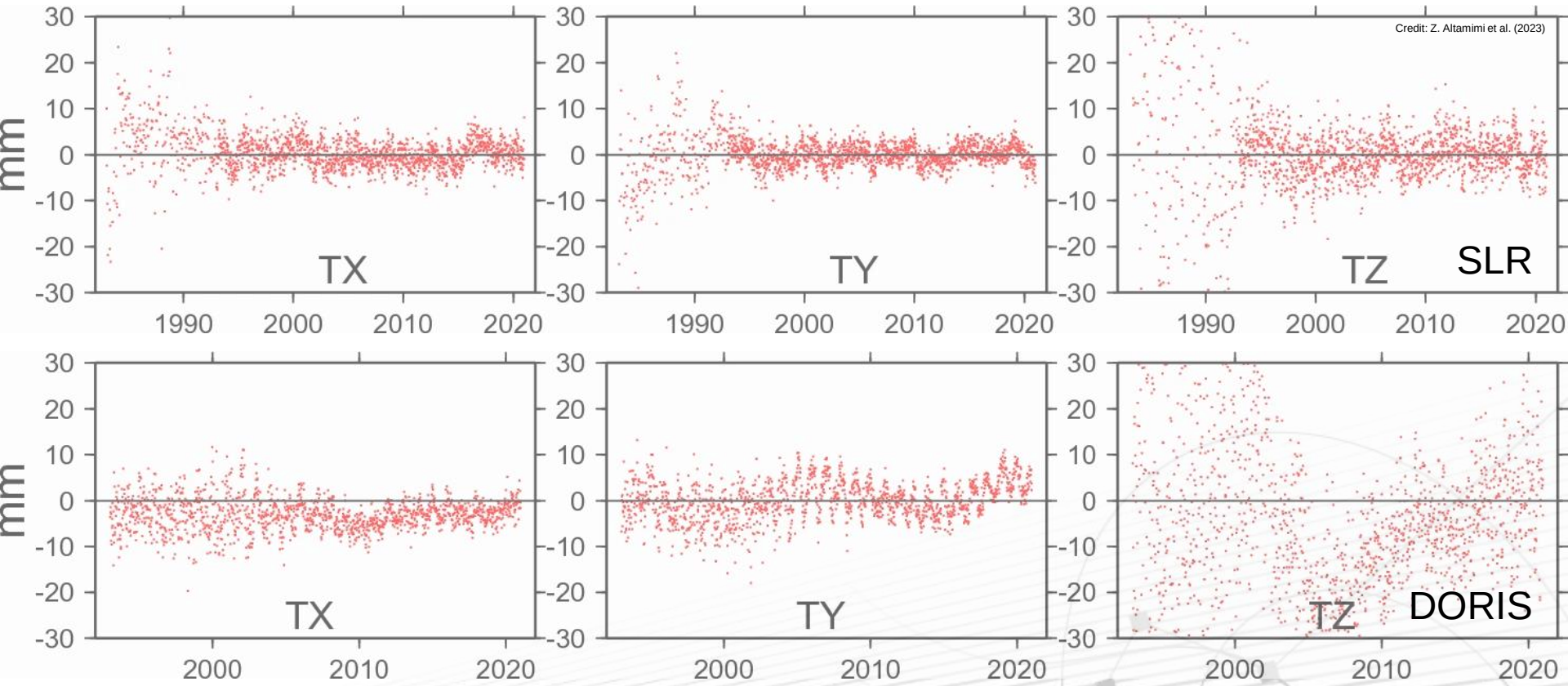
Credit: Z. Altamimi et al. (2023)

Selected VLBI sessions **Selected SLR weeks** **GNSS time series** **DORIS time series**
Rejected VLBI sessions **Rejected SLR weeks**

ITRF2020 scale and scale rate are averages of VLBI selected sessions and SLR weekly solutions.

