GENESIS

Mission Summary – CDF ESA Assessment

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GENESIS

GENESIS-1 Mission Proposal

Presentation of the results and outcome of the CDF study

Recall of GENESIS Programme Context and GENESIS-1 Proposed first Mission

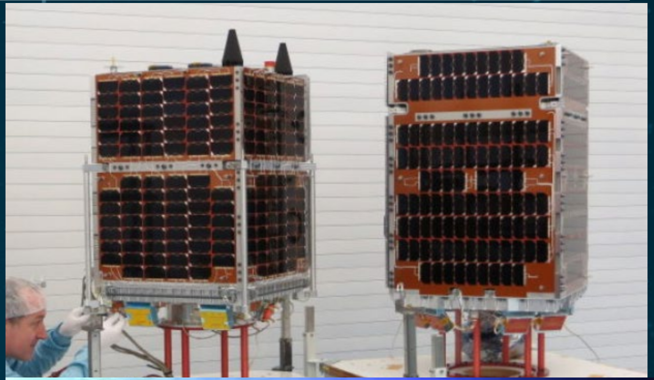

Geodesy
& Geophysics
Remote sensing of land, ocean and ice
Neutral and Ionized Atmosphere Sciences
Metrology
Missions where precise positioning and/or timing, and/or the use of GNSS signals is the basis of the experiment
Quantum Physics
Time & Frequency transfer
Fundamental Physics (relativity, etc)

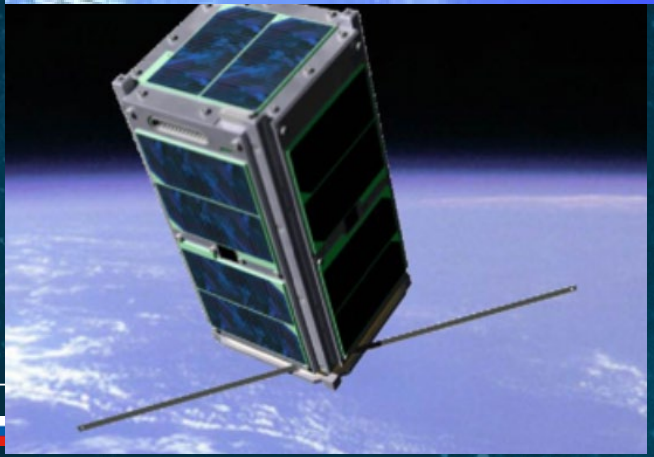
GNSS SCIENCE MISSIONS: BASED ON THE USE OF SMALL SATELLITES

Envisaged NAV Science missions could be implemented through small MEO and/or LEO satellites, typically in the range of 200-400 Kg (for MEO) and 50-200Kg (for LEO).

The use of standard, low-cost platforms and new-space approaches will be favoured to lower the cost of the missions.

For some scientific experiments, the deployment of small Cubesat dedicated constellations may also be considered





Some potential Candidates for future GENESIS Missions

- **First ever space-colocation of all space-based geodetic techniques GNSS, VLBI, SLR and DORIS Complementing ground-based co-location**

- **Precise Optical Time Transfer in space**: Most precise optical time transfer demonstration over free-space supporting global-scale geodesy and high-accuracy time-frequency distribution. This could in turn become a major source of dedicated scientific tests (e.g. tests of fundamental Physics in general relativity, etc) and new applications.

- **PNT Missions in support to Fundamental Physics:** A large number of scientific breakthroughs (or pathfinders for future scientific tests) in the field of fundamental physics based on precise time and orbit determination and/or by setting up very accurate metrological intersatellite relative positions with ultra stable on-board clocks via a dedicated NAV Science missions.

- **Advanced modelling of non-gravitational forces:** dedicated experiments and technologies for the accurate modelling of non gravitational forces (e.g. sun radiation pressure). This could in turn allow the development of enhanced orbitography techniques including dynamic models of high interest for science and future navigation missions

NAV Science Missions – Proposed Programmatic Approach

Objective = a dedicated GENESIS Mission per every 3-4 years

CMin prep | **CMin 2022** | **Period 1** | **CMin 2025** | **Period 2** | **CMin 2028** | **Period 3**

CMin 2022: Decision on New NAV Programme + Subscription to Period 1 activities

CMin 2025: Decision on Programme Continuation + Subscription to Period 2 activities

CMin 2028: Decision on Programme Continuation + Subscription to Period 3 activities

CMin prep

- Selection of a **first Pilot NAV Science Mission**
- **CDF detailed Mission analysis and cost**
- Identification of top candidate Missions for future analysis
- Programme Proposal and legal documents for a new NAV Envelop Programme

Period 1

- Setting-up of formal **Evaluation Committee**
- **Partnership developments** with relevant International and national entities
- **Development & Launch of first pilot NAV Science Mission (launch 2027)**
- Implementation **Phase 0/A/B1 activities / CDF** for future candidate NAV Science Missions
- Research and Pre-development activities for identified instruments / equipments
- **Assessment and selection of future NAV Science Mission for implementation in Period 2 and launch** (launch 2029)

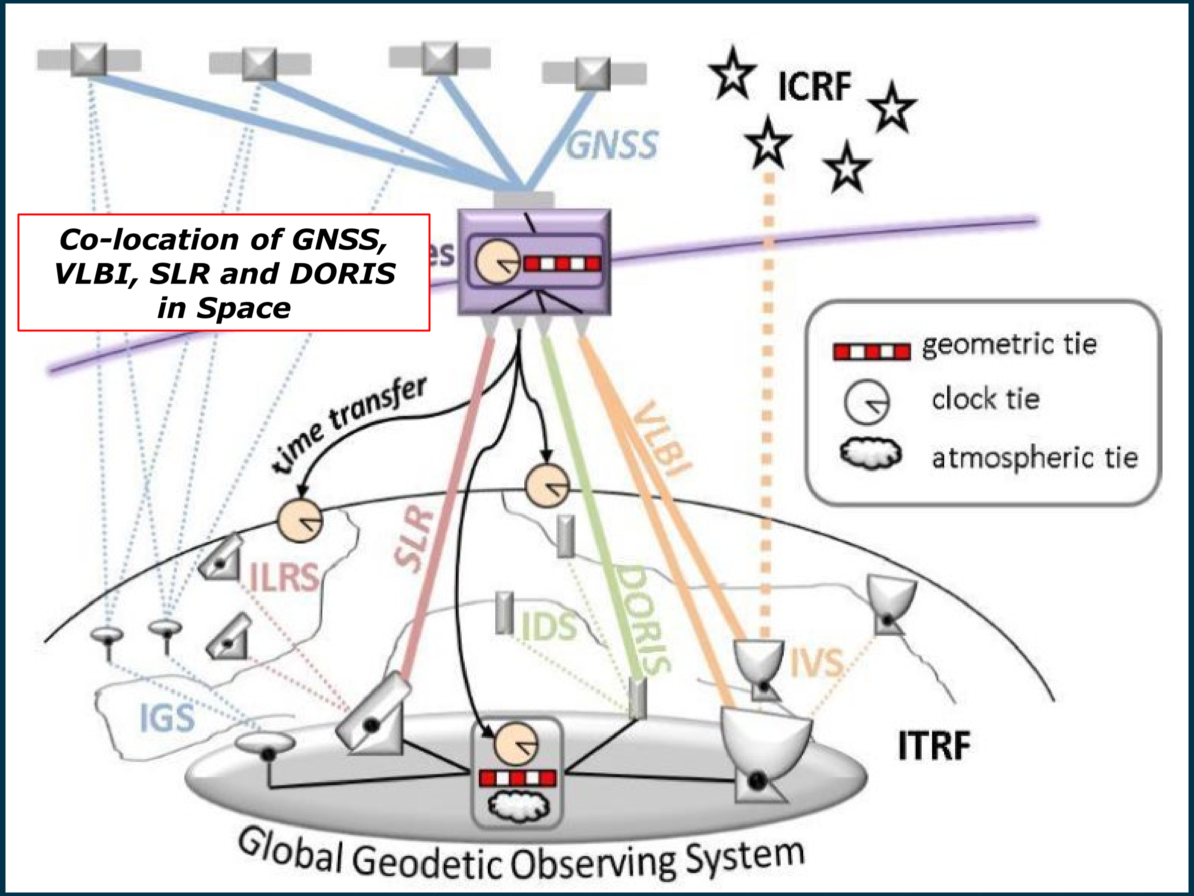
Period 2

- **Partnership developments** with relevant International and national entities
- **Development & Launch of second selected NAV Science Mission**
- Implementation **Phase 0/A/B1 activities / CDF** for future candidate NAV Science Missions
- Research and Pre-development activities for identified instruments / equipments
- **Assessment and selection next NAV Science Mission** for implementation in the period 2029-2031 (Period 3)

Period 3

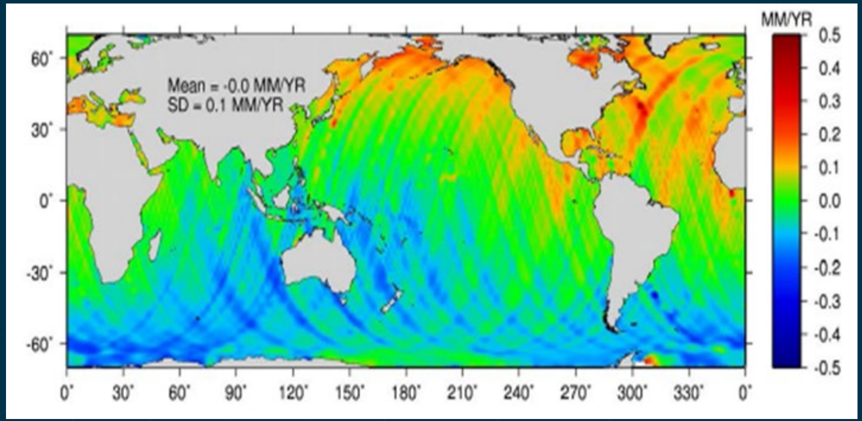
- **Development & Launch** selected NAV Science Mission
- Assessment and selection of NAV Science Missions for implementation in the next period
- ….

GENESIS-1 (proposed as first mission): GEODESY AND GEOPHYSICS



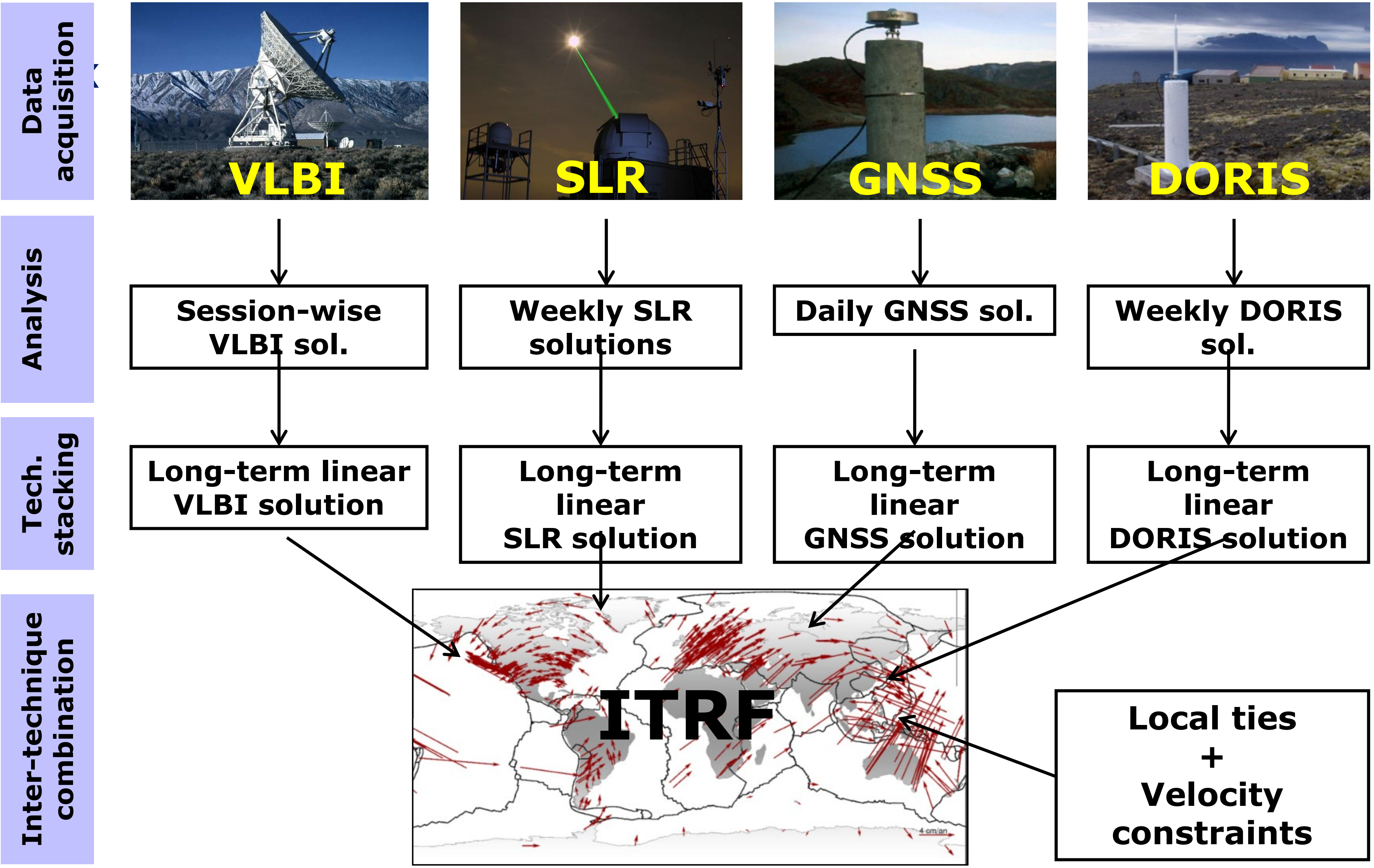
First time ever space-colocation of all space-based geodetic techniques GNSS, VLBI, SLR and DORIS Complementing ground-based co-location

- Coupled with high-precision time transfer (T2L2)
- Some major benefits:
  - ITRF major improvement (factor 5 to 10)
  - Improvement of EOP parameters
  - Altimetry and sea level rise
  - Ice mass loss
  - Improve geodetic datasets
  - Improvement of GNSS positioning
  - Improve the POD of all space missions

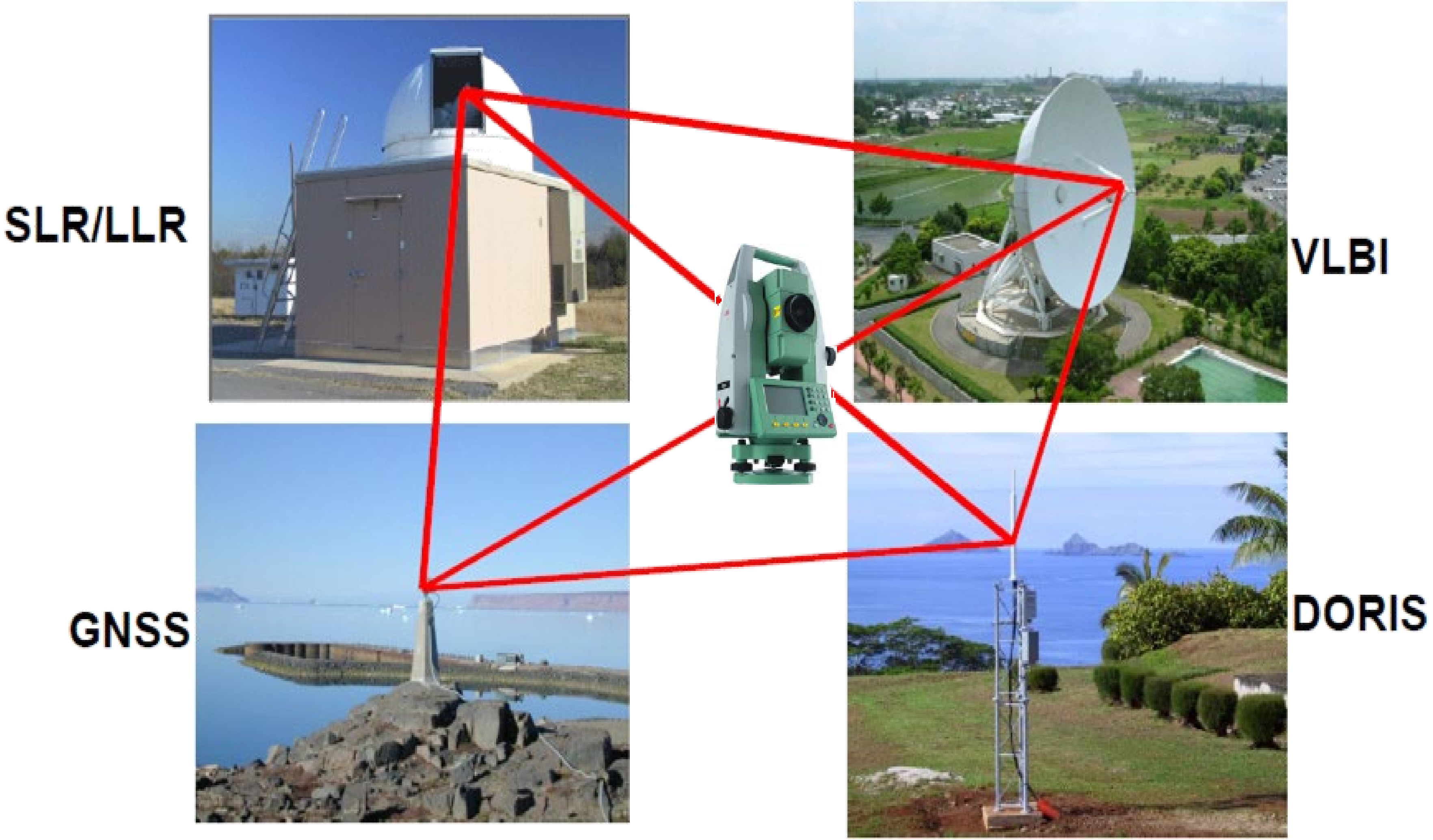


Jason-2 sea level trend difference between ITRF2014 and ITRF2008 (±0.5 mm/y)

