

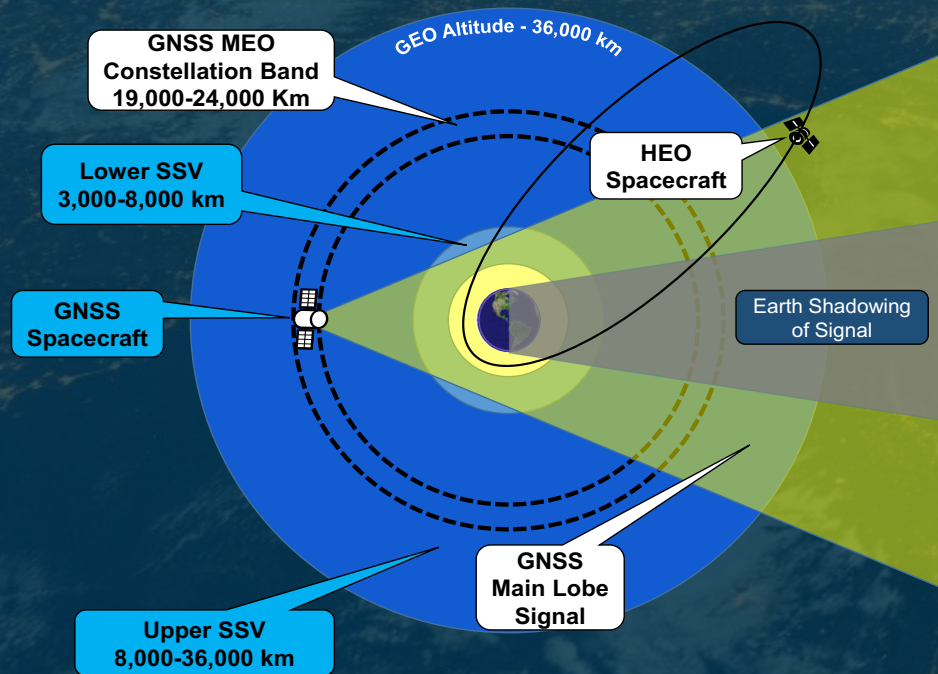
Nutzungspotenziale von GNSS für die Raumfahrt: GNSS – Space Service Volume