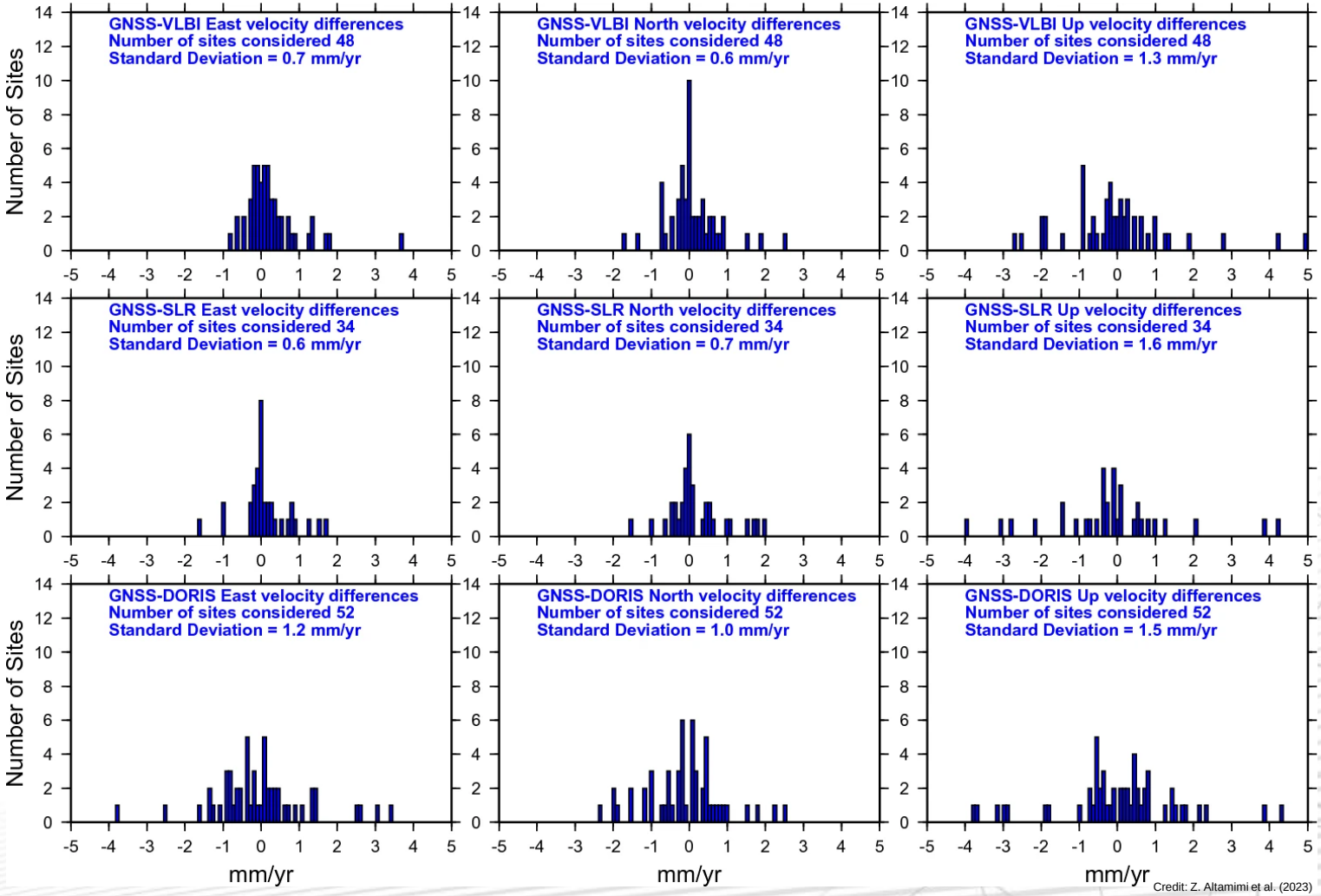
Mean scale offset between ITRF2020 and ITRF2014 is about 2.4 mm.

ITRF2020 Origin



Current accuracy and stability of the ITRF long-term origin achievable today is at the level of 5 mm in position and 0.5 mm/yr in time variation

