



GNSS Space Service Volume (SSV) and Lunar GNSS Activities

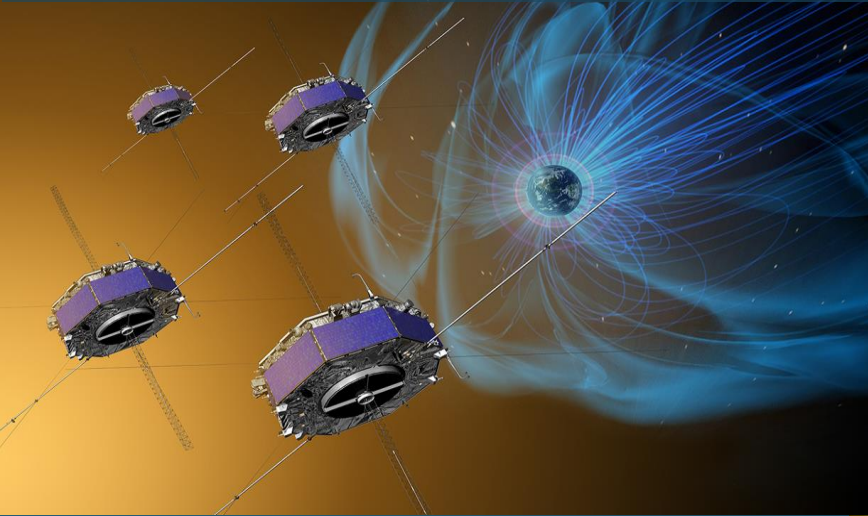
Joel J. K. Parker, NASA, United States
On behalf of the ICG WG-B Space Use Subgroup