ITRF elaboration

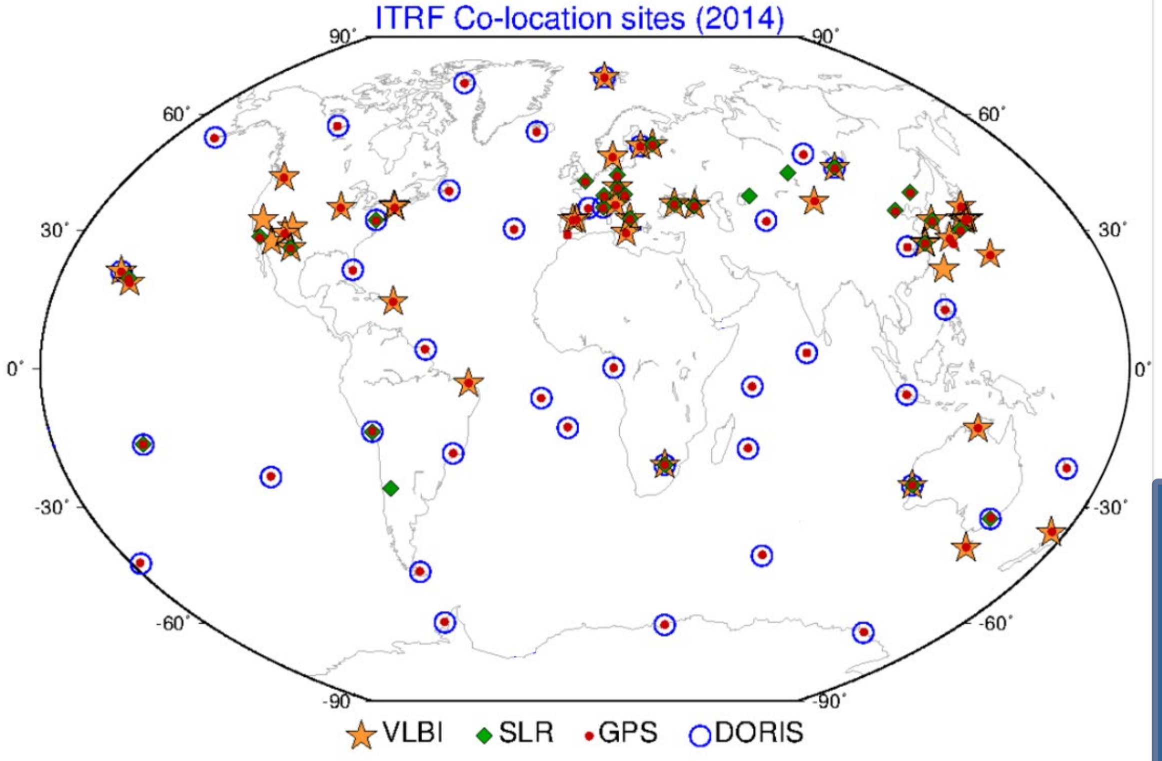


Terrestrial (local) ties



Credits: Z. Altamimi, ICG-7, Beijing, China, 5-9 November, 2012

Limits of the terrestrial tie approach

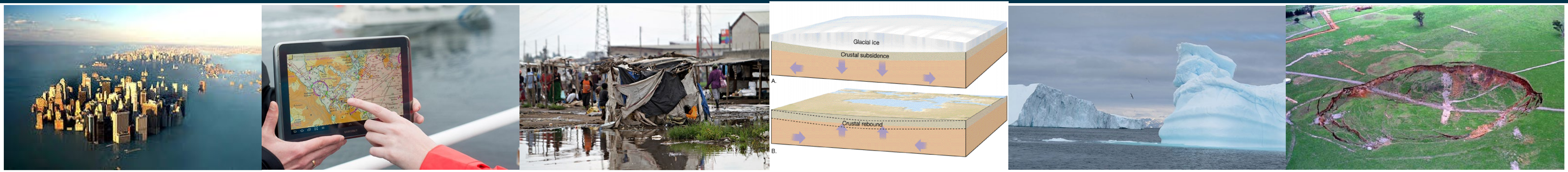


Courtesy of Dr. Z. Altamimi

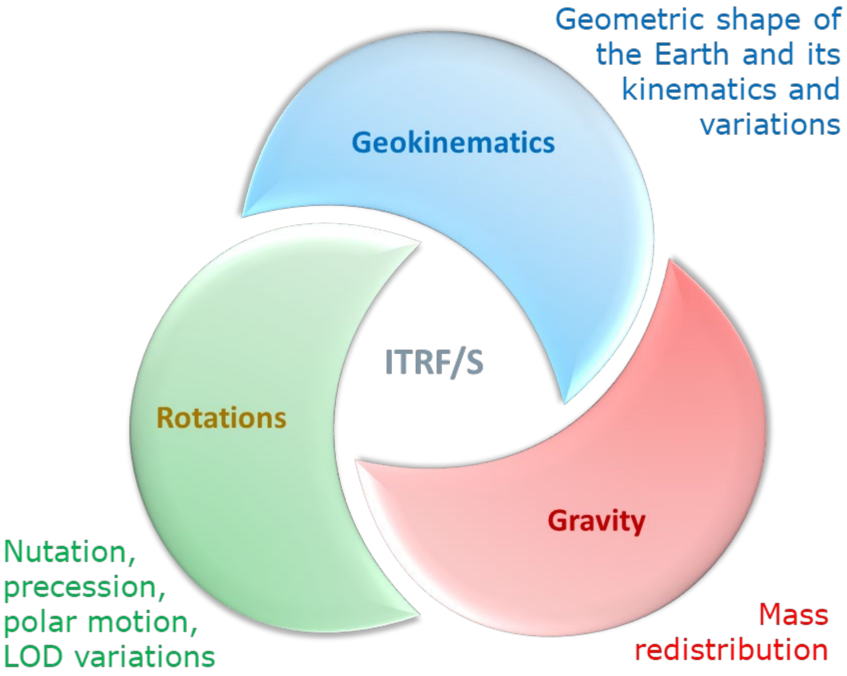
- difficulty to accurately measure the local ties between the reference points
- Inhomogeneous distribution and Unfrequently updated
- Discrepancies with space geodesy estimates due to systematic errors (e.g. discrepancies often at the level of 10 mm)

PROPOSAL: With GENESIS-1 we will co-locate and combine for the first time the four space-geodetic techniques GNSS, SLR, VLBI, and DORIS aboard a single well-calibrated satellite establishing precise and stable ties between the key geodetic techniques. A dynamic space geodetic observatory allowing to determine all the instrumental biases inherent to the different observing techniques simultaneously

ITRF: The foundation for all space- and ground-based observations in Earth Science and Navigation



Credits: UNGGRF http://www.unggrf.org/



Adapted from: Global Geodetic Observing System. Meeting the requirements of a global society on a changing planet, Plag and Pearlman Eds, 2009

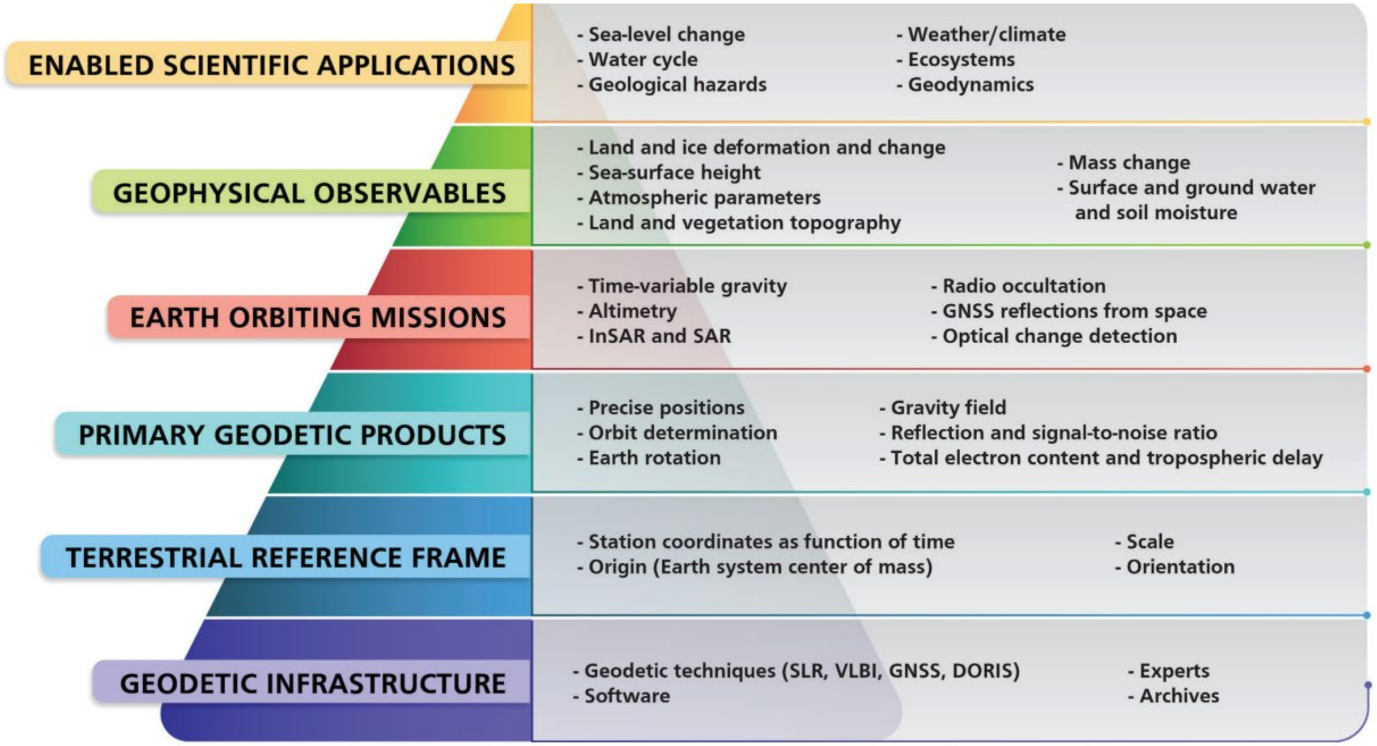
All navigation and positioning applications rely on accurate and reliable ITRF. The ITRF provides the foundation for all space- and ground-based observations in Earth Science.

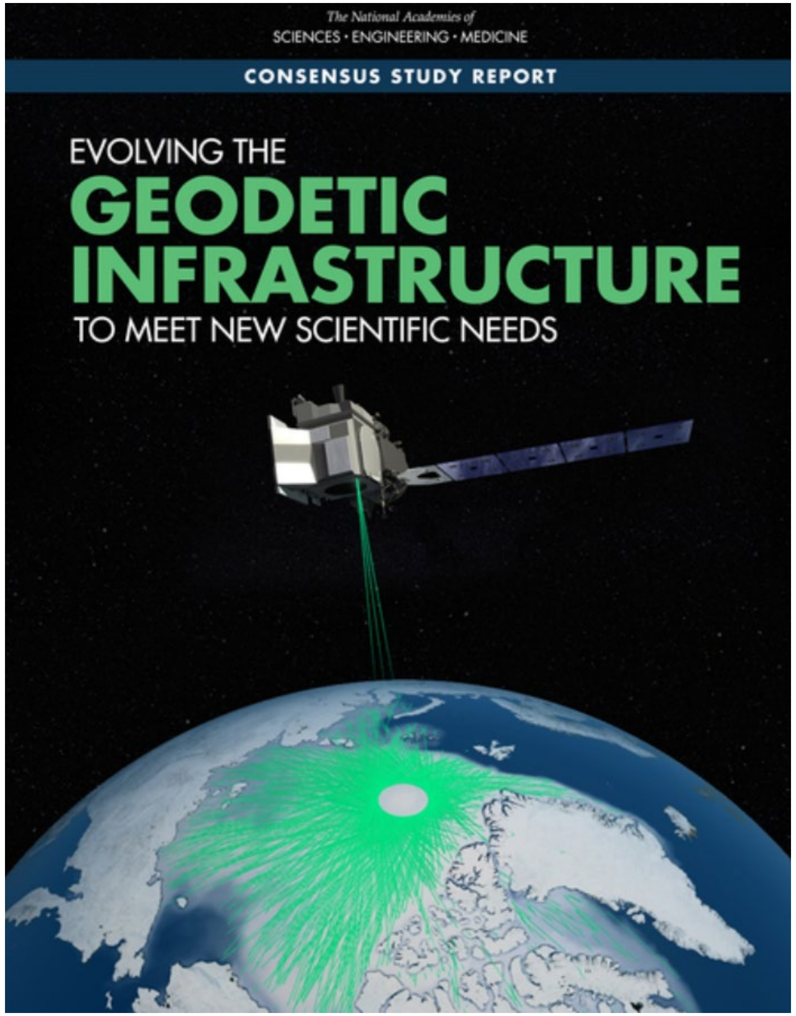
It is also essential for positioning and navigation in the civil society

Scientific applications drive the requirements for the realization of the frame parameters (GGOS defined goal and UN resolution A/RES/69/266):

accuracy: 1mm
stability: 0.1 mm/year

ITRF: The foundation for all space- and ground-based observations in Earth Science and Navigation





"The International Terrestrial Reference Frame (ITRF) underpins high priority science questions and associated space observational requirements for atmosphere and climate, weather, hydrology, ecosystems, and solid earth science."

(Source: US National Academy of Science- Engineering- Medicine)

SCIENTIFIC BENEFITS OF GENESIS-1 MISSION

1. **Geodesy**
   - Improvement of the International Terrestrial Reference Frame (ITRF) – reaching the goal of a Geodetic Global Observing System with position accuracy of 1 mm and velocity (rate) uncertainty of 0.1 mm/year (UN Resolution on sustainable development, A/RES/69/266).
   - Unification of reference frames and improvement of Earth rotation parameters
2. **Earth Sciences**
   - Improvements in sea level change measurements
   - Improvement of ice mass losses
   - Gravity field improvement (Long-wavelength)
   - Improvement of Earth radiation budget, etc
3. **Navigation**
   - Improvement on GNSS orbits and GNSS positioning
   - GNSS antenna phase centre calibration
   - Improvement on the POD of LEO satellites
4. **Metrology**
   - Time transfer demonstration over inter-continental level

Dedicated White paper produced by the Scientific Community

GENESIS-1 Mission: additional benefits

1. **Best ever GNSS Precise Orbit Determination (POD) achieved** in orbit (mm level)
2. **The most precise modelling of the non-gravitational forces** affecting an earth rotating satellite (precise modelling of the optical and thermal material properties (absorption, reflection and such) of the satellite; on-board accelerometer option)
3. First ever VLBI **long baseline** observation from an artificial satellite
4. Unique detailed **Inter-technique orbit validation experiment**
5. **Validation of multiple instruments of potential interest in future Galileo satellites**
   - VLBI
   - DORIS
   - On-board accelerometer
   - ALR
6. **Creating a plethora of new potential market opportunities**: a major increase on the overall accuracy, stability and availability of geodetic datasets may stimulate the creation of a plethora of enhanced or new applications. Some of the industrial fields that may benefit include: intelligent transportation industry; timing industry; sensors & Internet of Things (IoT); surveying industry; etc.

CDF Study Summary

CDF Study Calendar

CDF Study Team (About 50 experts involved) with dedicated joint working sessions and detailed topic splinter meetings during 1.5 months

Session	Day	Date	Hour
Kick-Off (KO)	Tuesday	08 March	09:30 - 13:30
Session #2	Thursday	10 March	09:30 - 13:30
Session #3	Tuesday	15 March	09:30 - 13:30
Session #4	Thursday	17 March	09:30 - 13:30
Session #5	Tuesday	22 March	09:30 - 13:30
Session #6	Thursday	24 March	09:30 - 13:30
Session #7	Thursday	31 March	09:30 - 13:30
Internal Final Presentation (IFP)	Thursday	07 April	09:30 - 17:00
Report Writing Session	Wednesday	13 April	09:30 - 16:00

CDF analysis performed (extensive and complete assessment)

- System Analysis
- Orbit Options
- Mission Analysis
- Chemical Propulsion
- Electrical Propulsion
- AOCS
- Communications
- Data Handling
- Power
- Thermal
- Structures
- Radiation
- Risks and programmatics
- Costs

CDF Study: Key System-level Requirements identified

1. A total of **<u>67 Requirements</u>** at system level initially identified for GENESIS-1 Mission:
   - 2 req. concern programmatics
   - 10 reqs. concern mission profile
   - 3 reqs. concern data storage and downlink
   - 2 reqs. concern On-board time management
   - 3 reqs concern S/C configuration
   - 4 reqs concern AOCS
   - 2 reqs. concern science operations
   - 13 reqs. concern VLBI performance and functionality
   - 8 reqs. GNSS performance and functonality
   - 8 reqs. concern DORIS performance and functionality
   - 12 req. concern LRR/ALR

Key High-level Design Drivers

1. Need to ensure selected Orbit allows VLBI Long Baseline observability
2. Radiation environment conditions
3. Accommodation of 4 Geodetic instruments on-board
4. Available launch options and associated Propulsion subsystem needs
5. Maximum mass for SSMS Vega-C launch (400kg)
6. Power optimisation in all mission phases
7. Adoption of flight equipment with the highest TRL available
8. Total mission cost to be reduced (~80-90 Meuros program range)

GENESIS-1: Mission specific Technical drivers

1. **Very Precise on-Board Metrology (calibrated ties)**: The offset between each payload and the satellite CoM shall be known with accuracy around 1 mm (TBC). Offset stability shall remain within 1 mm-level during the whole duration of the mission. (adequate thermoelastic materials, extremely accurate on-ground calibration tests).
2. **A common time reference for all on-board instruments (all geodetic instruments shall be referenced and synchronized to each other)**
3. **Highly accurate Precise Orbit Determination**: GENESIS-1 will have to be able to determine the orbit with TBD mm accuracy (best ever GNSS POD – requiring a high success rate Integer ambiguity resolution and very accurate radiation pressure model of the GENESIS-1 satellite
4. **Simultaneous operation of Geodetic techniques**: leads to MEO or HEO orbit selection, driven by VLBI long baseline observability.