ITRF2020 Velocity Discrepancies

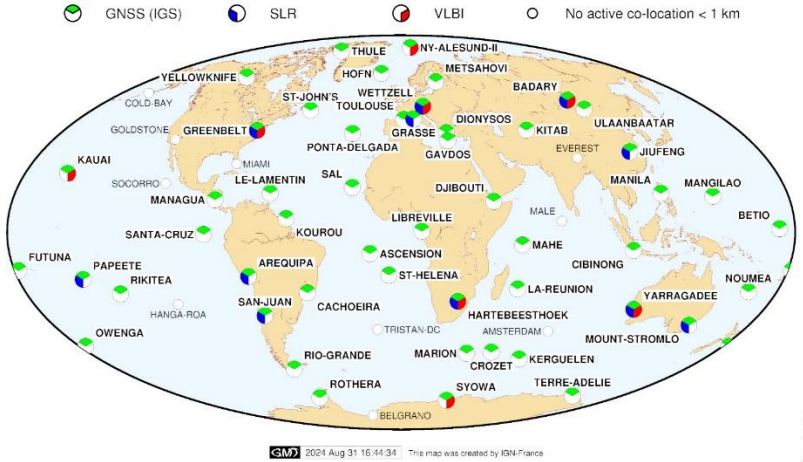


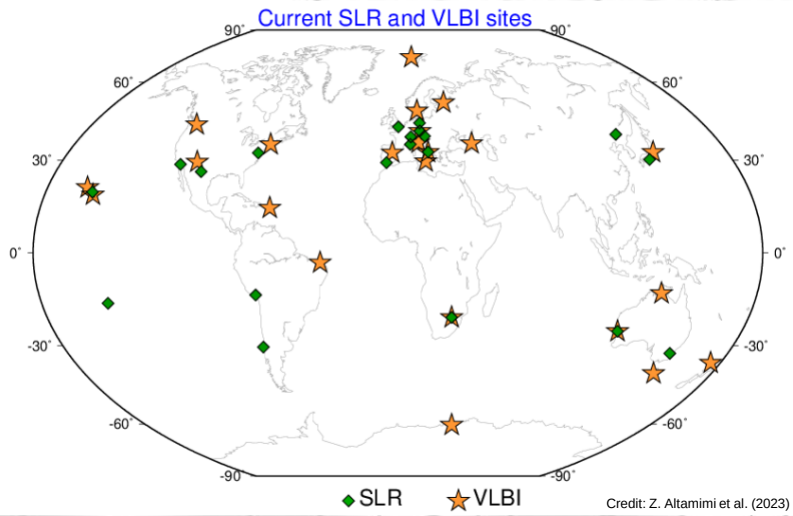
Credit: Z. Altamimi et al. (2023)