COPUOS STSC, 13 Feb 2023



International Committee on
Global Navigation Satellite Systems

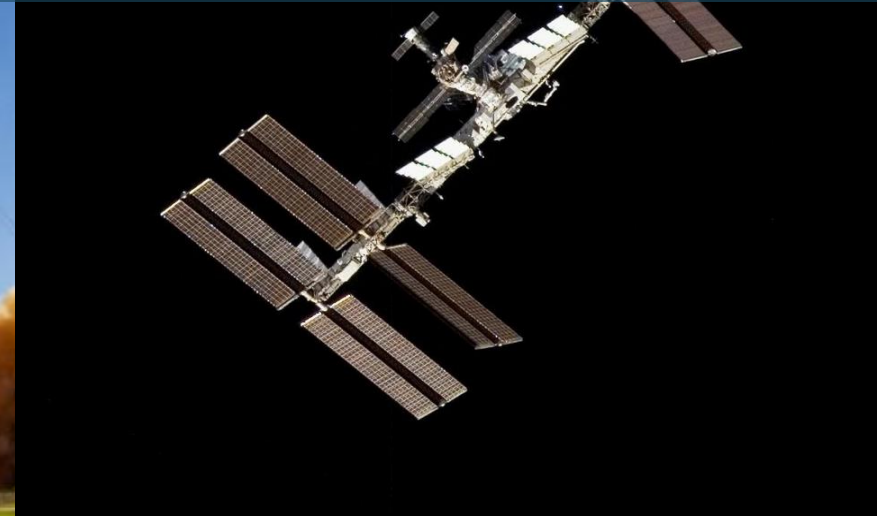
Real-Time On-Board Nav



Launch Vehicle Range Ops



Attitude Determination

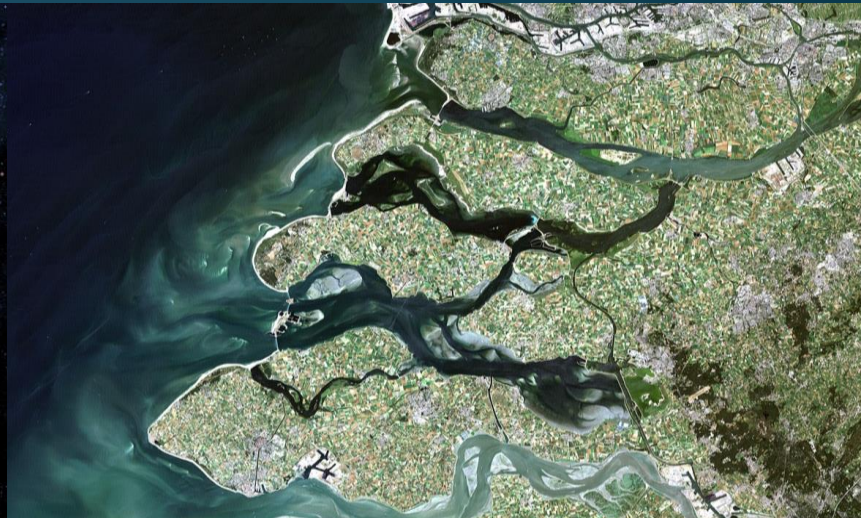


Active Space Uses of GNSS