GENESIS-1 Baseline Orbit selection

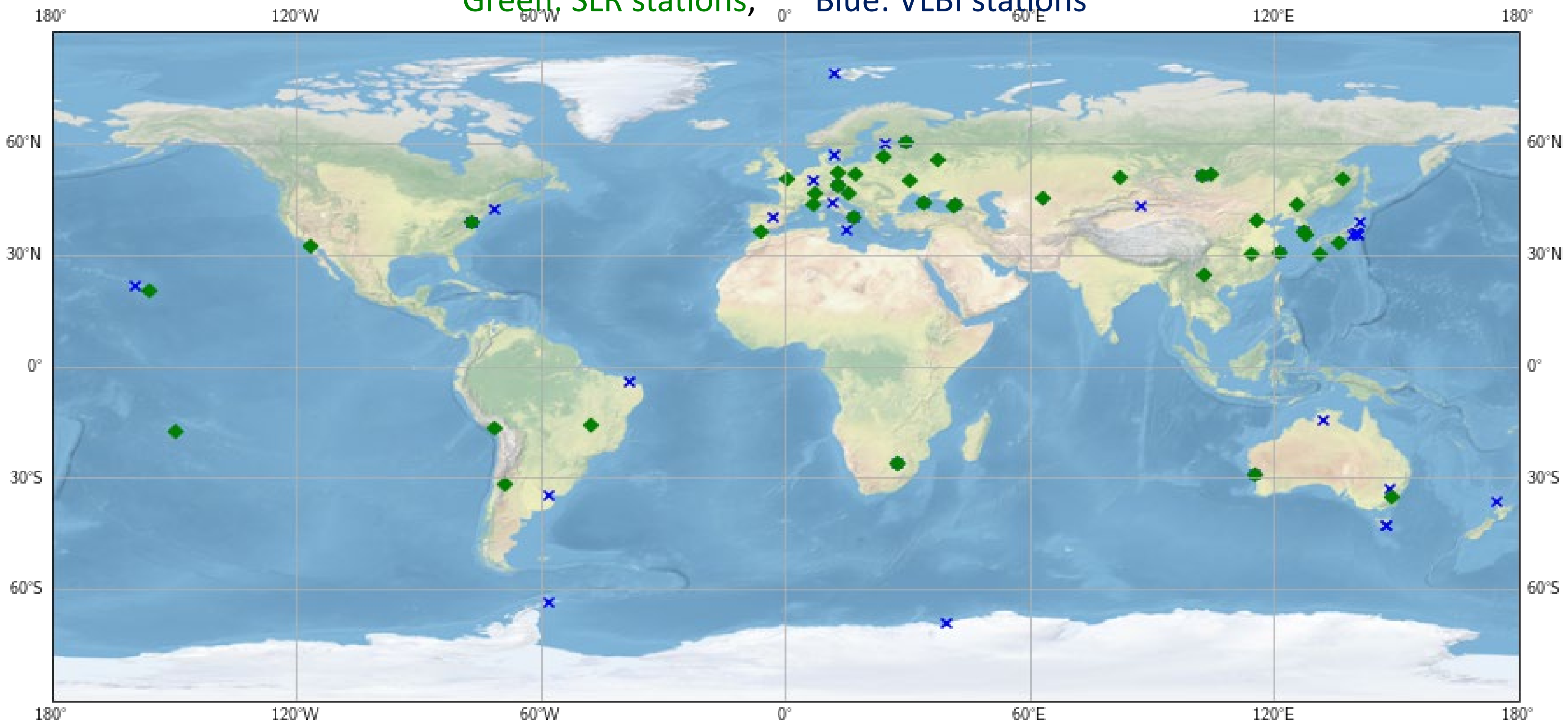
GENESIS-1 ORBIT SELECTION: MAIN TRADE-OFFS

The choice of the orbit for GENESIS-1 mission notably depends on the following factors:

1. Optimise in-orbit performances of the various payloads, guaranteeing *the maximum contemporary use of the 4 on-board geodetic techniques (and at least 2 at all times)* (with best performances).
2. Simultaneous visibility from different ground stations for the various geodetic techniques should be ensured (long baseline –intercontinental level- for VLBI observations)
3. GNSS satellites visibility and opportunity to meet POD stringer requirements.
4. Compatibility with launcher opportunities, taking into account cost-effectiveness of the selection.

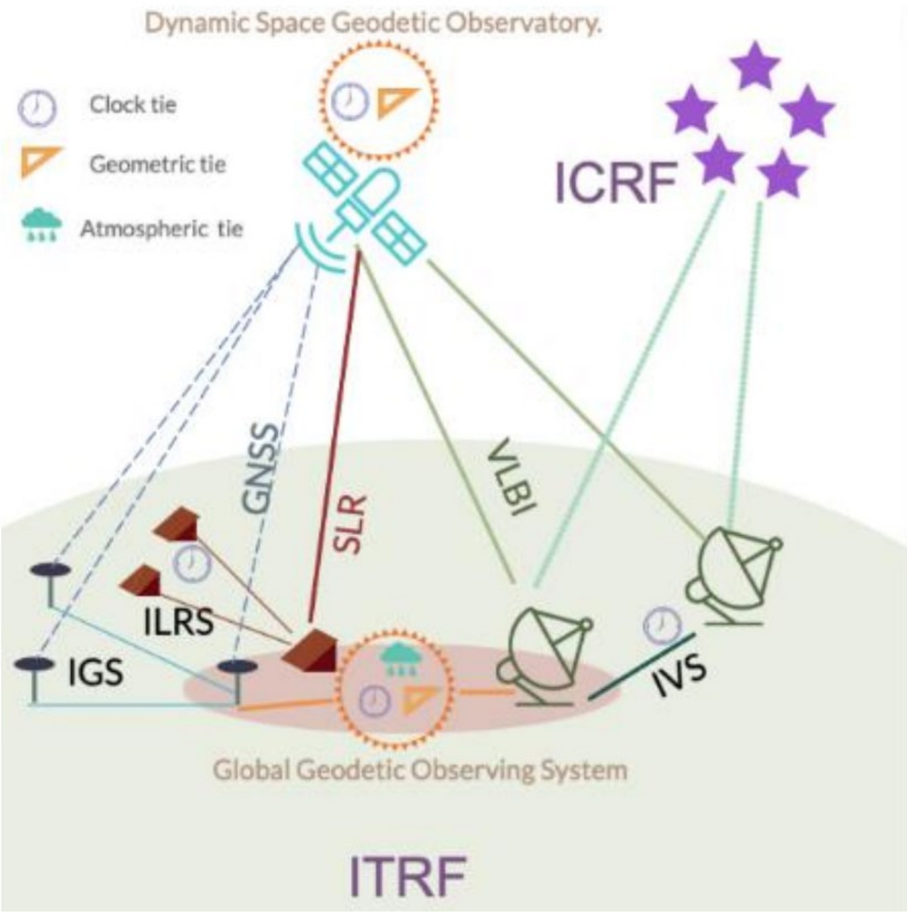
Existing Laser and VLBI world-wide Ground Stations

Green: SLR stations, Blue: VLBI stations

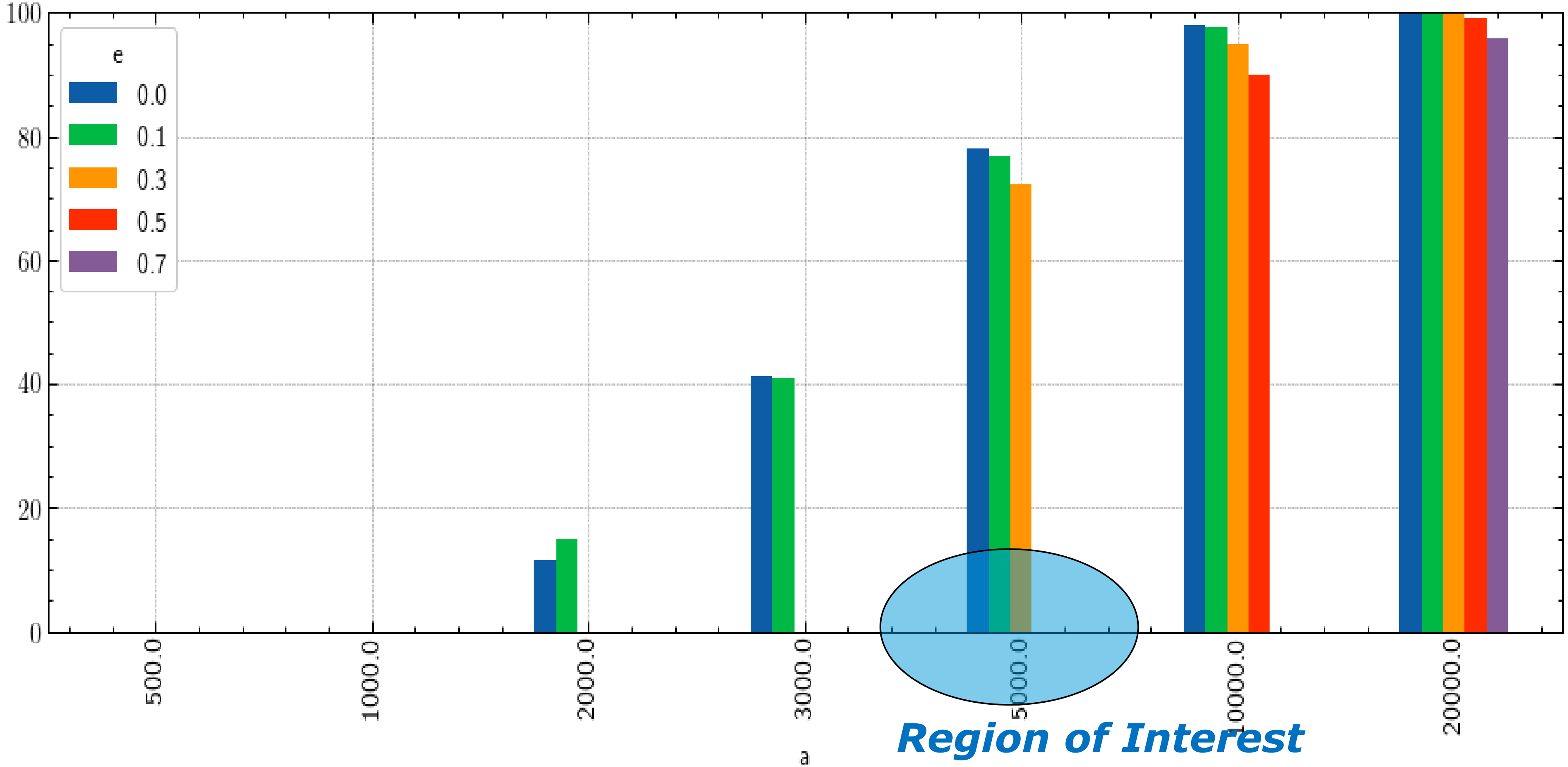


Source: Royal Observatory of Belgium (ROB)

Ideal scenario: Common visibility by VLBI stations providing a long observability baselines (intercontinental level)



Major Driver: Common visibility by VLBI stations providing a long baselines of observability (> 6500 Km distance)



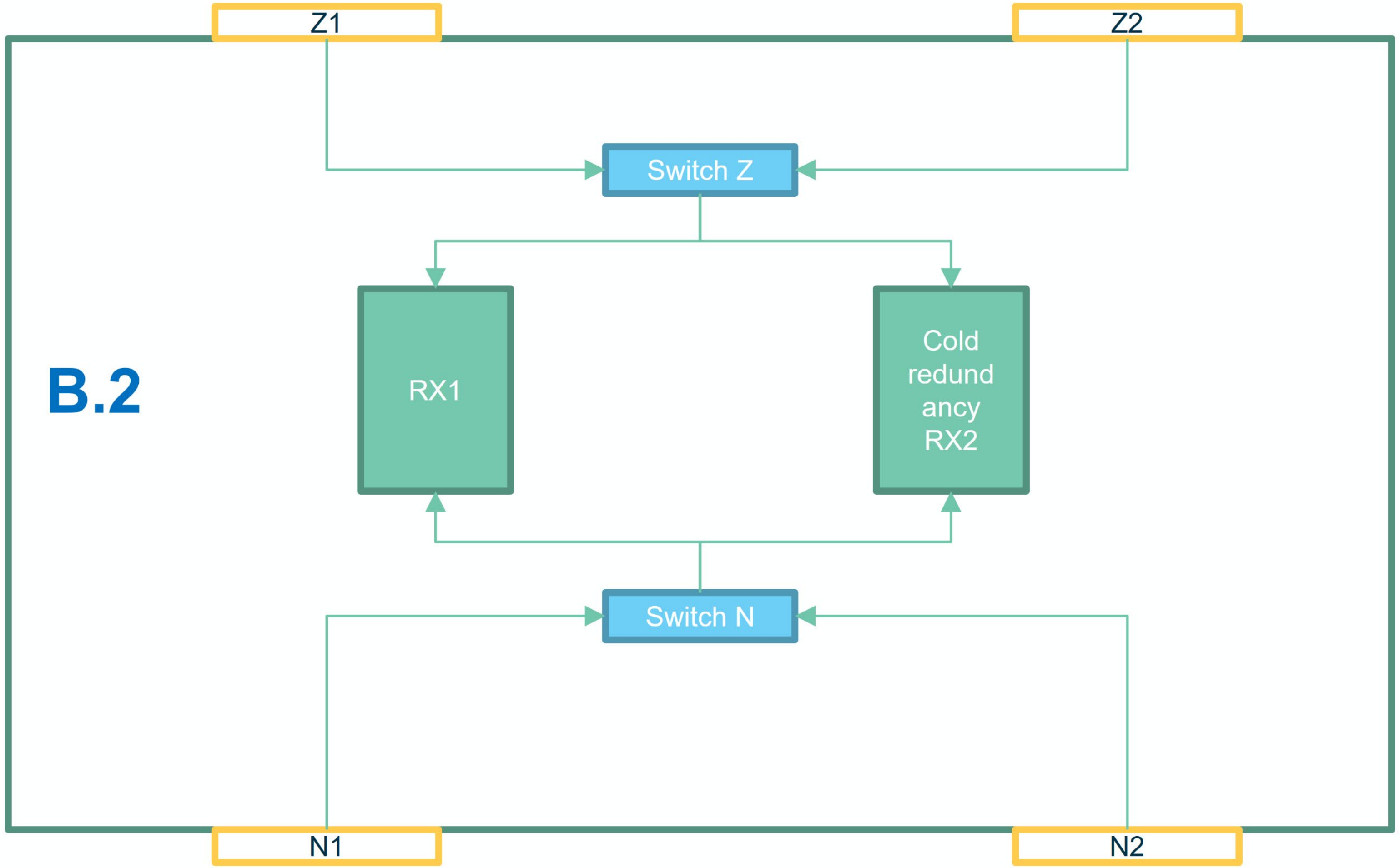
VLBI visibility percentage by at least of 2 VLBI station with a baseline greater than 6500 km (a) (simulations during 10 days). Note: Simulations performed by the Royal Observatory of Belgium (ROB)

Requirements on measurement suitable for POD

A sufficient number of satellite measurement (15 to 25 satellites) has to:

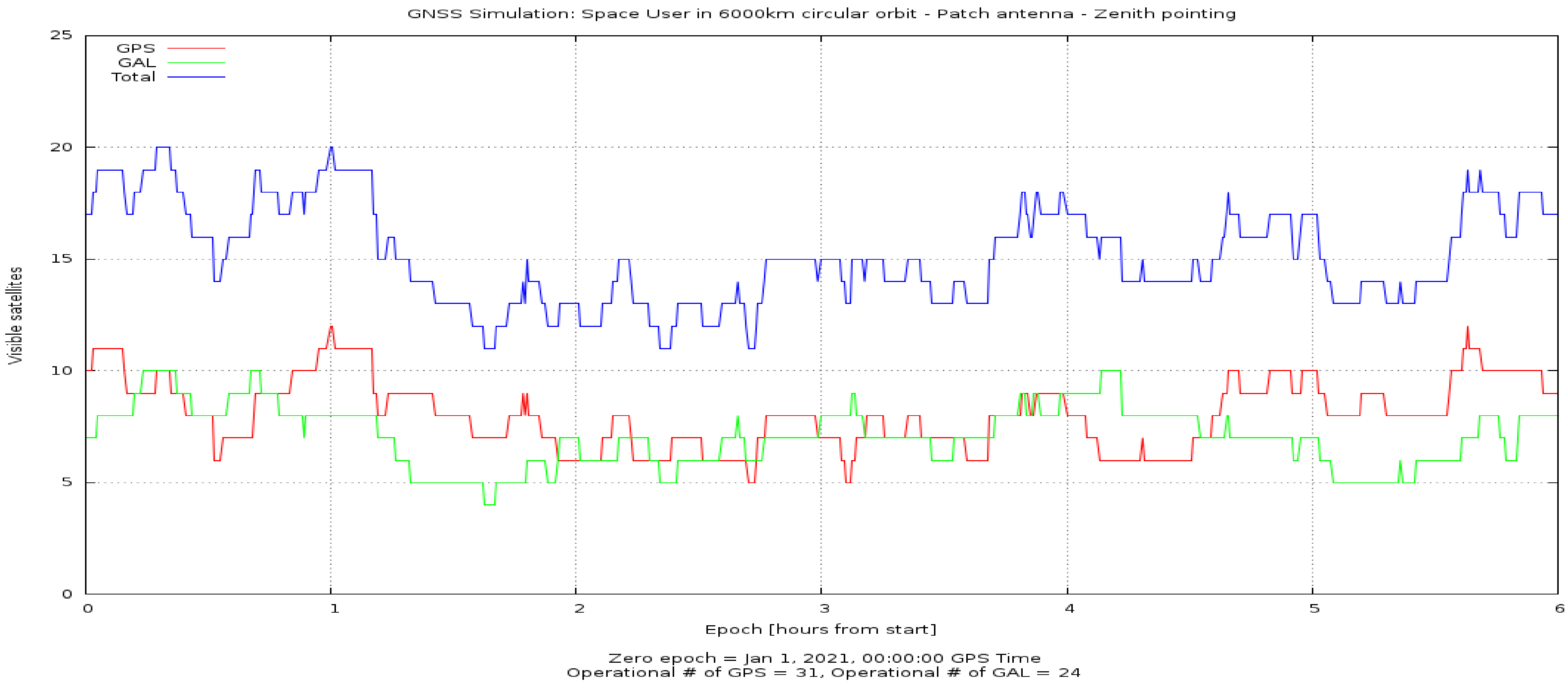
- come from satellite antenna main lobe;
- have a CN0 above 25 dBHz;
- GNSS Zenith and Nadir antennas are needed
- Multi-constellation and dual frequency measurement simultaneously available
- We have to measure (know as well as possible) the optical and thermal material properties (absorption, reflection and such) of the satellite outer surfaces to make an accurate radiation pressure model of the satellite.
- GNSS observations (combined Galileo and GPS) must be of high quality and unbiased (after calibration is applied) to allow **high success rate Integer ambiguity resolution**

GNSS on-Board configuration (baseline)



GNSS Visibility Analysis - Simulation Results

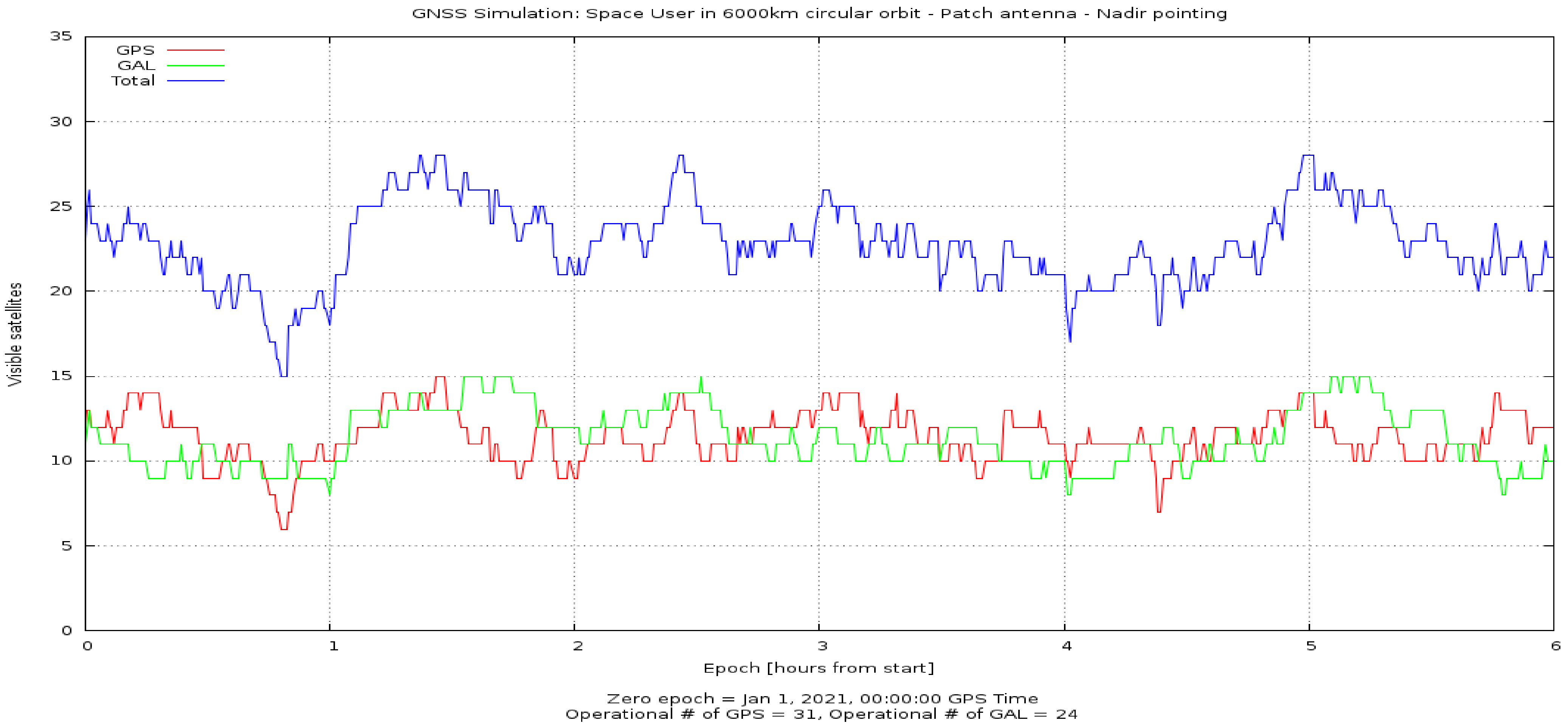
Patch Antenna – Zenith Pointing, SNR = 25dBHz