caused mainly by technique systematic errors

Main issues of the ITRF Realizations

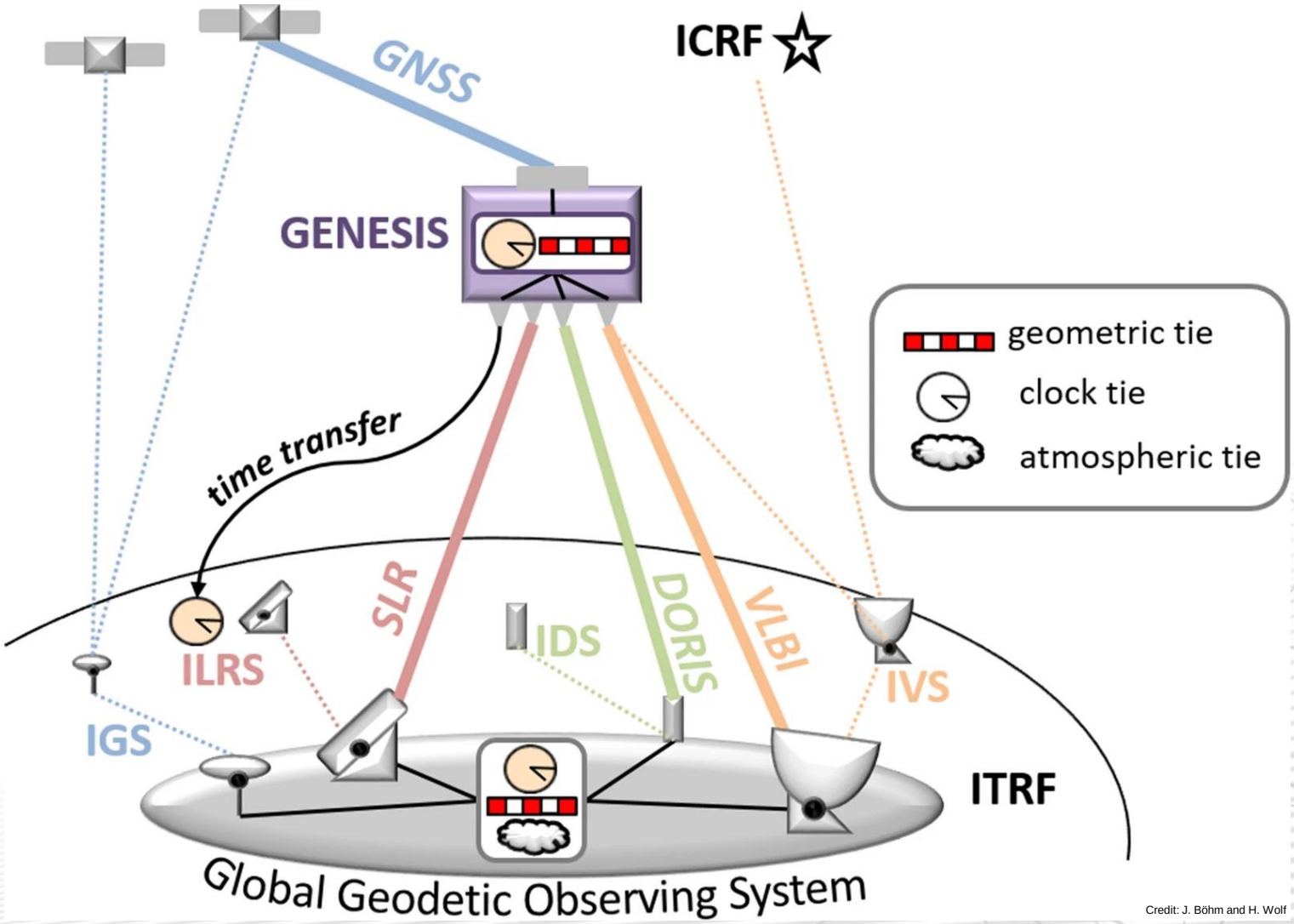
- ✓ Number and accuracy of the measurements of the **local ties** between the reference points of different techniques.
- ✓ Poor/uneven distribution of the **SLR and VLBI stations** but fundamental for the ITRF definition.
- ✓ Each space geodetic technique suffers from its own **systematic effects:** range biases, phase centers, multipath, solar radiation pressure, South Atlantic Anomaly, gravitational sag, tropospheric refraction, quasar structures, ...





Credit: Z. Altamimi et al. (2023)

Concept of TRF Space Geodetic Mission

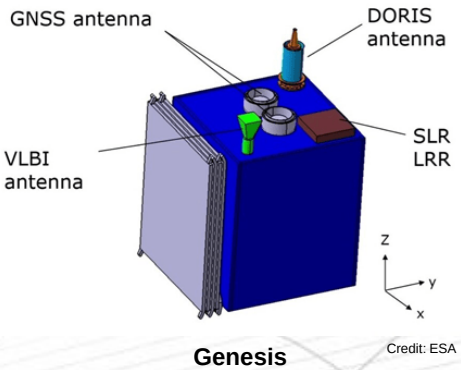


Credit: J. Böhm and H. Wolf

Benefits of TRF Space Geodetic Mission

One satellite

- ✓ Four geodetic techniques + same clock + same body ➔ understand/reduce systematic errors by looking at the single technique satellite CoM time series.
- ✓ Same clock ➔ onboard clock ties.
- ✓ Four techniques ➔ space ties.



Genesis Credit: ESA

Simultaneous observations at co-located sites

- ✓ Simultaneous observations at same site ➔ ionospheric ties.
- ✓ Same meterological conditions ➔ tropospheric ties.
- ✓ Same local conditions ➔ differences between single technique coordinate time series may result from systematic errors and may be of interest for understanding ground tie discrepancies.
- ✓ Connected clocks ➔ facilitate studies on systematic errors
  ➔ ground clock ties.