Global Navigation meets Geoinformation 2021, ESA/ESOC, Darmstadt, 17 Juni 2021

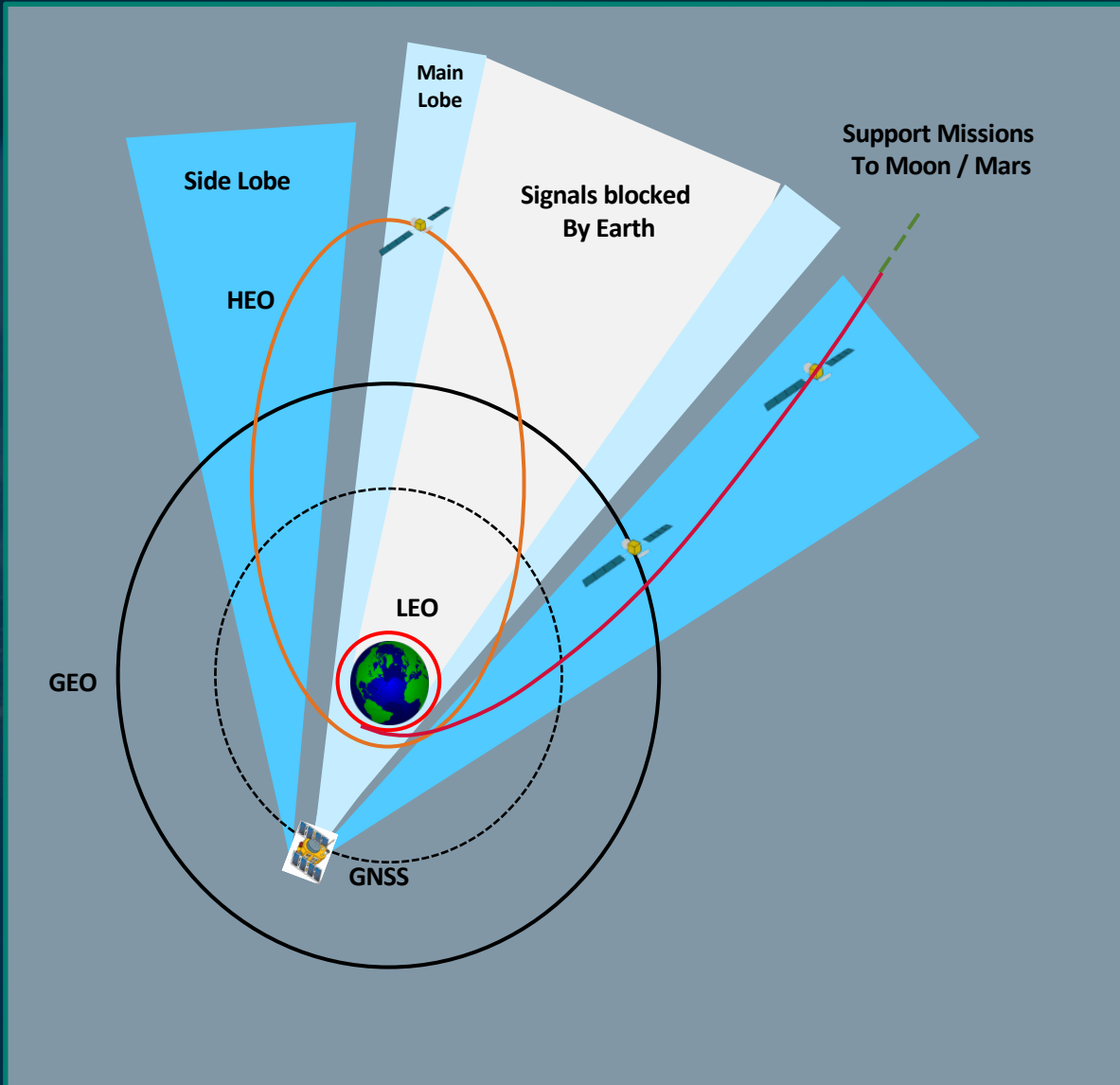
Prof. Dr.-Ing. Werner Enderle – ESA/ESOC - Navigation Support Office

Introduction – Definition of Interoperable GNSS Space Service Volume (SSV)

- Only GPS and Galileo (since 2020) have a definition for SSV
- Definition for GPS SSV is different to definition of Galileo SSV
- UN – International Committee on GNSS (ICG) Space Use Subgroup provided a definition of an interoperable GNSS SSV