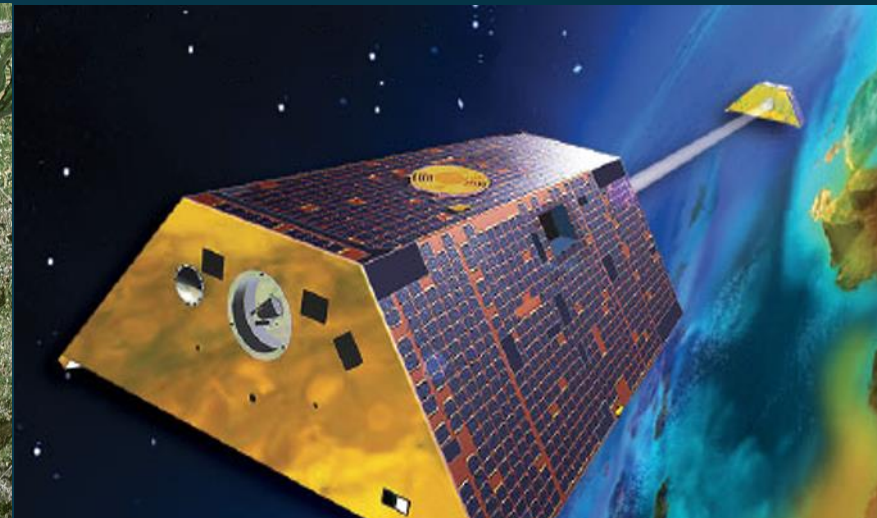
Time Synchronization



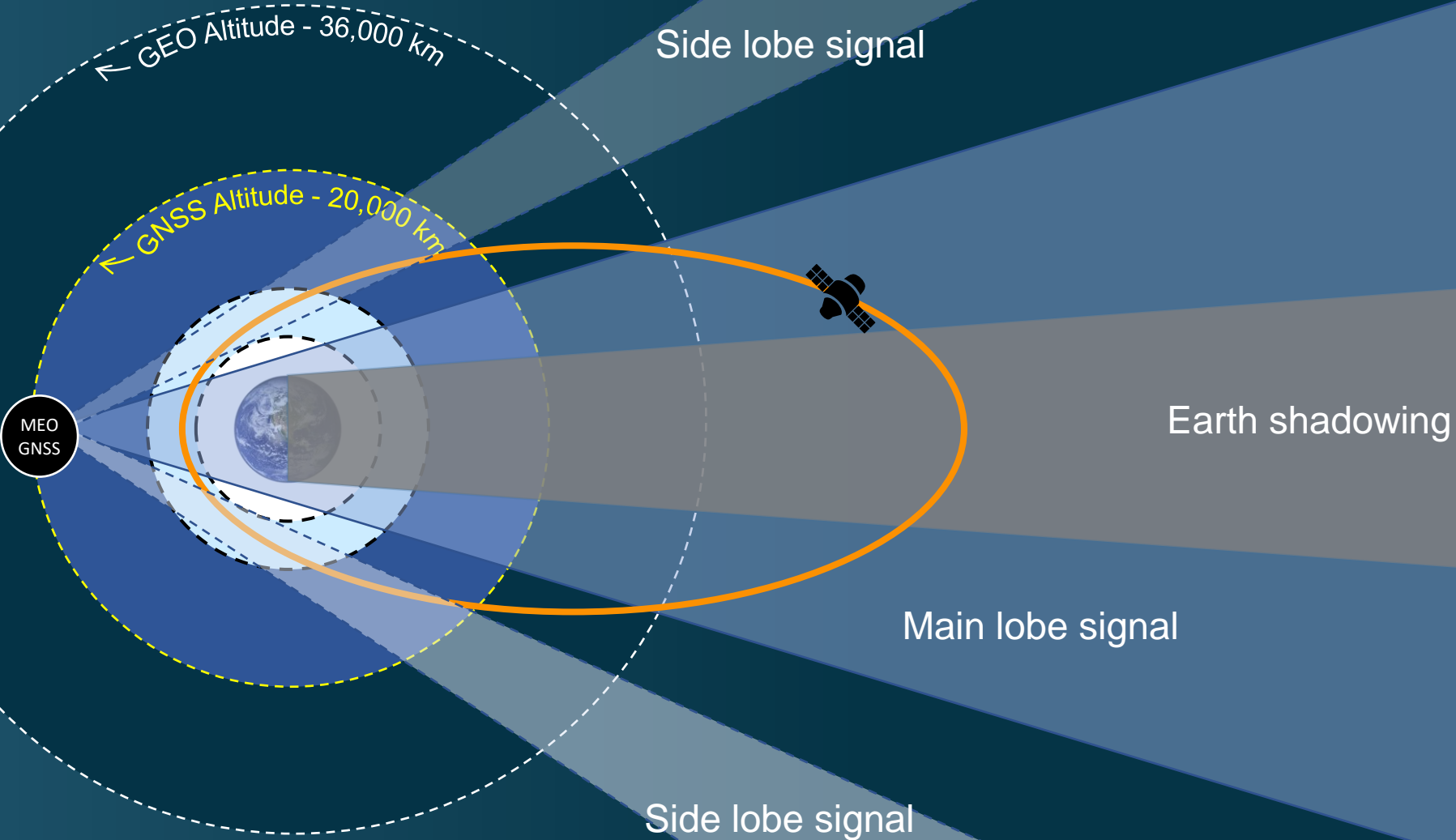
Earth Sciences



Precise Orbit Determination

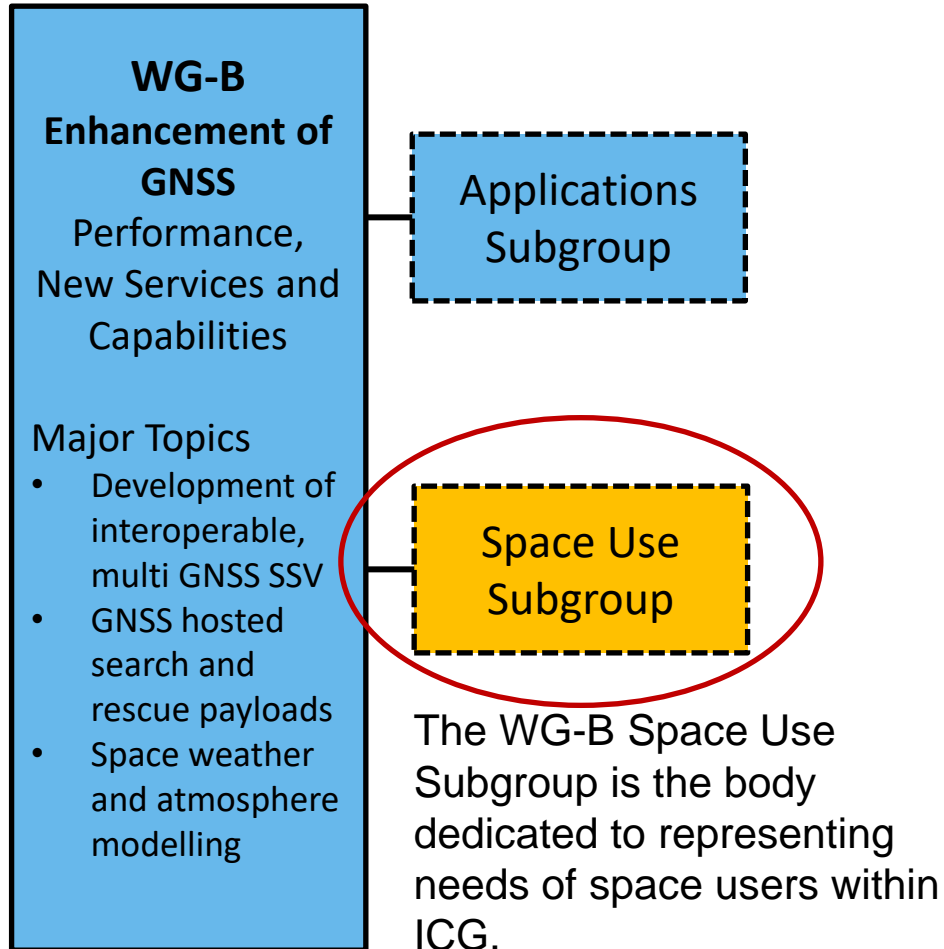


Signal Reception in the GNSS Space Service Volume (SSV)