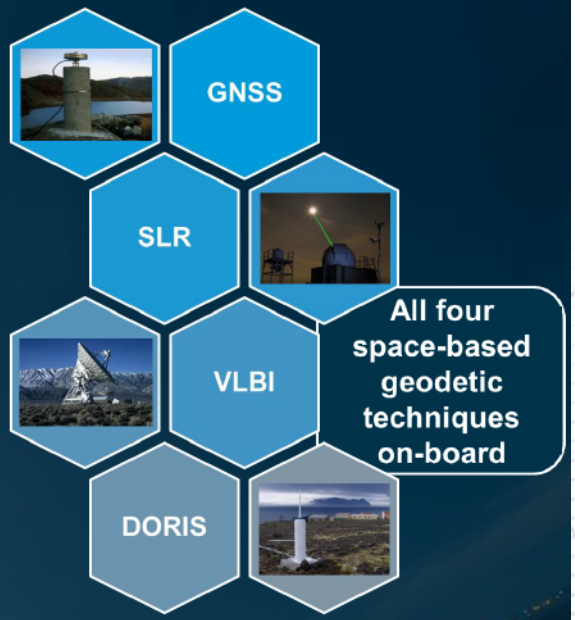
Overview of the GENESIS Mission

Overview

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

Mission scope

- Design, development and qualification 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)



Genesis Satellite Payload

GENESIS Satellite and Payload Overview

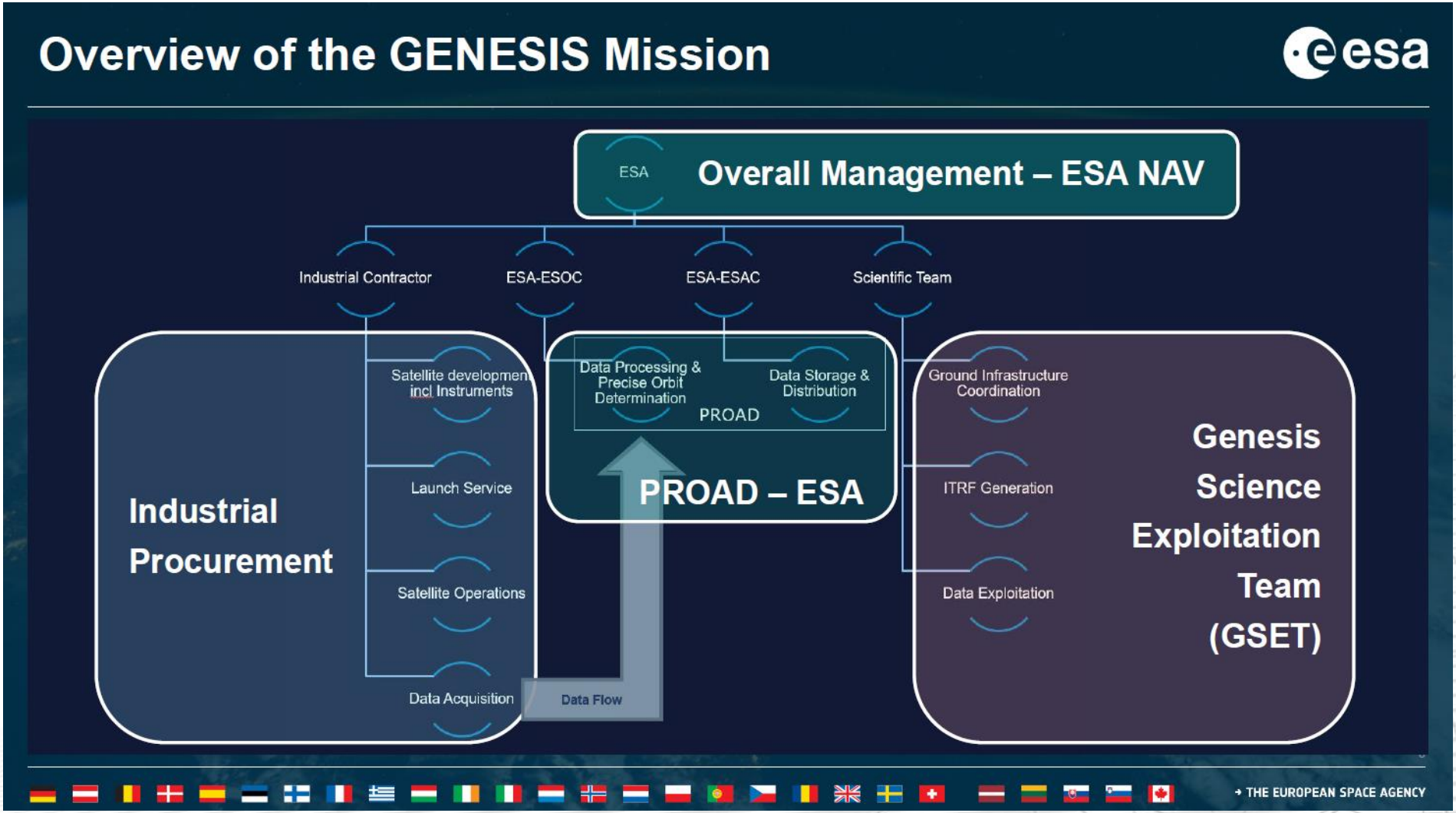
Description

- Single satellite ~250-300kg, ~6000km alt. (MEO), ~95° 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