<https://undocs.org/ST/SPACE/75>

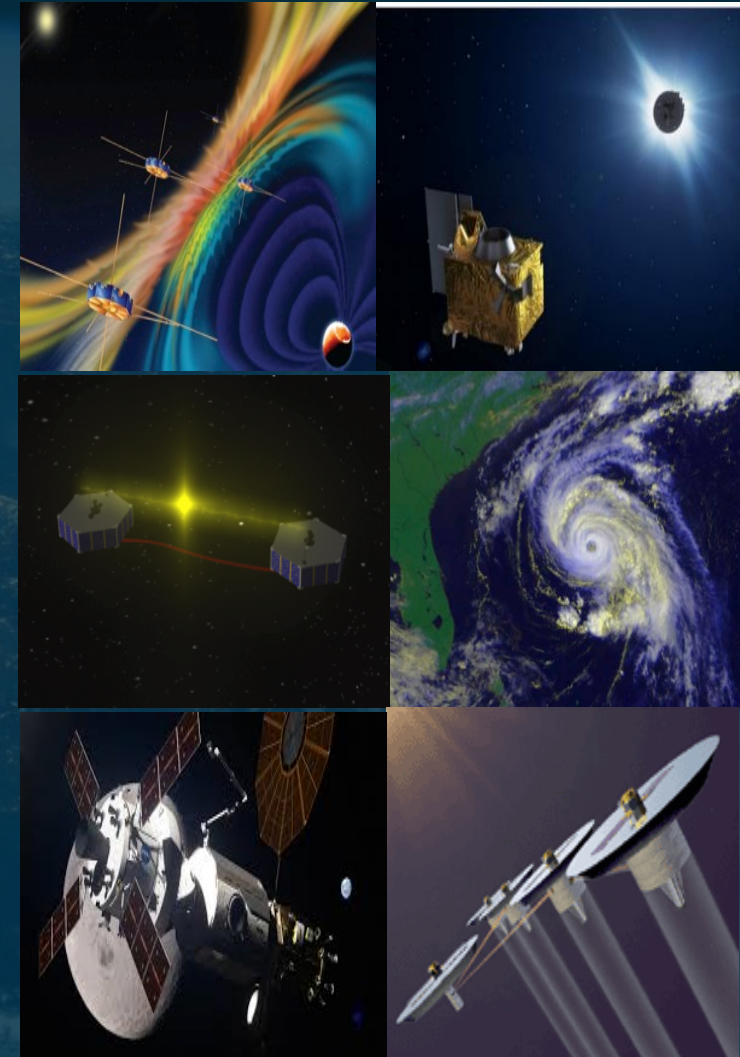


Space User Community is Very DIVERSE

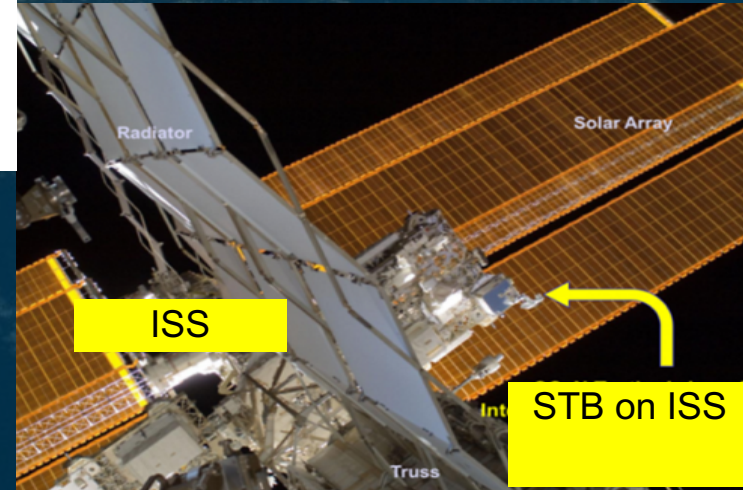
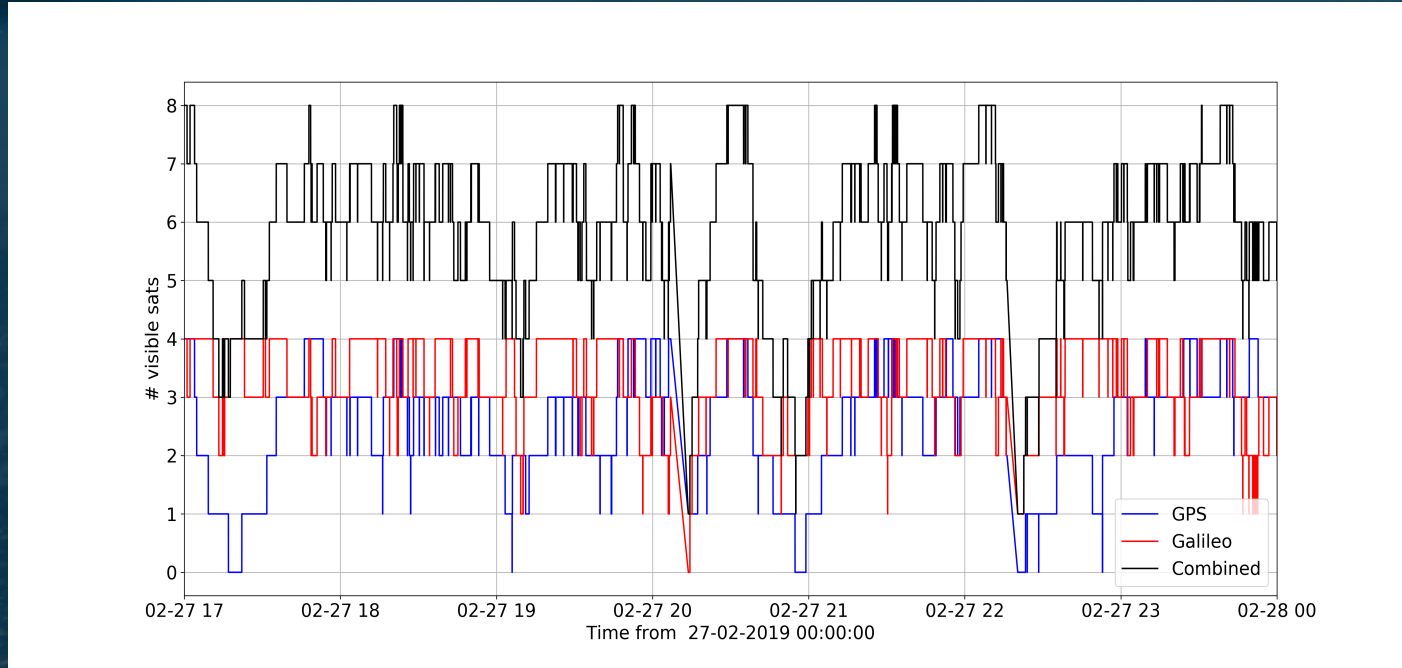
- Orbital Regime (LEO, ..., Moon)
- Size of Spacecraft (CubSat, ISS)
- Applications (Earth Obs, Com, Sci)
- Single Sat, Formation Flying
- Level of Accuracy (100m, <5cm)
- Navigation Concept (on-board, Ground)