GNSS visibility and POD accuracy Analysis (6000 Km height)

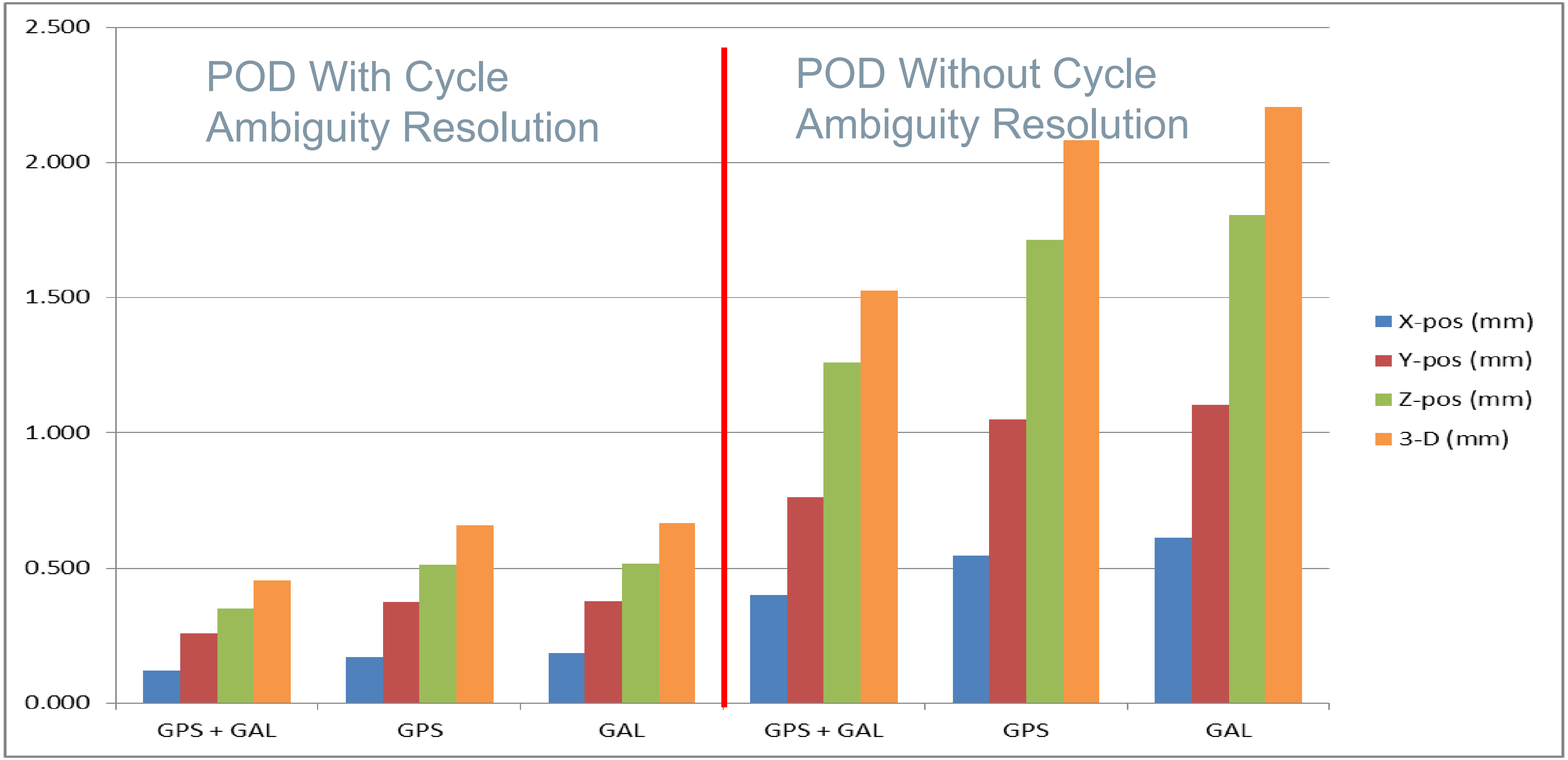
GNSS Visibility Analysis - Simulation Results

Patch Antenna – Nadir Pointing, SNR = 25dBHz

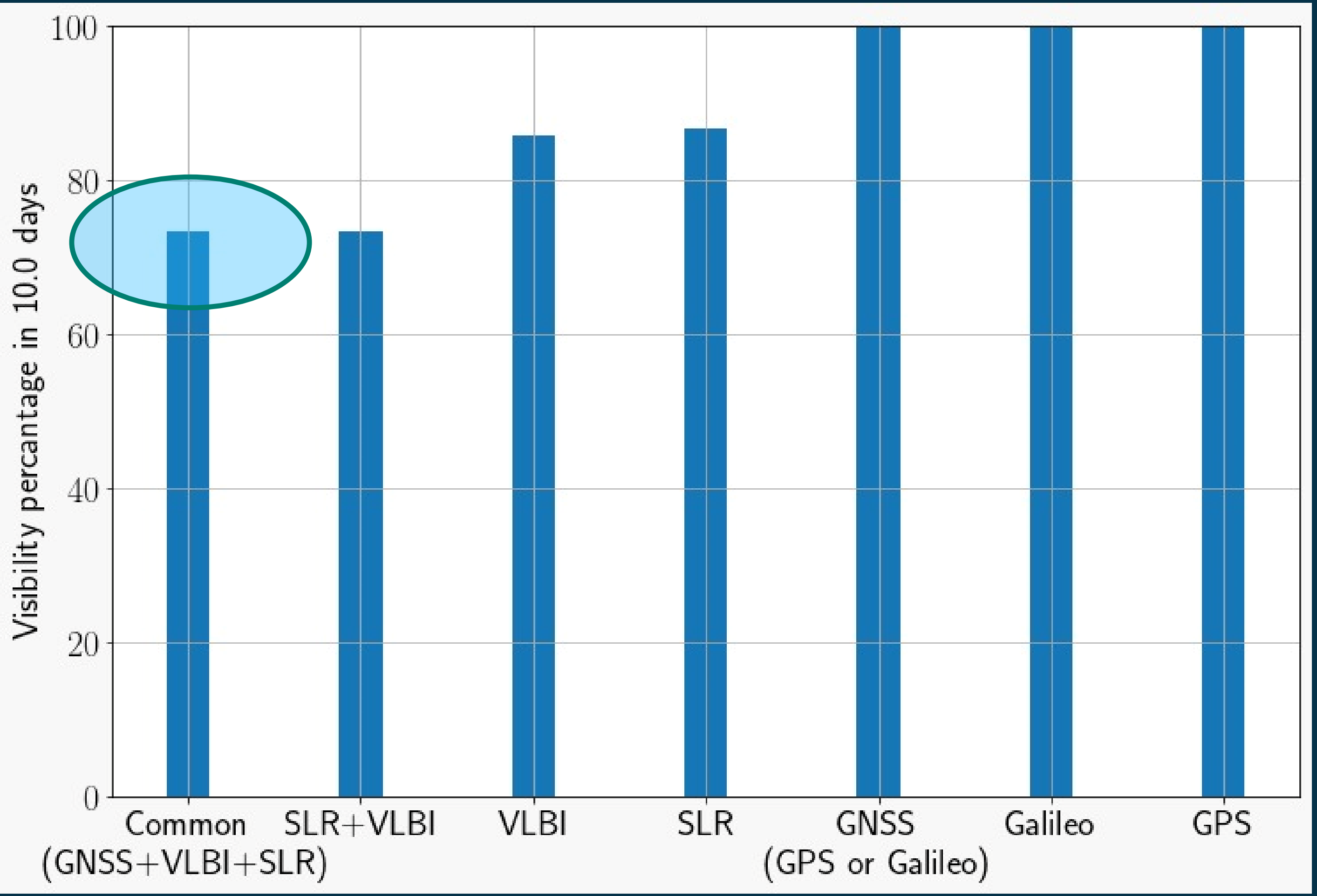


GNSS visibility and POD accuracy Analysis

POD Analysis - Main Results: Satellite Position Formal Errors (mm)



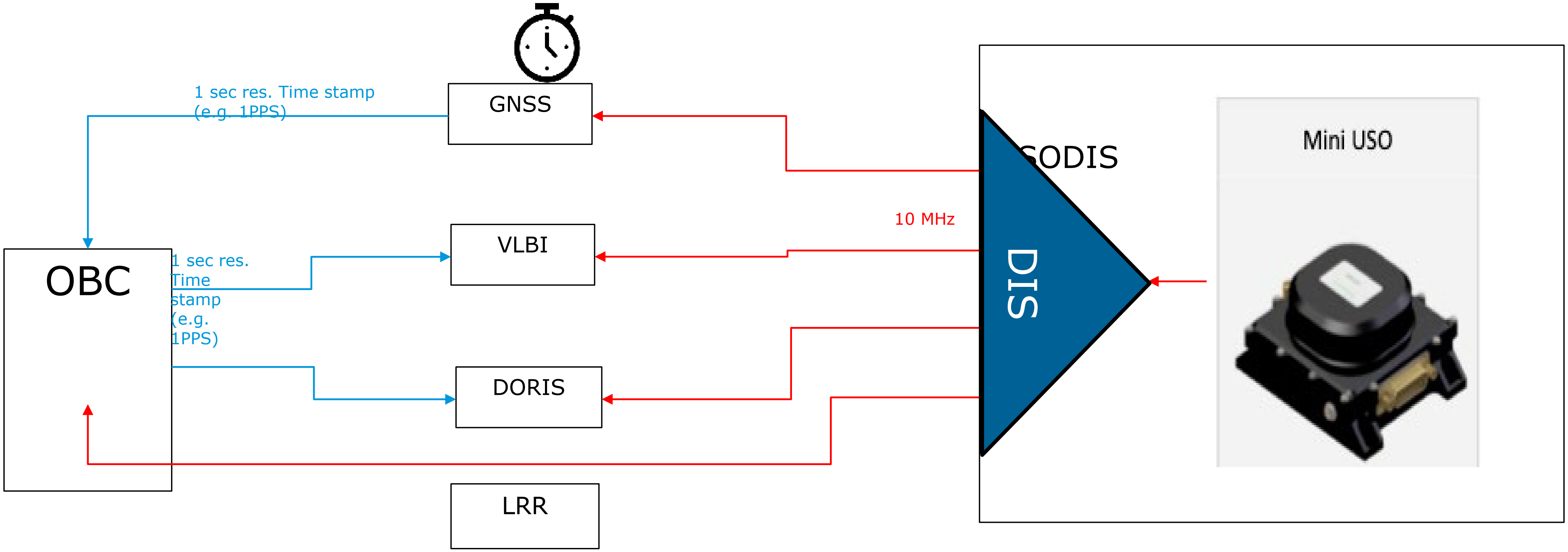
GEODETIC Techniques; Visibility Percentage (MEO orbit 6000 Km height)



Common Visibility of GNSS, VLBI and SLR about 75% of the time (10 days simulation)

Note: Results computed by the Royal Observatory of Belgium (ROB)

All geodetic instruments shall be referenced and synchronized to each other: USO + DIS



GENESIS-1 Assessed Mission Options

GENESIS-1 Mission Options

GENESIS

- **Option 1**
  - Piggy-back SSO launch
  - EPROP
  - 6000km
  - Long transfer to nominal orbit
  - 2+ 1 years operations
  - Radiation shielding
  - Vega-C
  - Allows VLBI large baseline
- **~~(Option 1b)~~**
  - ~~CPROP~~
  - ~~Fast transfer~~
  - ~~6000km~~
  - ~~Piggy-back~~
  - ~~2+1 (TBC) years operations~~
  - ~~Vega-C~~
  - ~~Radiation shielding~~
- **Option 2**
  - Direct Injection 6000 to 8000 Km height
  - Different launch options (e.g. Rocket Factory, ISAR Aerospace)
  - 2+1 years of operations
  - Radiation shielding
  - Allows VLBI Large Baseline

GENESIS-1 Con-Ops (Option 1 with EPROP)

1

Launch Year	2027
Launcher	Vega-C
Altitude	500km

2

Phase	LEOP
Notes	S/C switch on at separation from launcher

3

Phase	Transfer
Altitude Change	500km – 1500km
Transfer Duration	EPROP: 2 (TBC) months
Wait Duration	Up to 2 months (TBC), until eclipse season is over. Operations TBC

Phase	Transfer
Altitude Change	1500km – **6000km** (TBC)
Transfer Duration	EPROP: ~5 months

4

Phase	Commissioning
Note	Not a driving phase

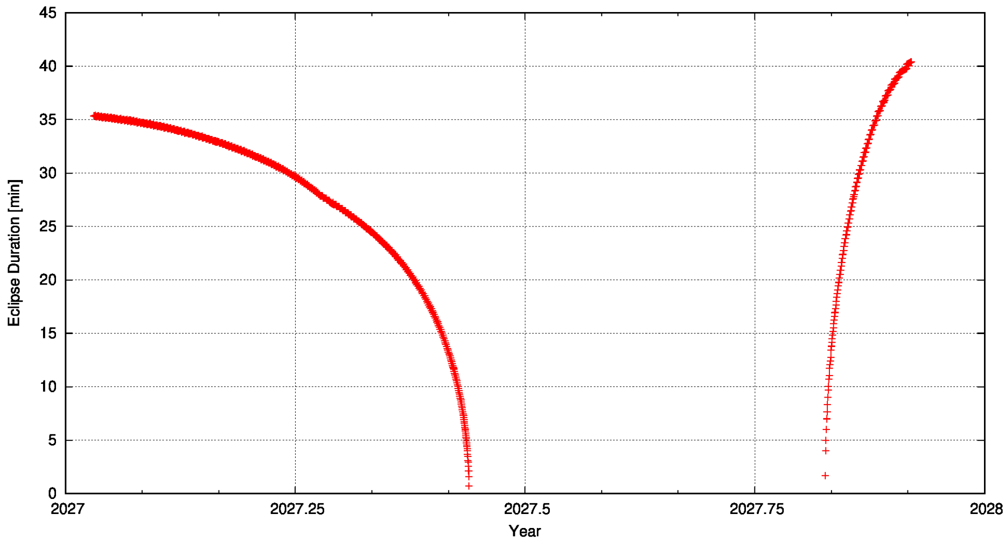
5

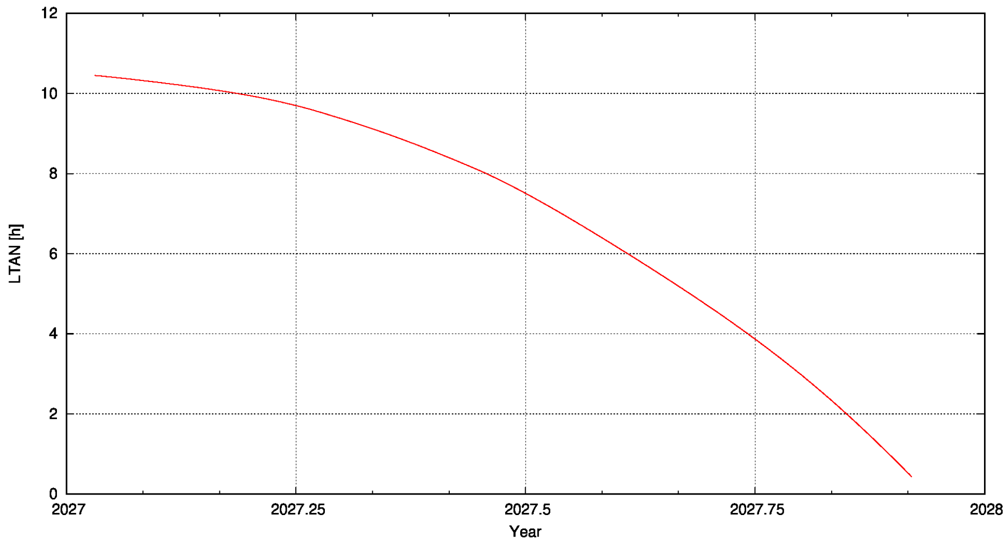
Phase	Nominal Mission
Duration	3 years (TBC)

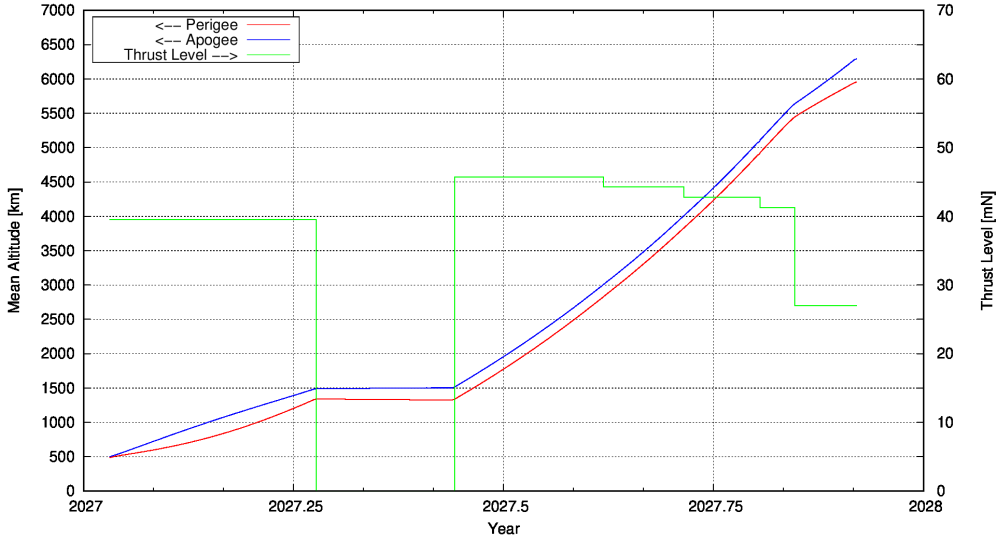
6

Phase	Disposal
Year	2029/30

Target Orbit Acquisition Using SEP

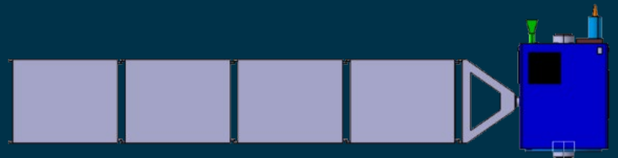






- Initial LTAN 10:30
- LTAN decreases as orbit rises, as prograde node precession slows
- Wait-out of >2 months required as LTAN drifts from 09:30 to 08:00
- Rapid raising of orbit to ~5500 km during 4 month eclipse-free period
- Final raise: thrust arcs interrupted by eclipses, end after ~11 months
- Eccentricity build up due to eclipse-induced thrust gap
- Final orbit eccentric with mean altitude 5750-6250 km, ecc. ~0.02