ESA Organization



GENESIS Science Exploitation Team (GSET)

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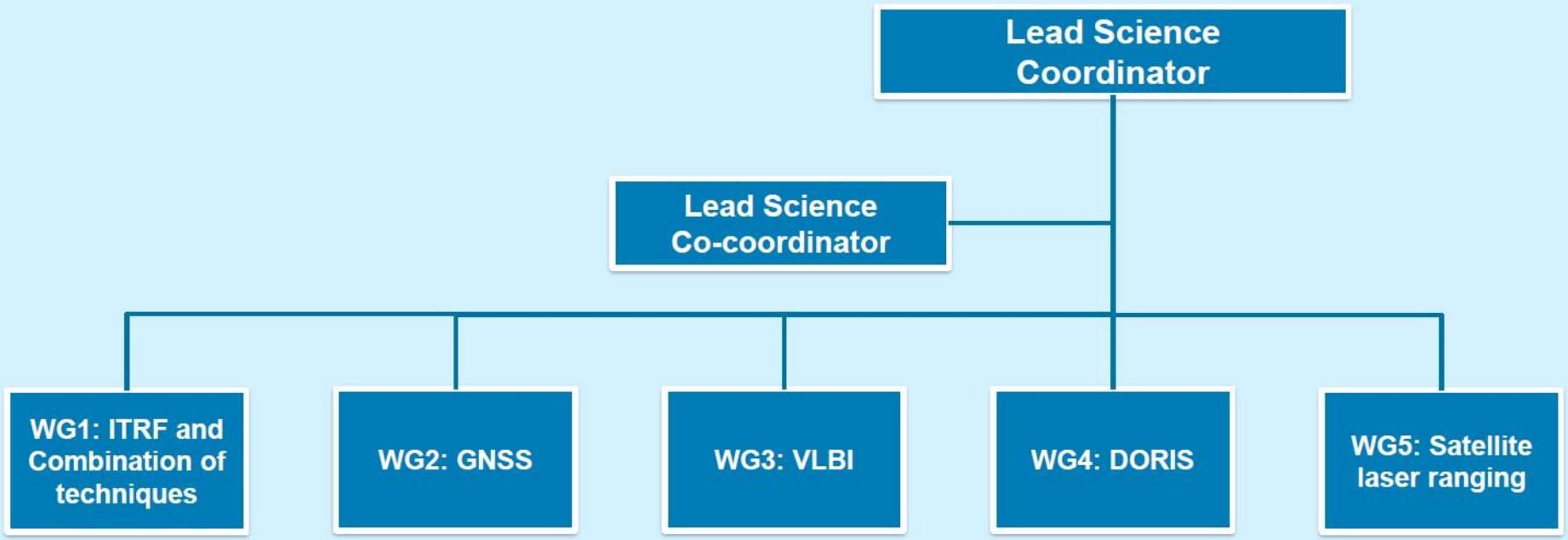

Extensive interactions across WGs will be essential as the mission objectives can only be achieved with a combination of the geodetic techniques and an extensive availability of auxiliary data

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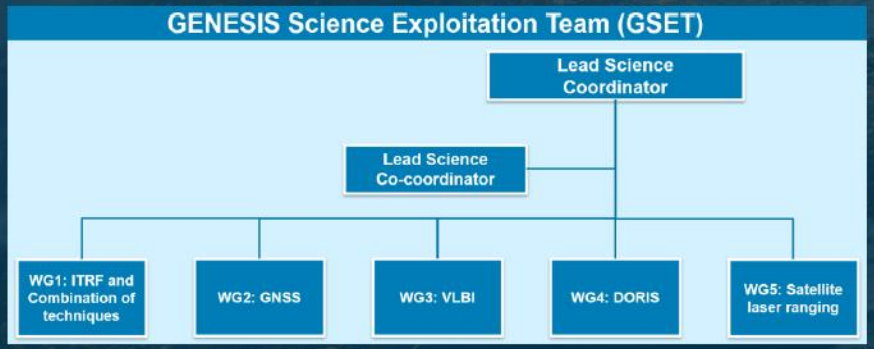
GSET Tasks