- Performance
 - On-board generation of Position, Velocity and Time (PVT) with high accuracy
 - Interoperable GNSS SSV allows development of new positioning concepts/algorithms tailored to specific mission needs
 - Precise Orbit Determination (POD) – highest possible accuracy
- Operational
 - New operations concepts with reduced Ground interaction
 - Increase of on-board autonomy
 - Increase of robustness of spacecraft navigation and operations resilience
- Technology
 - Enabler for new mission and service concepts
 - Development of GNSS Receiver core technology

- Position, Velocity and Time (PVT) for on-board Navigation
- Precise Orbit Determination – Highest Level of Accuracy (on-ground or on-board)
- On-board Attitude Determination (3-Axis or spinning SV)
- Rendezvous and Docking
- Time synchronisation
- Launch Vehicle Range Operations
- Earth Science/Science
- Manoeuvre calibration
- Relative Navigation for Sat Formation Flying or Sat Constellation



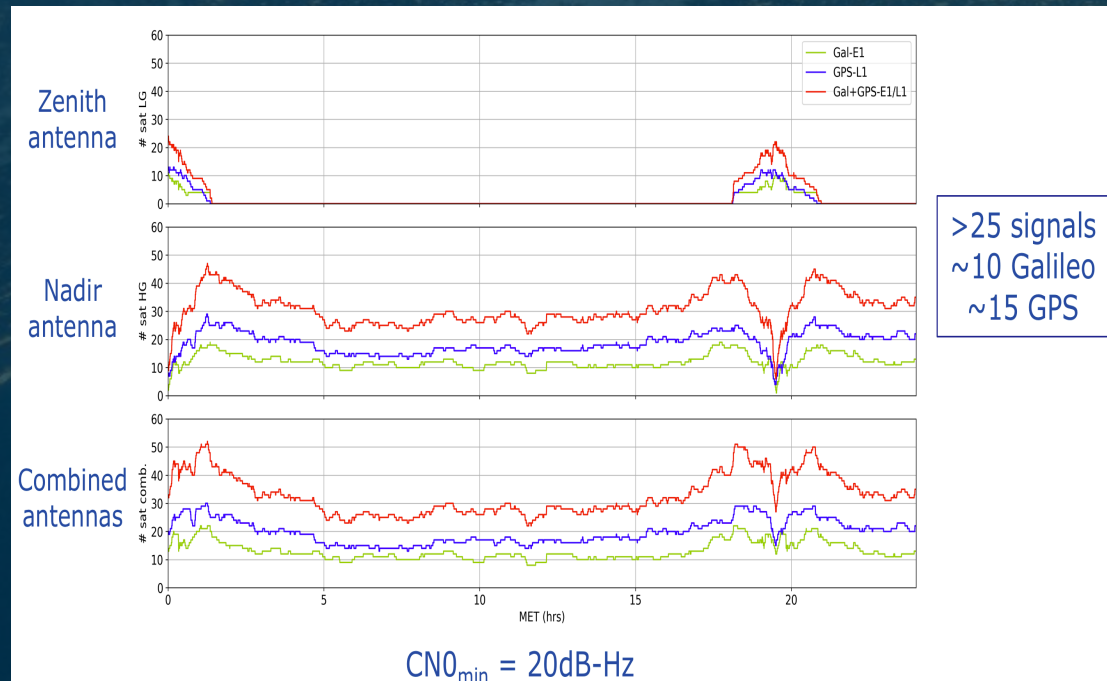
Joint ESA-NASA Galileo/GPS Experiment Onboard the ISS



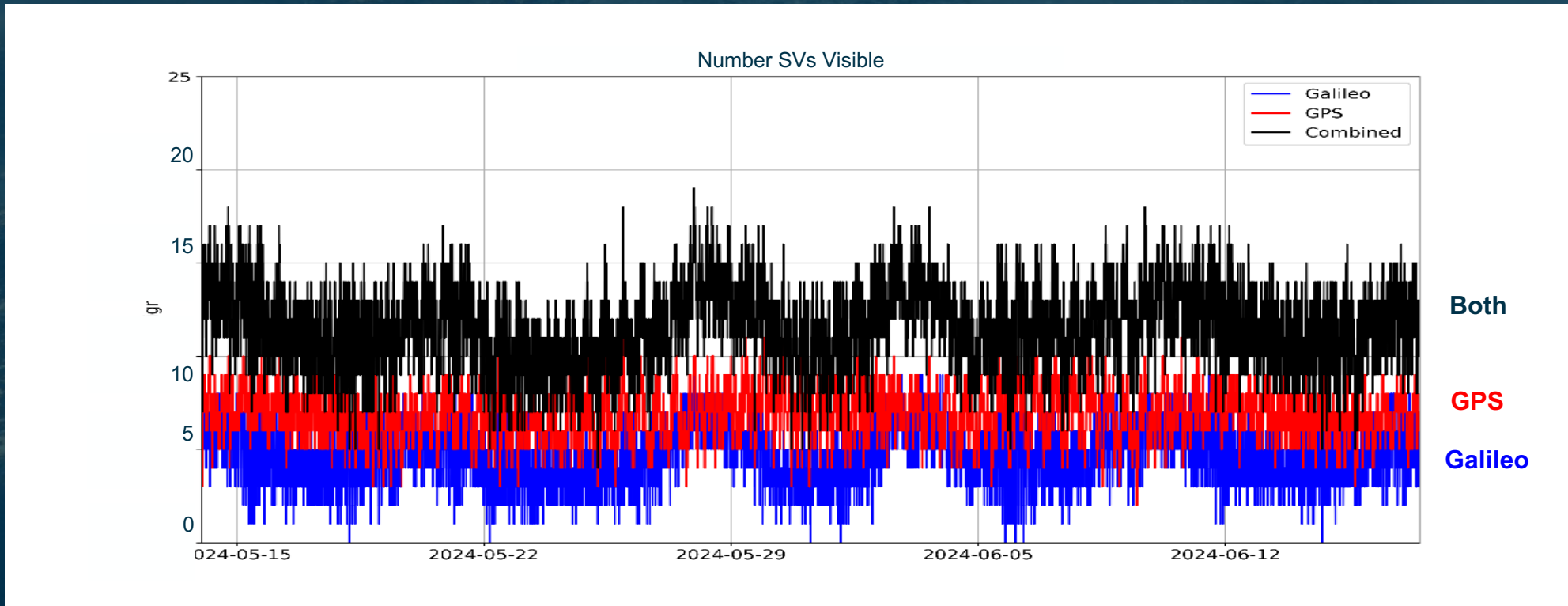
- Joint ESA/NASA Project - Demonstration of added value of GNSS SSV – Visibility of GAL/GPS SV
- First Position Fix in space from GAL/GPS E5a/L5