GENESIS-1 Option 1 Design Summary



Orbit	6000km circular 95.5° inclination	
Mass w/ system margin	Dry	310kg
	Wet	375kg
	Propellant	63kg
Power w/system margin	285W during nominal mode 726W during transfer mode	
Dimensions Stowed	Max Height	1460mm
	Max Width	950mm
	Max Depth	1015mm
Payload Mass & power w/maturity margin	GNSS 12.2kg, 21W DORIS 21kg, 26.3W VLBI 2.4kg, 17.4W SLR 1.6kg, passive USO 1.8kg, 12W	
Structure Mass w/maturity margin	55kg box structure with shear panels	
Communication/GSO	S-Band used for TT&C LGA Ground station: 15m antenna	

AOCS	2 x magnetometers 3 x magnetorquers 4 x reaction wheels 6 x sun sensors 3 x star trackers
Data Handling	Intergrated data handling unit (e.g. based on PROBA)
Power Mass w/maturity margin	2.8m^2 solar array, 15.6kg SADM Battery, 5.4kg PCDU, 12.8kg
Electrical Propulsion	4 x thrusters (max 55mN) 2 x tanks 264mm Ø, 662mm height 63kg Xenon fuel 1950m/s deltaV
Thermal Mass w/maturity margin Power w/maturity margin	Simple thermal control: Heaters, radiators, MLI, paint, mirrors
Radiation shielding	100krad of TID 32.6kg platform shielding 2.3kg payload shielding

GENESIS-1 Potential industrial participants

GENESIS-1 Scientific Instruments:

VLBI Instrument: Antwerp Space
DORIS: THALES / CNES / IGN
GNSS: RUAG, TAS-I, SpacePNT, U-Blox, Quascom, Deimos, Syrlinks, GMV
LRR: INFN / TAS-I; GFZ-D
USO: Multiple (e.g TAS-I, SpT-CH, Rakon, ADS-UK, Accubeat, etc)

Optional instruments:
A-LRR: Czech Technical University; TUM
Hollow: INFN
Accelerometer: INAF-TAS-I; ONERA

Potential NASA Payload
GRITSS : NASA CFI

GENESIS-1 Platfom:

Platform of 200-400 Kg mass (depending on SSO/EEP launch option or direct injection)

Several options:
Proba-V, TAS, Airbus, OHB or new-Space small Satellite platform approach

GENESIS-1 Launch options

SSO + EEP: Piggy back VEGA-C

Direct Injection:
Rocket Factory; ISAR Aerospace

Piggy back Ariane 6-2 Galileo

GENESIS-1 Subsystems:

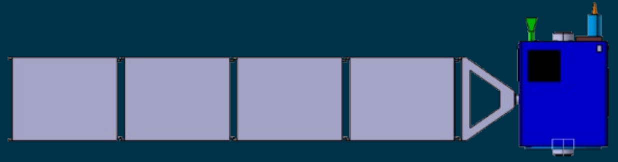
AOCS: Multiple (e.g. Zarm, ASTROFEIN, MTQ – Zarm, SCI, Sodern, Solar MEMS, etc)
Power: Multiple (LEONARDO, TAS-I, Airbus; Ruag; Azur; SAFT; TAS-B, ADS/Crisa, TERMA, etc).
OBDH: RUAG, Qinetiq
EEP: TBD
Thermal: Multiple
Comms: TAS-E, SSTL, Honeywell

GENESIS-1 G/S:
Redu, Kiruna, Kourou

GENESIS-1 MOC:
ESOC or REDU

GENESIS-1 SOC:

GENESIS-1 Option 2 Design Summary



Orbit	6000km circular 95.5° inclination	
Mass w/ system margin	Total Wet Mass	214 Kg
	Total Wet Mass incl launch adapter	218 kg
Power w/system margin	190 W during nominal mode	
Dimensions Stowed	Max Height	1460mm
	Max Width	950mm
	Max Depth	1015mm
Payload Mass & power w/maturity margin	GNSS 12.2kg, 21W DORIS 21kg, 26.3W VLBI 2.4kg, 17.4W SLR 1.6kg, passive USO 1.8kg, 12W	
Structure Mass w/maturity margin	55kg box structure with shear panels	
Communication/GSO	S-Band used for TT&C LGA Ground station: 15m antenna	

AOCS	Several simplifications with respect to Option 1 (no longer driven by disturbances in LEO or transfer orbits). Saving of about 8 Kg in mass wrt Option 1. Details CDF report.
Data Handling	Intergrated data handling unit (e.g. based on PROBA)
Power Mass w/maturity margin	Several simplifications with respect to Option 1. Details CDF report. Saving of about 10 Kg in mass. wrt Option 1.
Electrical Propulsion	No NEED (Direct injection)
Thermal Mass w/maturity margin Power w/maturity margin	Simple thermal control: Heaters, radiators, MLI, paint, mirrors
Radiation shielding	100krad of TID 29.3 kg platform and payload shielding. Saving of about 5 Kg in mass wrt Option 1.

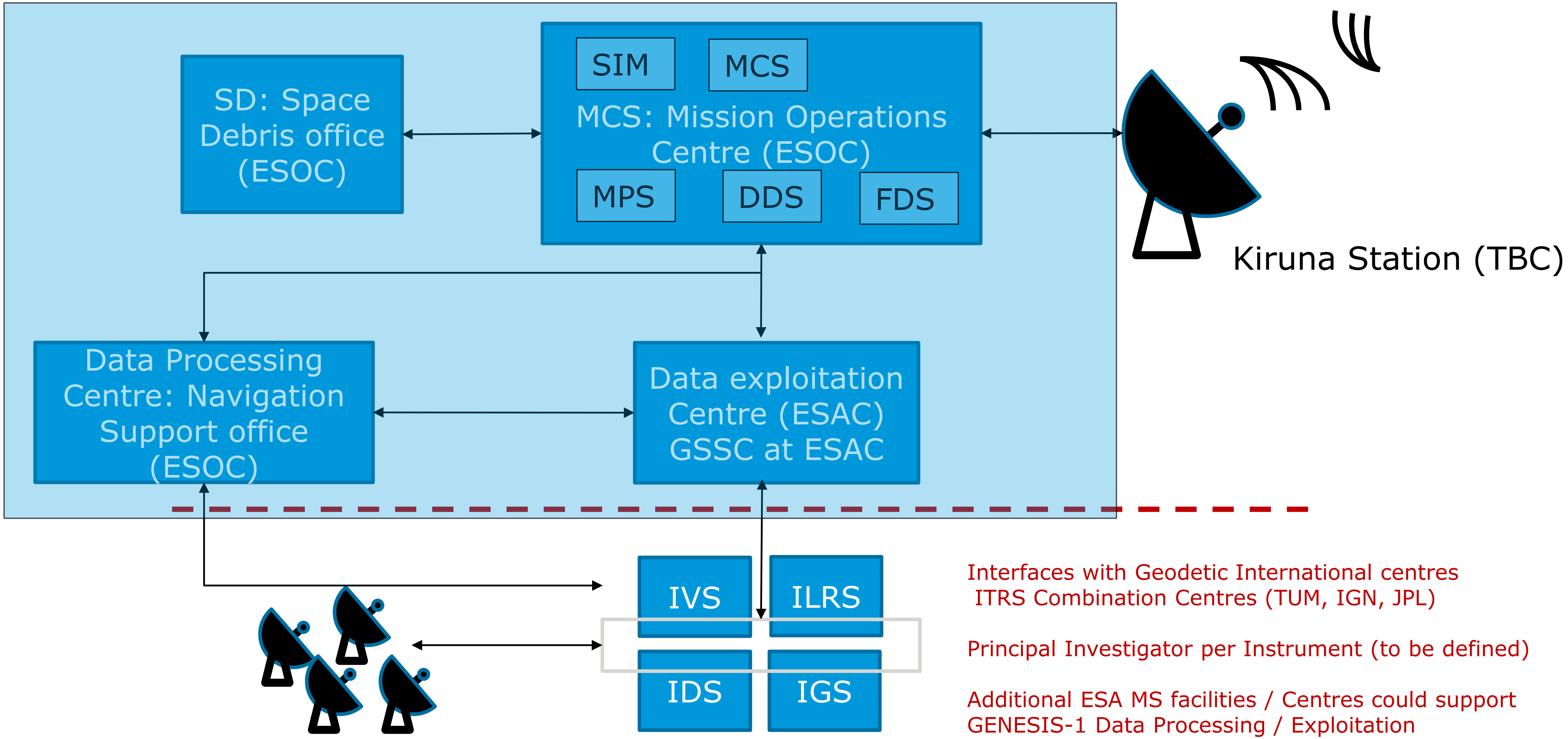
GENESIS-1: Option 1 (EEP raising): Mass Budget

System/Subsystem	S/C Mass Budget		Mass [kg]
Spacecraft			**253.50**
▼ AOGNC	Attitude, Orbit, Guidance, Navigation Control		14.76
▼ COM	Communications		4.53
▼ DH	Data-Handling		12.00
▼ EPROP	Electric Propulsion		53.40
▼ INS	Instruments		38.95
▼ PWR	Power		33.80
▼ STR	Structures		54.75
▼ TC	Thermal Control		6.51
▼ RAD	Radiation Shielding		34.80
	Harness		10.93
	Dry Mass w/o System Margin		**264.43**
	System Margin	20%	45.93
	Dry Mass including System Margin		**310.36**
	EPROP Propellant Mass		63.00
	EPROP Propellant Margin	2%	1.26
	Total Wet Mass		**374.62**
	Launcher Adapter		4.00
	Wet Mass + Adapter		**378.62**

Option 2 (Direct Injection 6000-8000 Km) – Mass Budget

System/Subsystem	S/C Mass Budget		Mass [kg]	Delta Mass [kg]
Spacecraft			**175.80**	
▼ AOGNC	Attitude, Orbit, Guidance, Navigation Control		6.66	-8.10
▼ COM	Communications		4.53	
▼ DH	Data-Handling		12.00	
▼ INS	Instruments		38.95	
▼ PWR	Power		23.10	-10.70
▼ STR	Structures		54.75	
▼ TC	Thermal Control		6.51	
▼ RAD	Radiation Shielding		29.30	-5.50
	Harness		7.33	
	Dry Mass w/o System Margin		**183.13**	
	System Margin	20%	30.77	
	Dry Mass including System Margin		**213.89**	-96.47
	Launcher Adapter		4.00	
	Wet Mass + Adapter		**217.89**	

GENESIS-1 Mission and Science Operations

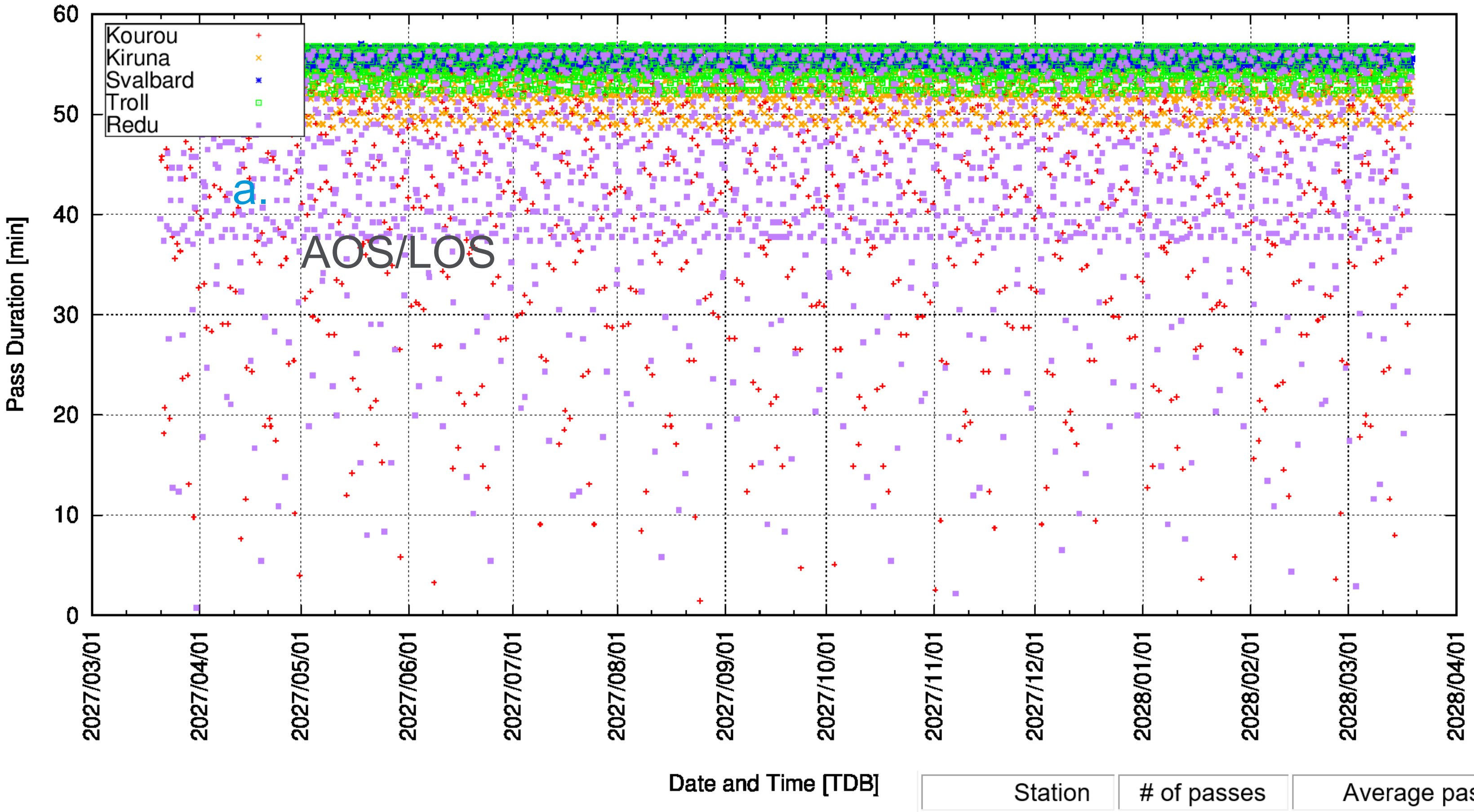


Interfaces with Geodetic International centres
ITRS Combination Centres (TUM, IGN, JPL)

Principal Investigator per Instrument (to be defined)

Additional ESA MS facilities / Centres could support GENESIS-1 Data Processing / Exploitation

Ground Station Coverage – 6000Km circular orbit Several ESTRACK G/S options



Based on 15 deg

Station	# of passes	Average pass duration [s]	Max pass duration [s]	Total coverage [h]
Kourou	1225	2660	3351	905
Kiruna	2302	3216	3408	2056
Svalbard	2302	3347	3420	2140
Troll	2301	3293	3419	2104
Redu	2114	2771	3387	1627

6 to 7 passes/day. 53 min/pass

5 to 6 passes/day. Avg. 45 min/pass

GENESIS-1 Instruments (Baseline and Optional)

Assessment of the GENESIS-1 Baseline Instruments

The GENESIS-1 Baseline instruments include a VLBI tx, a passive LRR, a enhanced GNSS multi-band/multifrequency Receiver and a DORIS receiver.

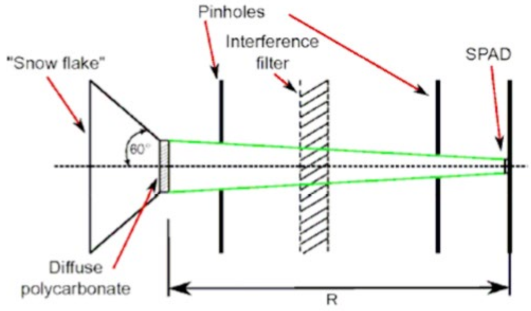
Dedicated expert groups have assessed in some detail the status of the GENESIS-1 instruments (incl potential providers) during the CDF study, concuding that while High-TRL reference representative instruments exist in Europe, some upgrades need to be performed to adapt those to the GENESIS-1 Mission profile (proposed to be performed in parallel to Phase A/B):

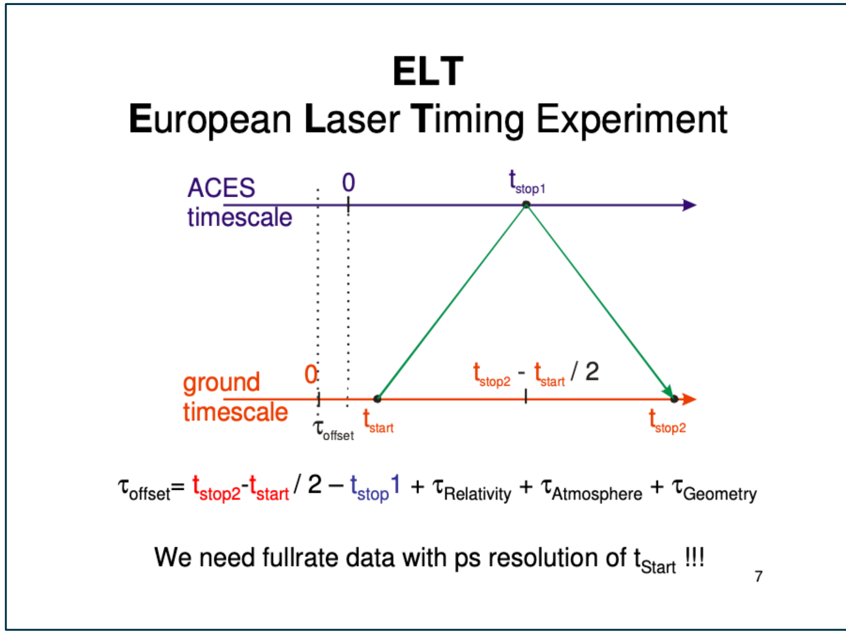
- DORIS instrument necessary adaptations to operate at 6000 Km orbit
- VLBI instrument upgrades from TRL 4/5 to TRL 8
- Adaptation of GNSS receiver to maximise high success rate Integer ambiguity resolution and to work with nadir and zenith antenna simultaneously

Optional Payload 1: Active Laser Ranging (ALR)

- An **Active-Laser-Ranging (ALR) on-board** will allow accurate time transfer between the ground stations and enable one-way ranging. It is divided in two pieces of hardware, a detector outside the platform and event timer inside. The ALR requires time synchronization and interface with the bus.