GENESIS Science Exploitation Team (GSET)



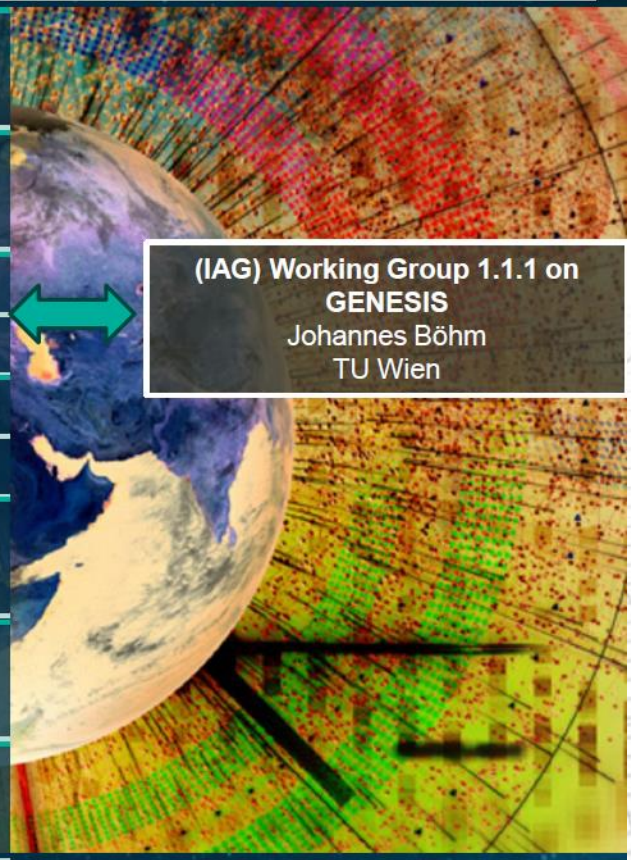
TASKS

- Coordinating the scientific activities of the GENISIS mission and acting as one of the 3 mission pillars together with ESA and industry
- Acting as advisory group to the ESA GENESIS project team for all aspects related to performance requirements and assessing the compliance to the mission objectives
- Advising on requirements changes
- Supporting the ESA GENESIS project team in the follow up of the developments, qualification and operations planning and execution
- Ensuring an extensive data exploitation of the GENESIS
- Assisting in the calibration, processing and validation of the GENESIS mission data

GSET WG Chairs

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

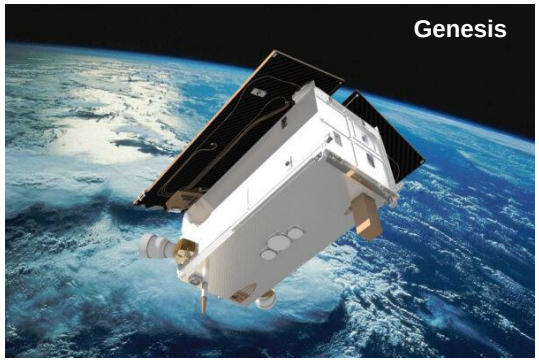
→ THE EUROPEAN SPACE AGENCY

Mission Status

Some Genesis Open Issues

On the satellite (manufactured by OHB Italia)

- ✓ USO selection.
- ✓ Orbit inclination.
- ✓ Solar panels: numbers and positions.
- ✓ …



Credit: OHB Italia

On the observations

- ✓ Unusual altitude ➔ DORIS Dopller collisions, GNSS PCV at low elevations, size of the laser reflector, VLBI sessions, …
- ✓ Contribution to the ITRF
  - ✓ Like nowadays: one contribution per Combination Center.

    Genesis may be used to reduce the systematic errors.
  - ✓ Combination at the observation level: full benefit of the space/atmospheric/clock ties.

  Requires a complete review of the Combination Center deliveries.