GNSS based Precise Orbit Determination for ESA's PROBA-3 Mission

- ESA's PROBA-3 mission is a Technology Demonstration Mission for high-precision formation-flying of a pair of satellites in an HEO orbit
- **Important: More Observations -> Better Orbit Determination Accuracy**
- **Precise Orbit Determination Accuracy: absolute 15cm, relative 3mm**



Impact of inclusion of GNSS Side Lobes Signals in Simulations for Gateway
(based on models, in orbit measurements and/or data released by the GNSS service providers)



Predicted Gateway GPS/Galileo visibility
(20 dB-Hz; ESA/ESOC)

ISS
 GAL/GPS Receiver
 on-board the ISS
 First E5a/L5 only
 position fix in space

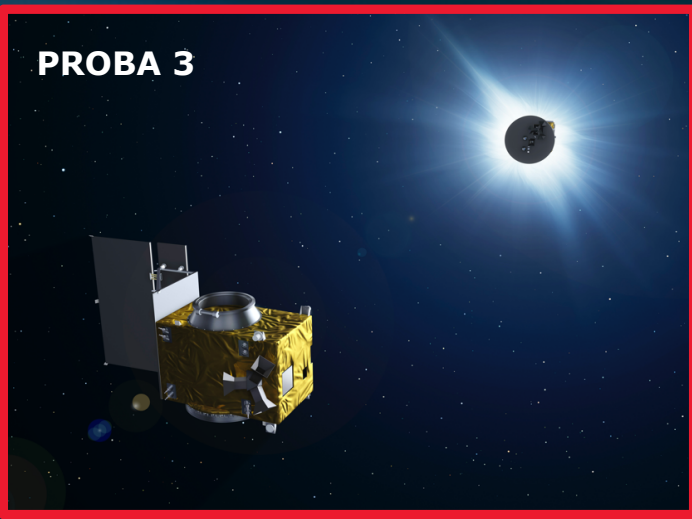


2018 - 2019

Sentinel – 6 A
 Precise Orbit Determination
 based on dual freq.
 GAL/GPS Receiver