ALR is a highly recommended optional payload for the GENESIS-1 mission which would allow demonstrating (in addition to core Mission objectives) time transfer over inter-continental level and on-board synchronisation with ground clocks. Given its low SWaP (< 1 Kg and < 1 Watt) and scientific interest its integration is highly desirable.

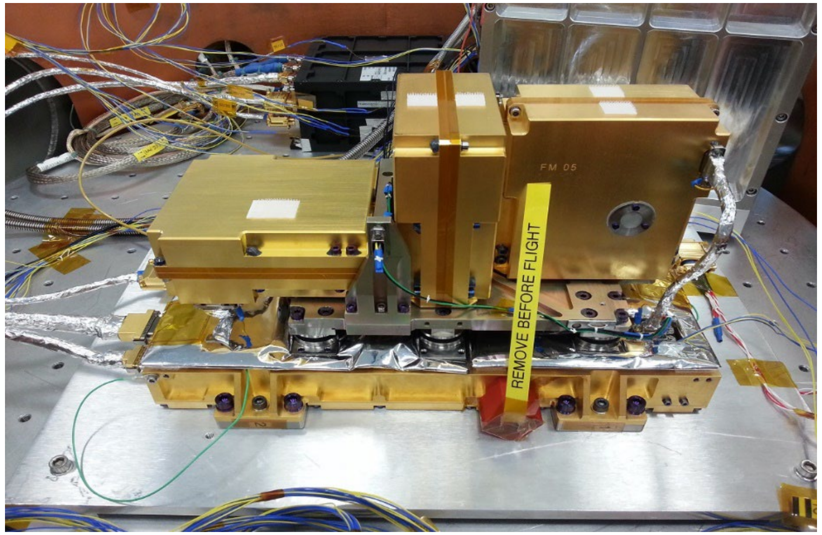




High-TRL but upgrades to adapt to the GENESIS-1 specific mission needs

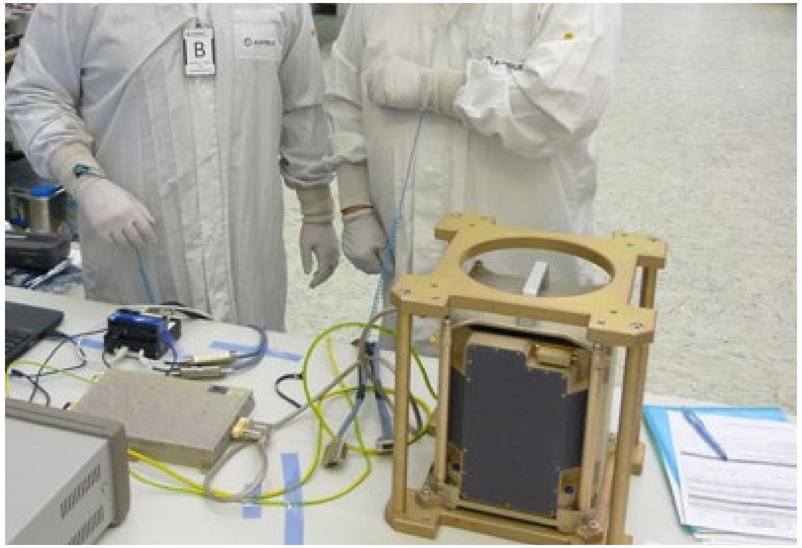
Optional Payload 2: Accelerometer

Integration of an accelerometer on-board will further support high-precision orbit determination, the modelling of non-conservative forces and would also allow in-orbit determination of the satellite Center of Mass (CoM).



INAF, TAS-I (I) – accelerometer

Bepicolombo, JUICE (2023)



ONERA(FR) – accelerometer

GRACE

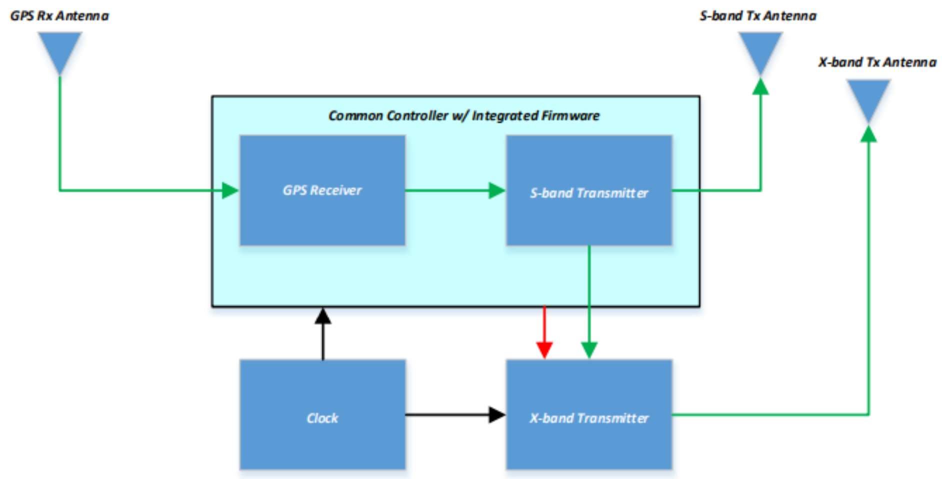
High-TRL but upgrades to adapt to the GENESIS-1 specific mission needs

POSSIBILITY OF COOPERATION WITH NASA

NASA has expressed high interest in exploring a cooperation with ESA for the GENESIS-1 mission. This could include:

- Scientific: Active participation from US-based multi-geodetic co-location stations and NASA data processing support.
- Integration in GENESIS-1 a dedicated NASA instrument, ***Geodetic Reference Instrument Transponder for Small Satellites*** (GRITSS.GRITSS concept is to upconvert the received GNSS signal and transponding it to VLBI stations (1-way biased range).

The GRITSS instrument would be an excellent complement (independent) to ESA proposed baseline instruments for GENESIS-1



Source: NASA (Beaudoin et al.)

Cooperation scenario under analysis between ESA and NASA

POSSIBILITY OF COOPERATION WITH NASA (GRITSS)

Dedicated letter of interest on the GENESIS-1 Mission received from NASA (May 2, 2022), stating:

“***The particular importance to NASA of the maintenance and improvement of the International Terrestrial Reference Frame*** *and the daily measurements of the Earth Orientation Parameters that are essential for spacecraft navigation and to geolocate Earth observations.*

The generation of these geodetic products relies on the Global Geodetic Observing System of geodetic ground stations. NASA is making significant investments in upgrading the NASA Space Geodesy Network and we were ***excited to learn about the proposed GENESIS program that includes a geodetic observatory for co-location of the geodetic techniques in space****.*

We are ***interested in exploring potential cooperation in this mission*** *and how it can be used to improve the geodetic products, particularly the International Terrestrial Reference Frame. Please keep us informed on the development of this interesting program.”*

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

May 2, 2022

Reply to Attn of: SMD/Earth Science Division

Dr. Javier Ventura-Traveset
Head of Galileo Navigation Science Office - NAV-P
ESA Navigation Directorate
European Space Agency

Dear Dr. Ventura-Traveset,

NASA and ESA have a common interest in space geodesy in support of our respective Earth science programs. As the foundation for modern positioning, navigation, and timing applications, the importance of space geodesy to science, commerce, and civilian society is clearly demonstrated on a daily basis, from the navigation of automobiles, ships, aircraft and satellites to the accurate time transfer required by our communication systems. It also enables powerful new techniques for monitoring the Earth system as exhibited in measurements of water resources, sea level rise, ocean circulation, and atmospheric weather.

Of particular importance to NASA is the maintenance and improvement of the International Terrestrial Reference Frame and the daily measurements of the Earth Orientation Parameters that are essential for spacecraft navigation and to geolocate Earth observations. The generation of these geodetic products relies on the Global Geodetic Observing System of geodetic ground stations. NASA is making significant investments in upgrading the NASA Space Geodesy Network and we were excited to learn about the proposed GENESIS program that includes a geodetic observatory for co-location of the geodetic techniques in space. We are interested in exploring potential cooperation in this mission and how it can be used to improve the geodetic products, particularly the International Terrestrial Reference Frame. Please keep us informed on the development of this interesting program.

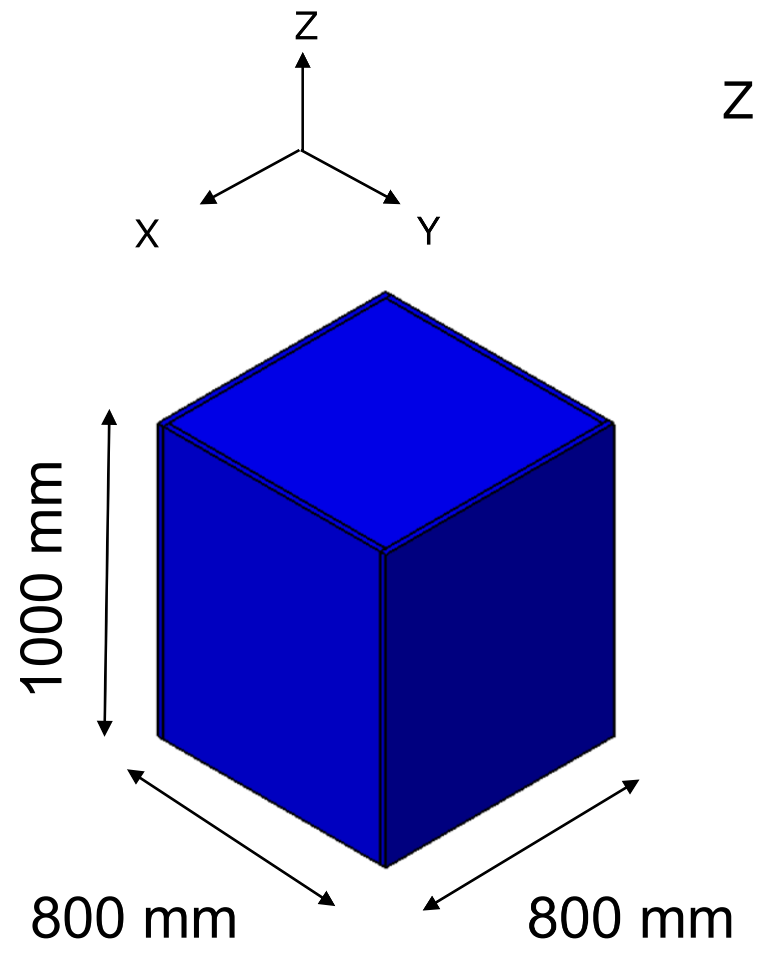
Sincerely,

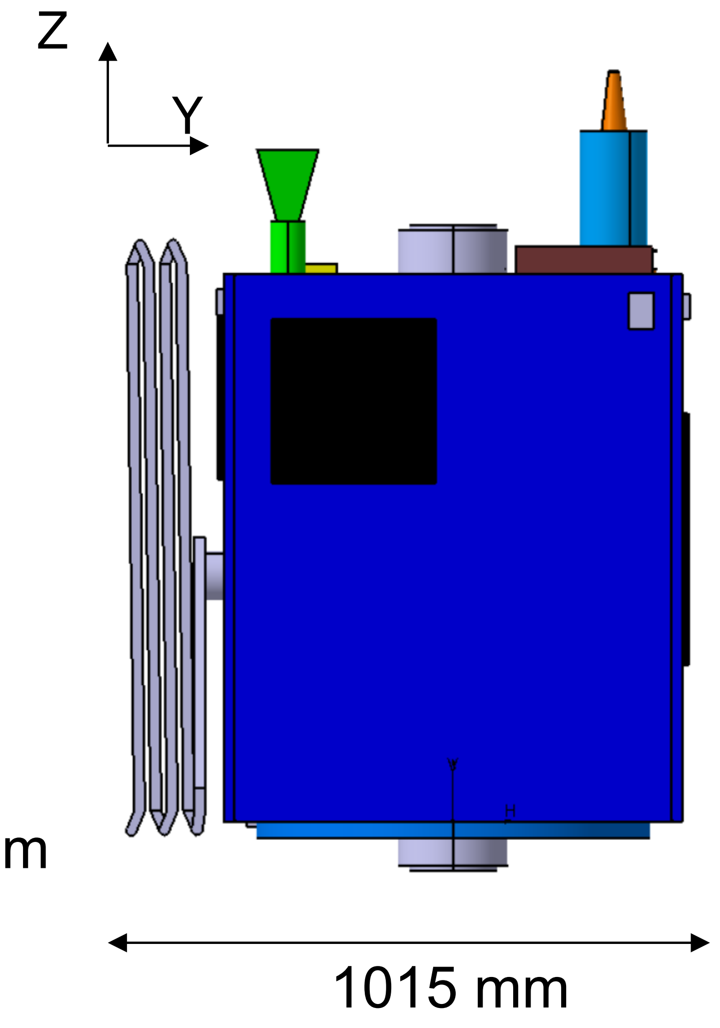
Benjamin Phillips
Lead, Earth Surface and Interior Focus Area
NASA Science Mission Directorate, Earth Science Division

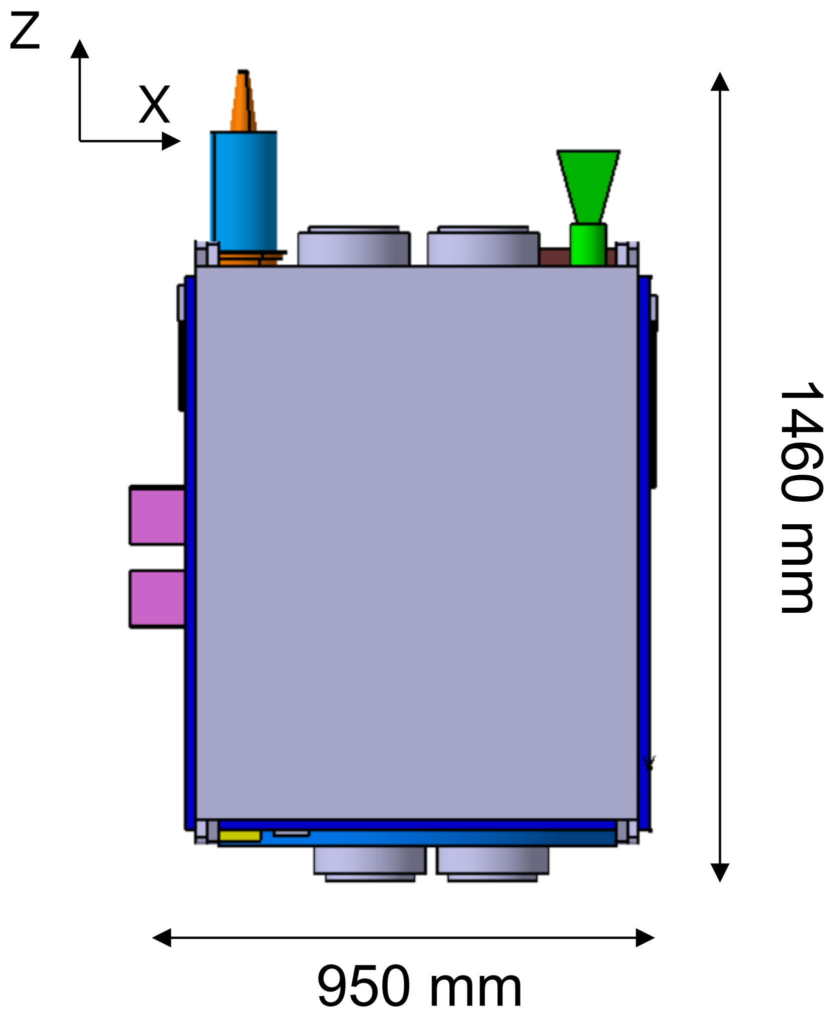
cc:
NASA Goddard Space Flight Center/Stephen Merkowitz
NASA Office of International and Interagency Relations/Peyton Blackstock

GENESIS-1 Platform and instruments, equipment allocation – CDF assessment

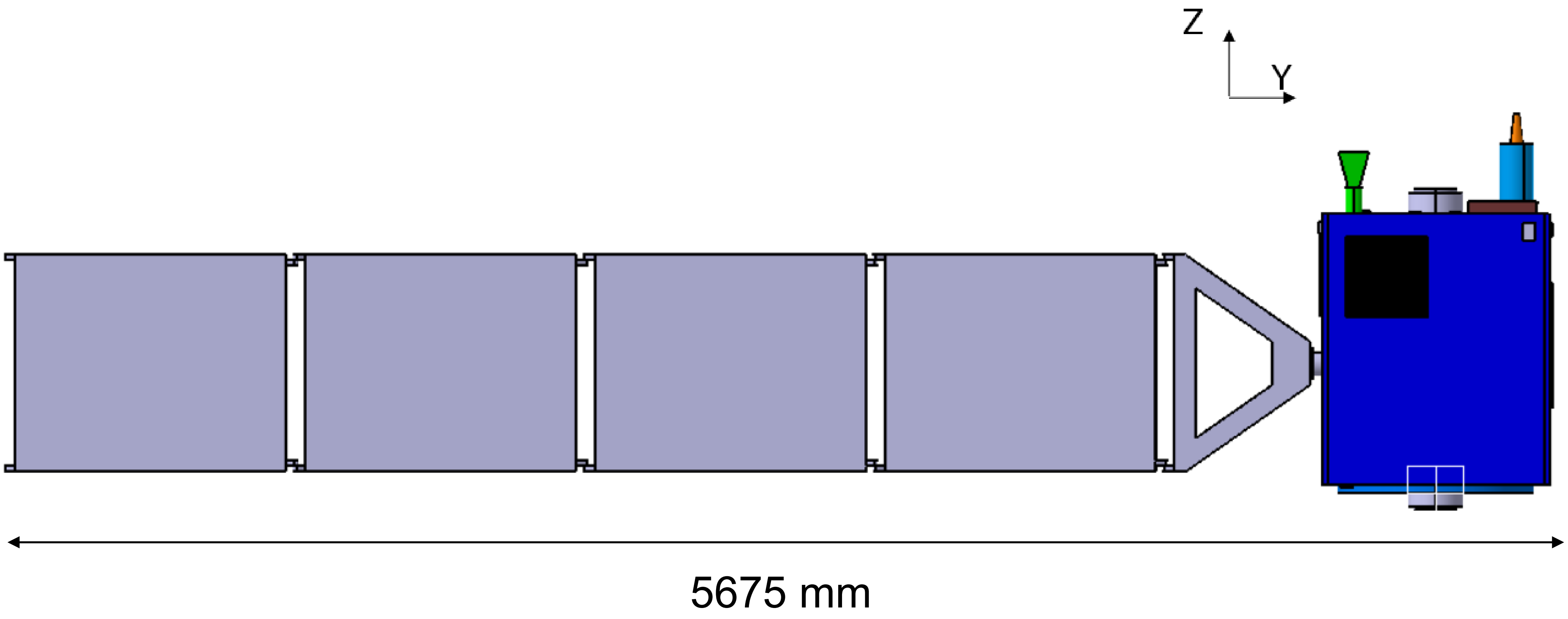
GENESIS-1: Satellite dimensions (ESA CDF assessment)





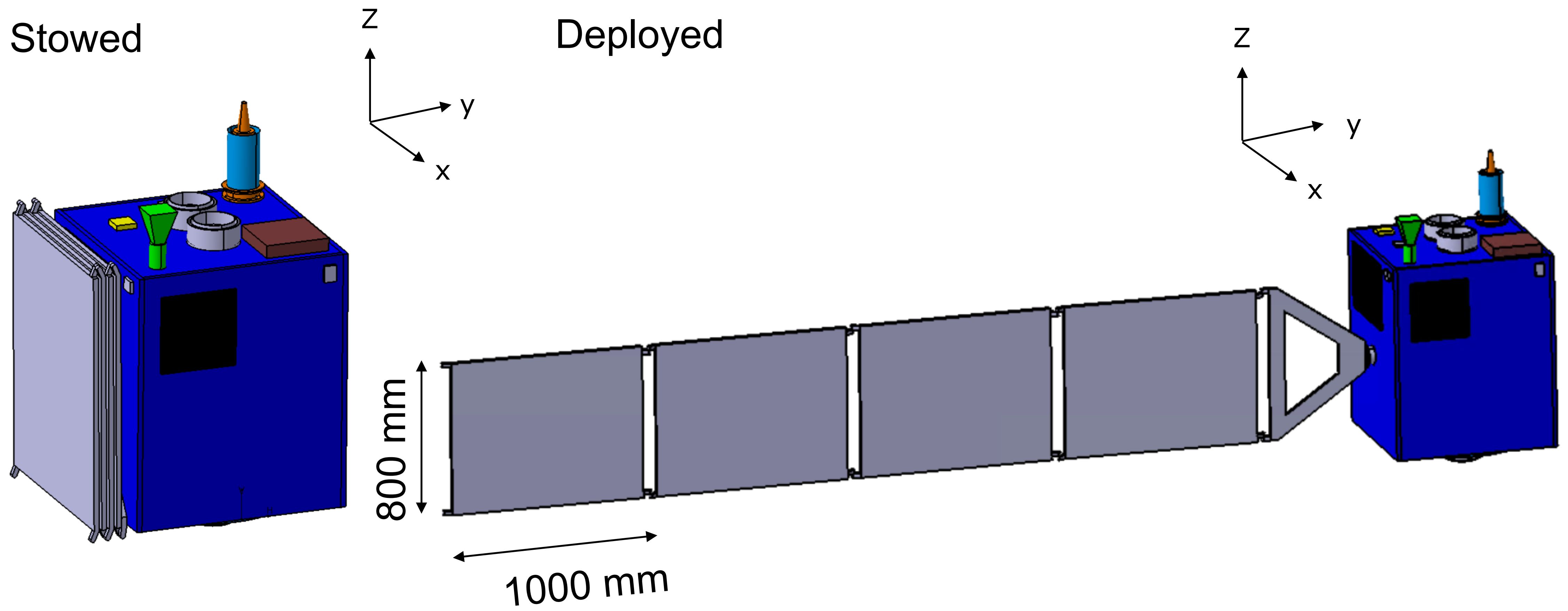


GENESIS-1: Satellite dimensions (1 solar Panel)

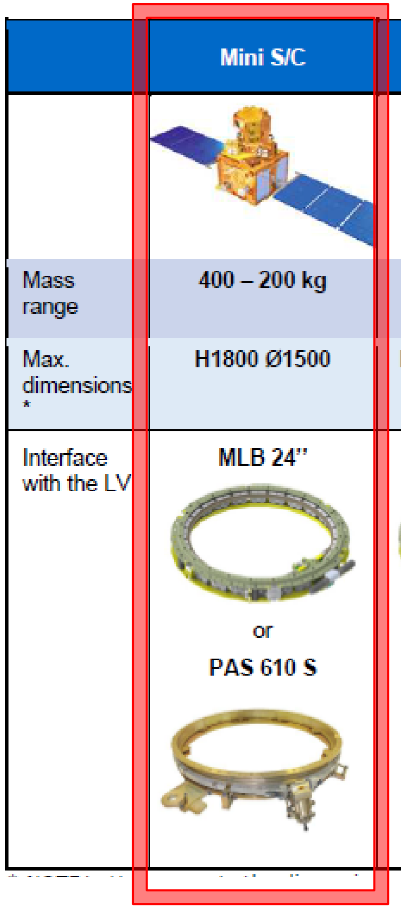


Solar Arrays

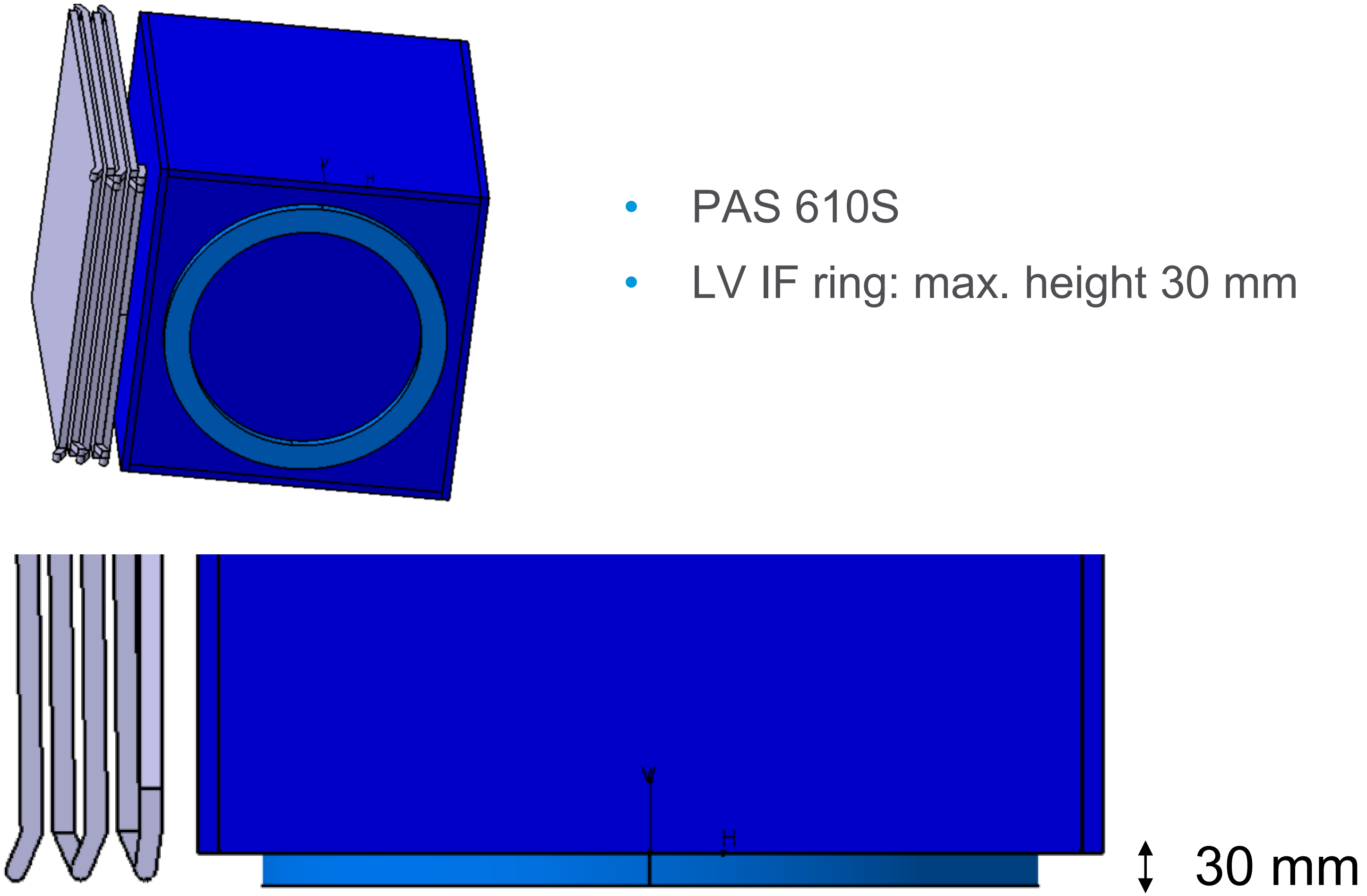
SADM + Array



LVA + LIR



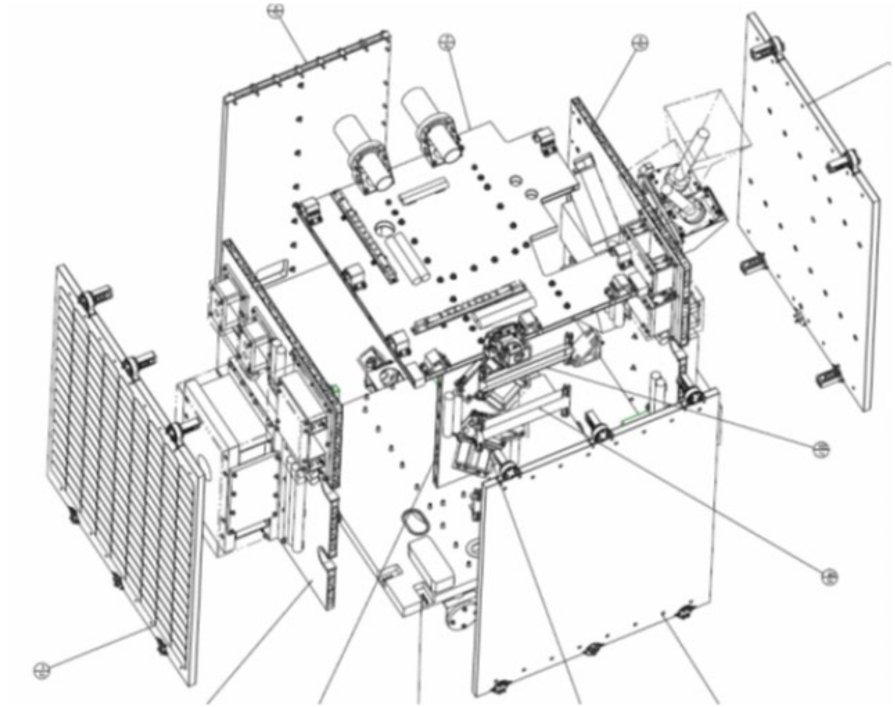
	Mini S/C
Mass range	400 – 200 kg
Max. dimensions *	H1800 Ø1500
Interface with the LV	MLB 24" or PAS 610 S



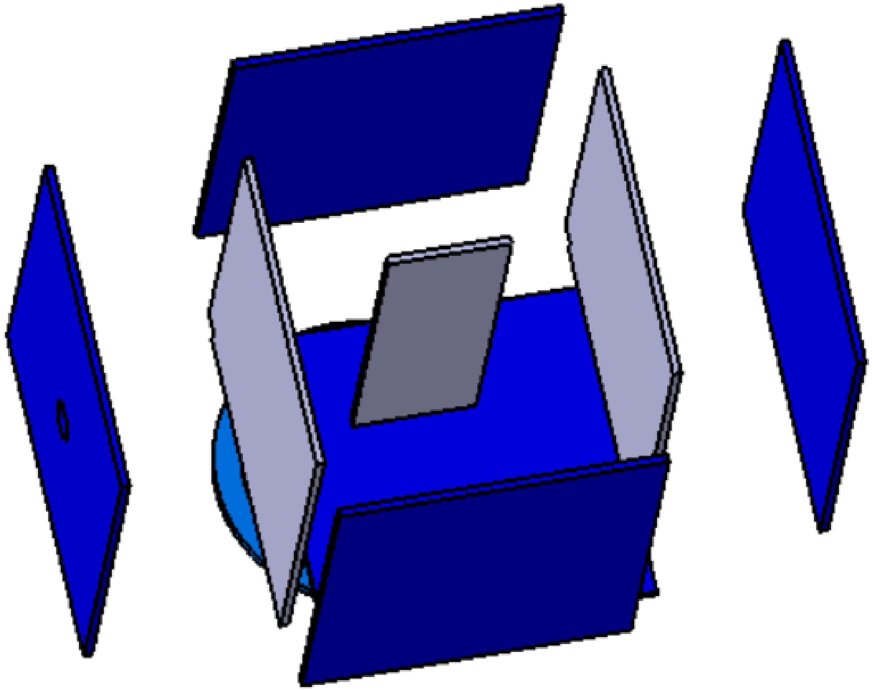
- PAS 610S
- LV IF ring: max. height 30 mm