2020



PROBA 3

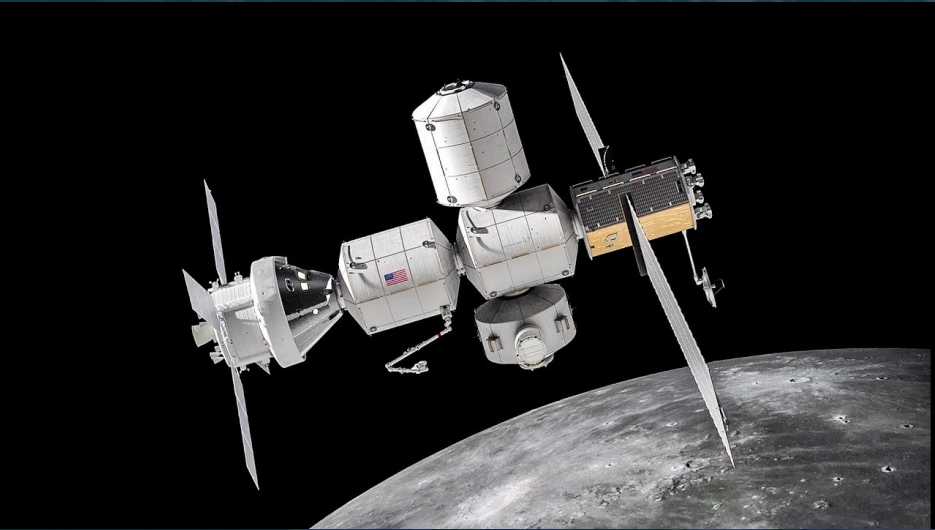
PROBA - 3
 absolute and relative
 Precise Orbit Determination
 based on dual freq.
 GAL/GPS Receiver

2023

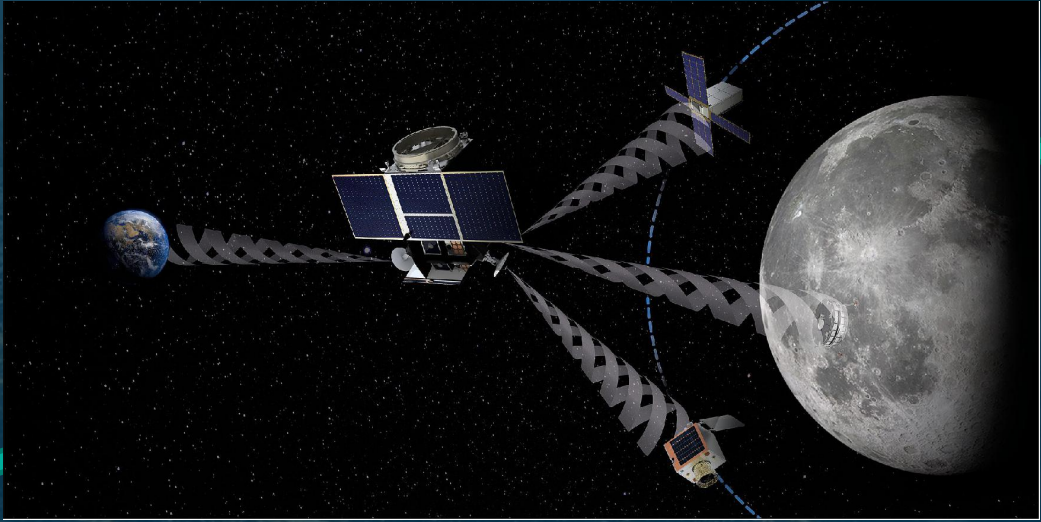


Lunar Pathfinder

- Galileo/GPS receiver and also a Laser Reflector onboard
- First time ever that such a combination is lying on a mission to the Moon
- Precise Orbit Determination Experiment based on GNSS and Laser Ranging



2023



GATEWAY

Proposal was made for on-board navigation and Precise Orbit Determination based on GAL/GPS Receiver

Future Vision

GNSS as an integral future infrastructure element for Spacecraft Navigation for missions to Moon and Mars

202x

- The interoperable multi-GNSS Space Service Volume (GNSS SSV) offers enormous benefits for space users and is an enabler for future advanced missions (Improved signal availability, Improved navigation performance)
- The number of Space Users in all orbital regimes, which are relaying on GNSS will grow significantly over the next 5 years
 - from **several 100's** to **several 10000's**
- With advanced GNSS equipment, GNSS signals can be tracked and used for navigation within Lunar missions
- ESA supports international activities related to the GNSS SSV, like ICG, IGS, IOAG, ISECG, CCSDS,...