GENESIS-1 Main structure

Proba-V

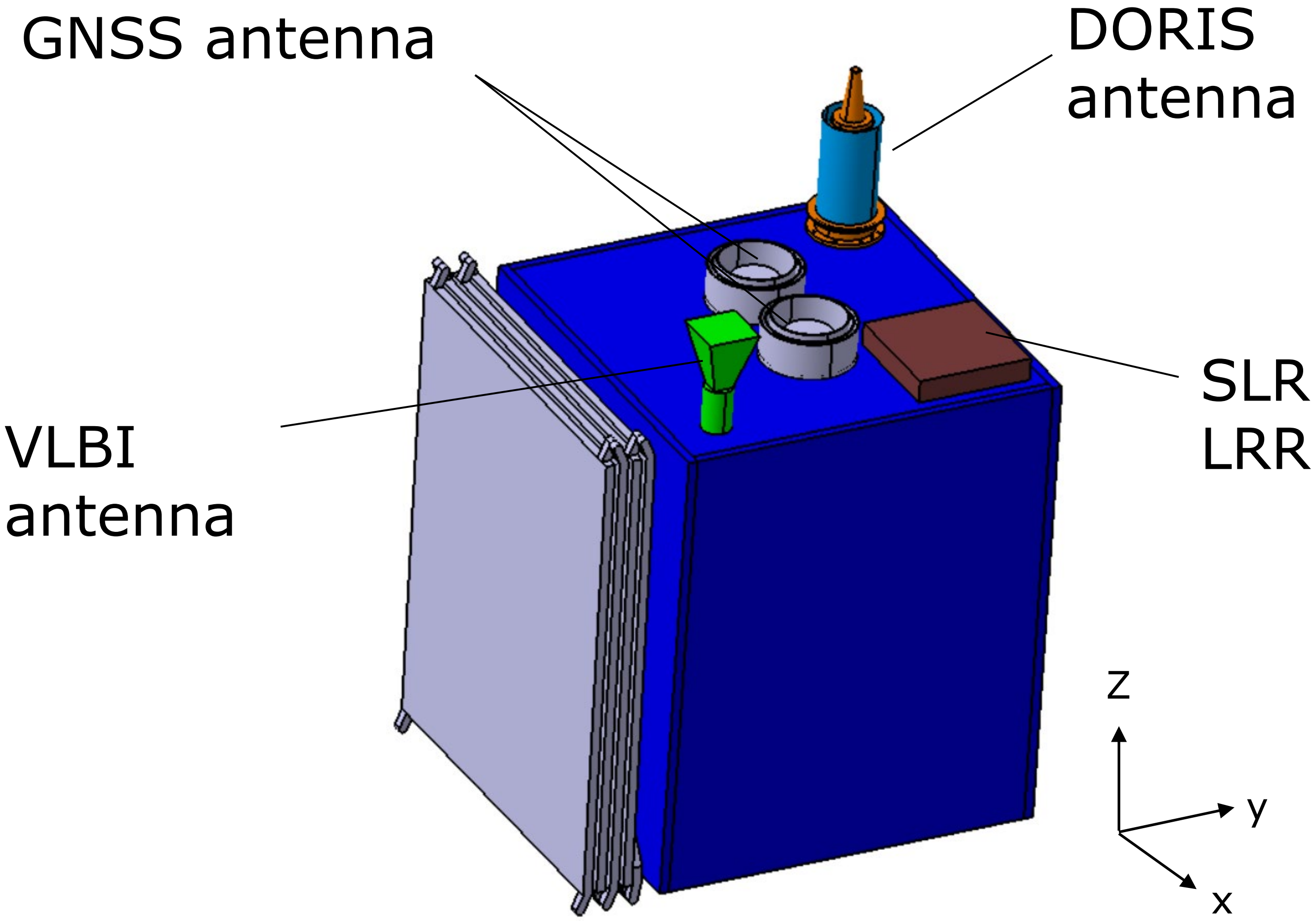


GENESIS1



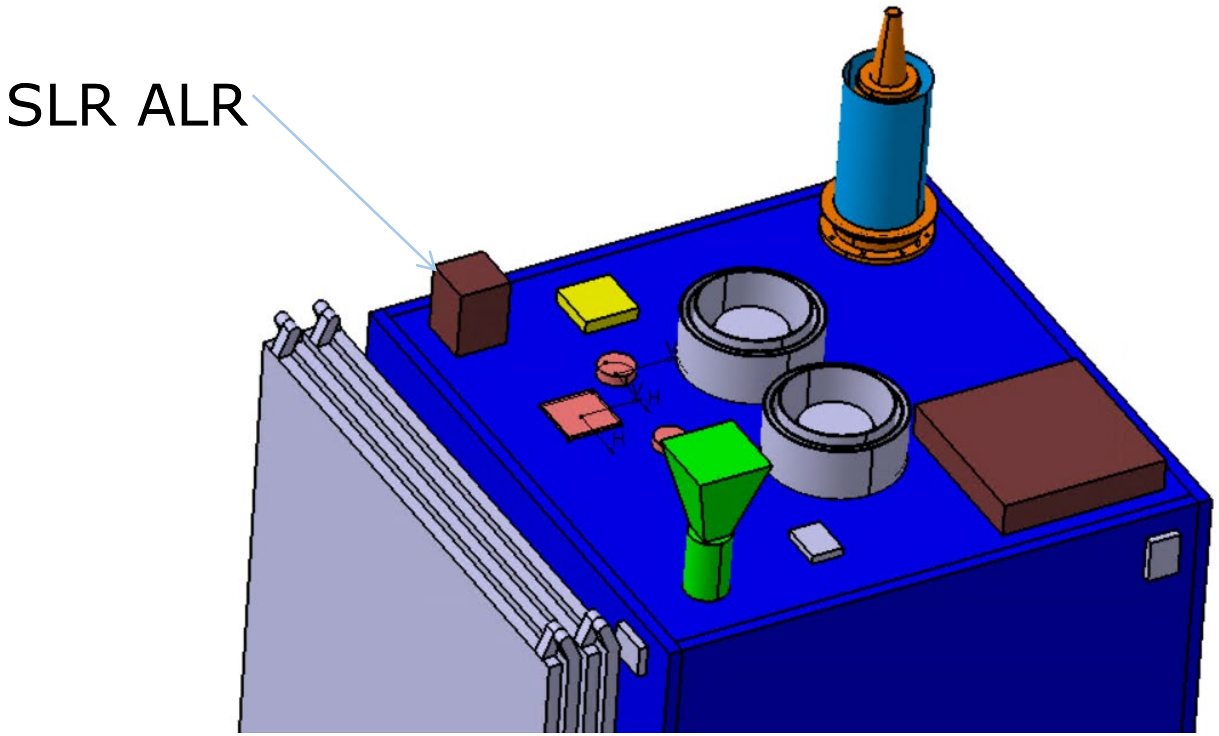
Compact design & stable structure

Instruments nadir

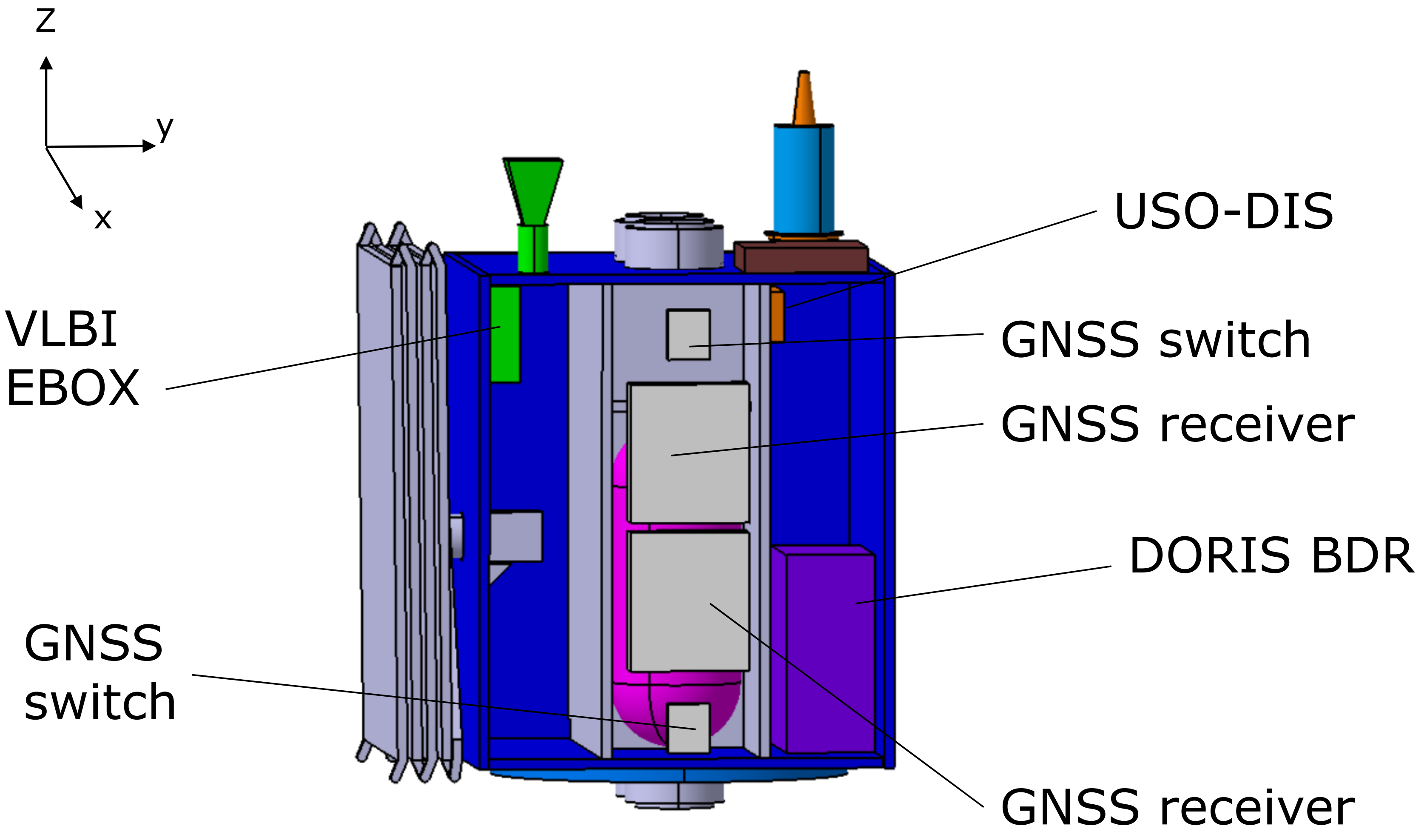


Requirements:
- Nadir-pointing of DORIS, GNSS antenna nadir, SLR and VLBI
- GNSS antennas placed in the middle of the panel
- DORIS and VLBI might have EMC issues – position as far away as possible
- Unobstructed field of view for GNSS, DORIS and VLBI

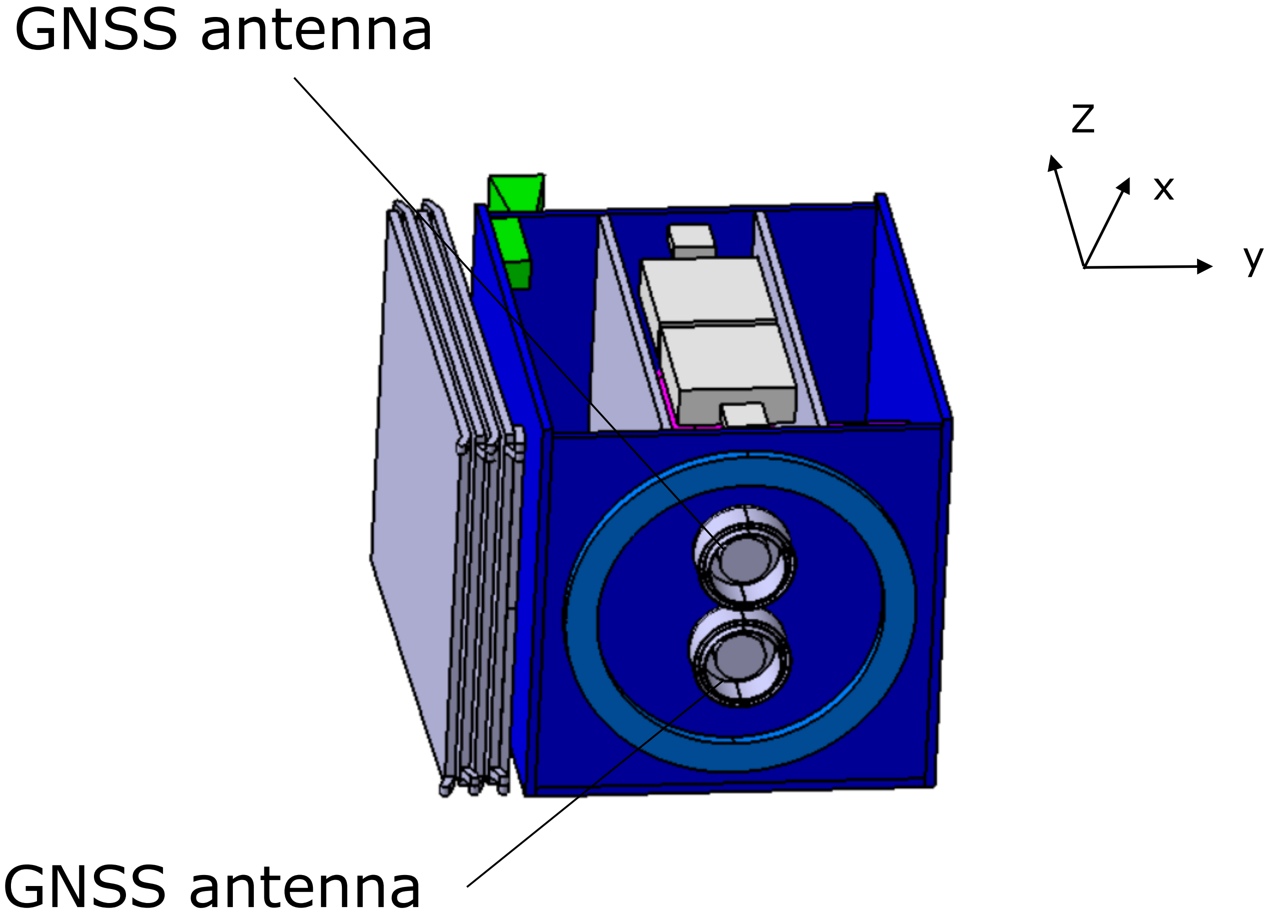
OPTIONAL: SLR ARL



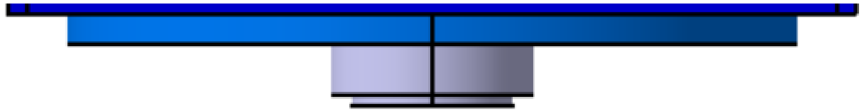
Instruments inside



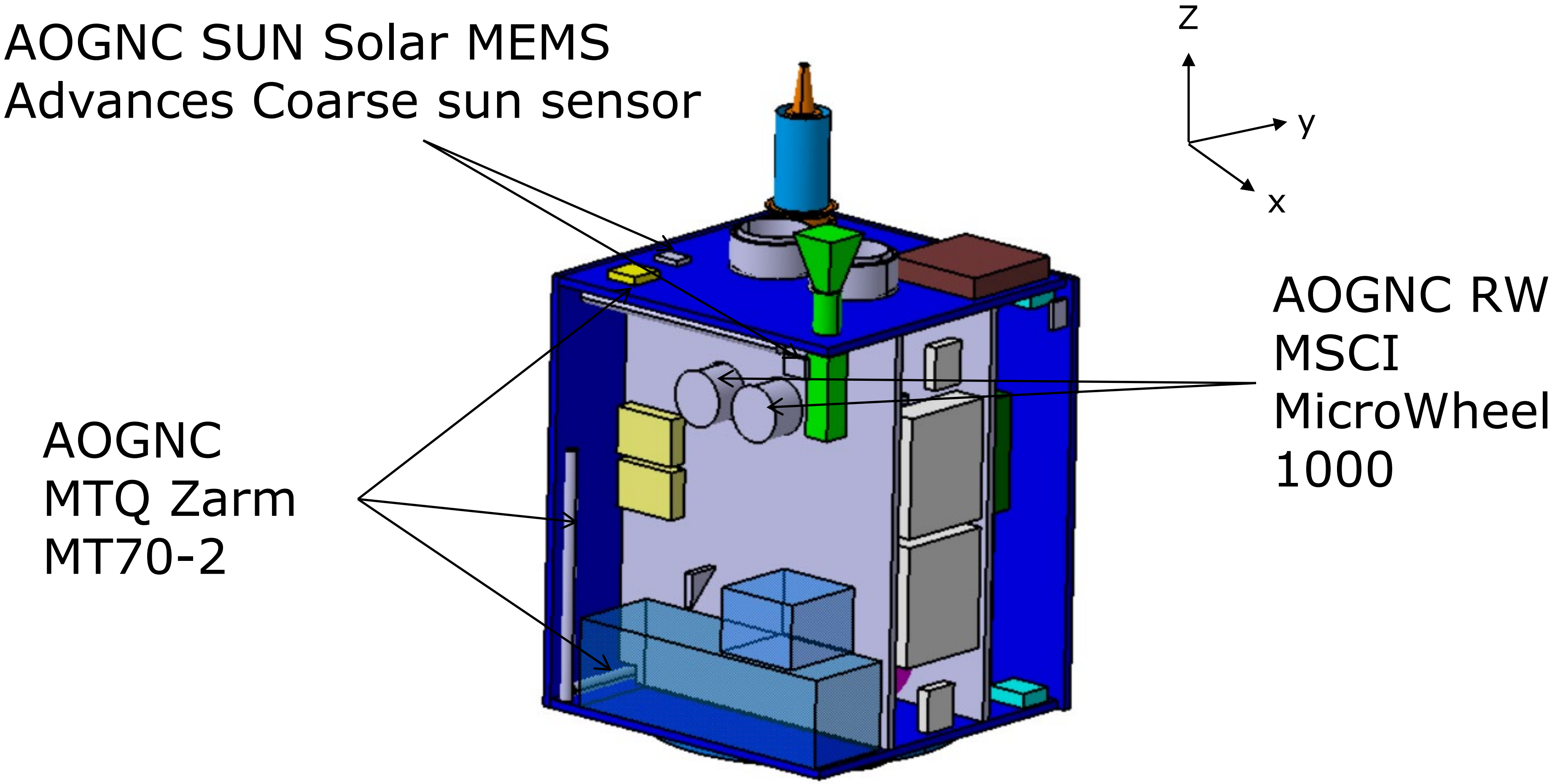
Instruments zenith



Requirements:
- Zenith pointing of GNSS antenna zenith
- GNSS antennas placed in the middle of the panel
- Unobstructed field of view for GNSS



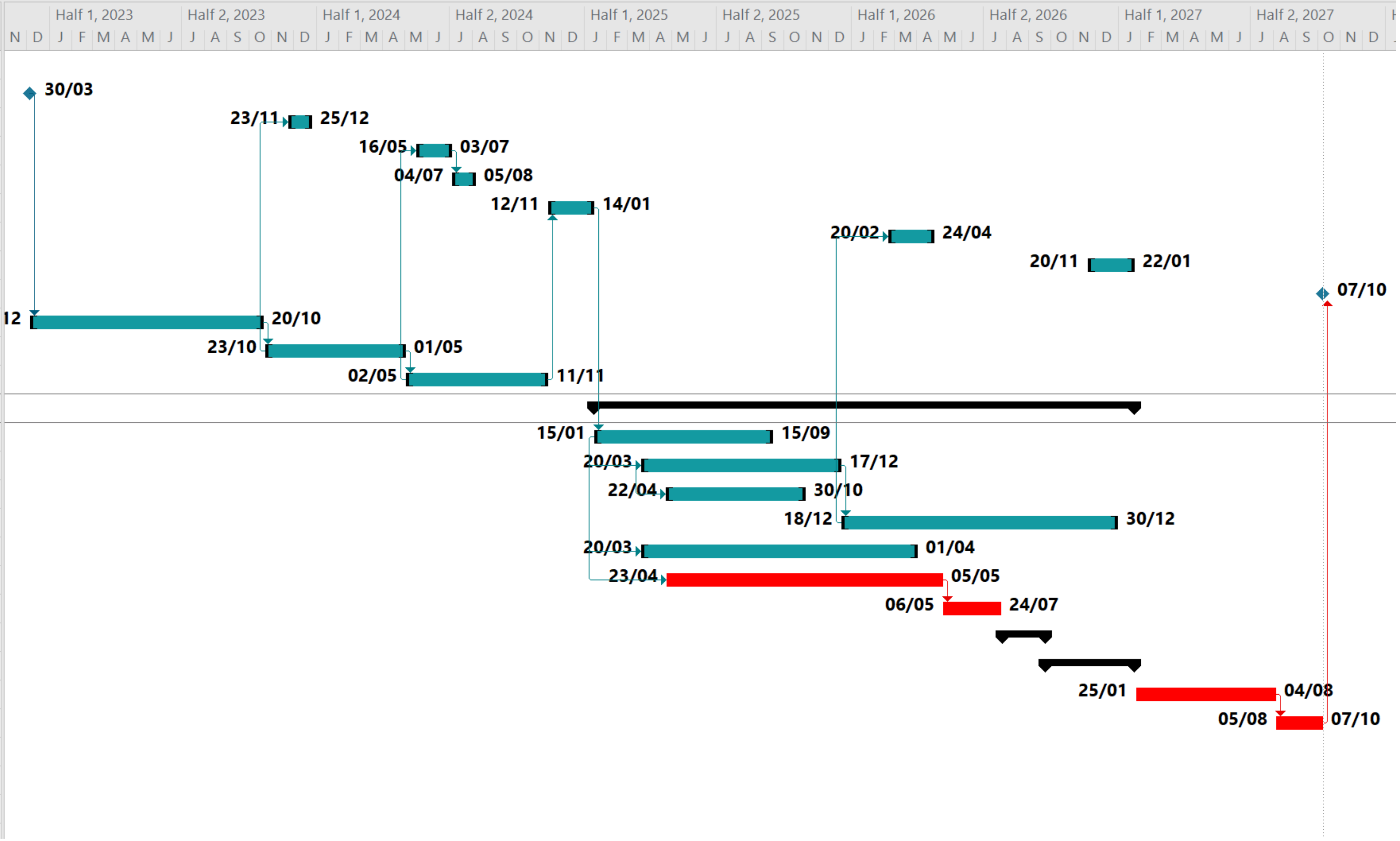
Equipment



AOGNC SUN Solar MEMS
Advances Coarse sun sensor
AOGNC
MTQ Zarm
MT70-2
AOGNC RW
MSCI
MicroWheel
1000
Z
y
x

GENESIS-1 Reference schedule – CDF Outcome (~4 years full development – launch in 2027)

Task Mode	Task Name	Duration
	K.O.	0 days
	PRR	23 days
	MAR	35 days
	SRR	23 days
	PDR	46 days
	CDR	46 days
	FAR	46 days
	Launch	0 days
	Phase A	230 days
	Phase B1	138 days
	Phase B2	138 days
	Phase C/D	**528 days**
	Detailed design	174 days
	Flat-Sat refurbishment/updat	195 days
	New EBB for Flat-Sat	138 days
	Flat-Sat functional tests	270 days
	PFM equipment Mfg and test	270 days
	Structure mfg and test	270 days
	PFM Integration	58 days
	PFM Functional Tests	**43 days**
	PFM Environmental Tests	**87 days**
	ESA Contingency	138 days
	Launch campaign	46 days



<Domain Name>

GENESIS-1 CDF Open Points for further analysis & High-level conclusions

Identified Open Points for further analysis

1. **Radiation analysis** (e.g. shielding can be reduced through smart configuration; include Heavy Ion effects)
2. Assess in more detail the different possibilities for a **launch direct injection** – Option 2
    - Launch on new European launchers under development (e.g. Rocket Factory, ISAR Aerospace)
    - Compatibility with a Galileo dual launch Ariane 6-2
    - Possibility to launch with a non-European launcher (e.g. via international cooperation)
3. Implementation of **Baseline instruments upgrades**
4. Assess in detail the opportunity of the **2 optional Payloads** (ALR and accelerometer) and their upgrades
5. Study has been instantiated on the **Proba-V generic platform for reference of small patform. Several other possible small platforms identified** in Europe, which are considered compatible with this mission concept (incl new space concepts) but would require dedicated Phase A study phase for dedicated design assessment.
6. Potential inclusion of NASA GRITSS payload and **cooperation with NASA**

GENESIS-1 Mission Assessment: High level conclusions (1 of 2)

1. Two possible GENESIS-1 Mission options have been analysed (SSO launch VEGA-C and EEP orbit raising up to 6000 Km; Direct injection to 6000-8000 Km;).
2. Reference Platform and all subsystems needs have been assessed
3. No major blocker identified. Instruments maturity considered high but specific upgrades are necessary
4. Operations (G/S, MOC and SOC) baseline identified
5. Risk Assessment performed reveals NO high Risk identified for this mission
6. Mission compatible with a development time of 4 years (launch in 2027 feasible)
7. Mission broadly compatible with GENESIS defined Program boundaries

GENESIS-1 Mission Assessment: High level conclusions (2 of 2)

1. Further work needs to be implemented as part of the Phase A/B to refine some Mission options and to perform the identified necessary instrument upgrades/adaptations (as identified in previous slides)

2. Interest from NASA for potential cooperation identified, which would need to be further explored to be fully defined

3. In parallel to CDF assessment, it is now confirmed a strong Scientific interest on GENESIS-1 Mission (clear outcome of the GENESIS-1 dedicated Science Workshop - April 26 – substantiated in a dedicated GENESIS-1 Science White paper produced and several support letters received from different highly European representative scientific organisations and NASA).

GENESIS-1: A great opportunity for Europe !

Thank you for your attention!