International Committee on GNSS (ICG)

The ICG consist of the GNSS Service Providers Forum and four Working Groups (WG-S, WG-B, WG-C and WG-D).



Space Use Subgroup Work Plan

WP#	Activity	Lead
1	Public availability of provider antenna/signal technical data and requisite models	India
2	GNSS space user mission data and profile	China
3	GNSS space user timing requirement analysis and space user operations recommendations	Europe
4	GNSS SSV and lunar PNT systems to support lunar operations	USA
5	GNSS space user Standards	Europe

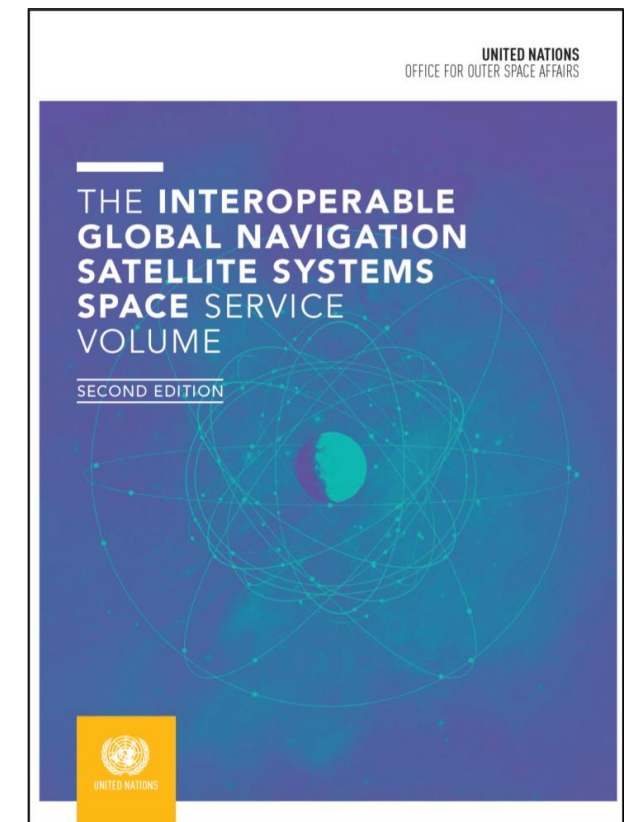
Space Use Subgroup (SUSG) – Accomplishments

• SSV Booklet 2nd Edition

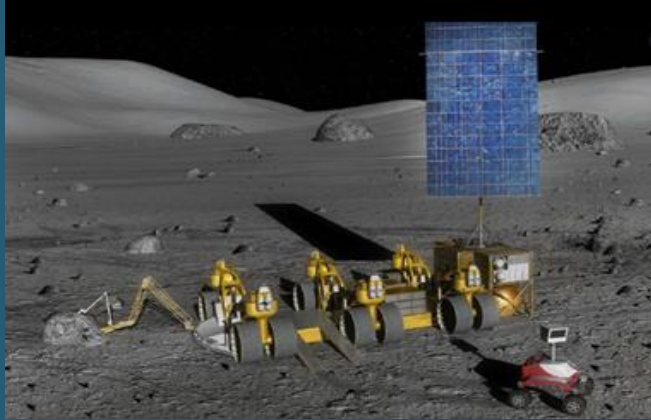
- Describes the Interoperable GNSS Space Service Volume, its benefits, per-constellation characteristics, and combined performance metrics
- 2nd Edition new content:
 - GNSS constellation updates
 - new Flight Experiences chapter featuring five real-world missions
 - additional analysis of geometric aspects of SSV
- **Published at ICG-15, 2021**
- Available at: <https://undocs.org/ST/SPACE/75/REV.1>

• SSV Video

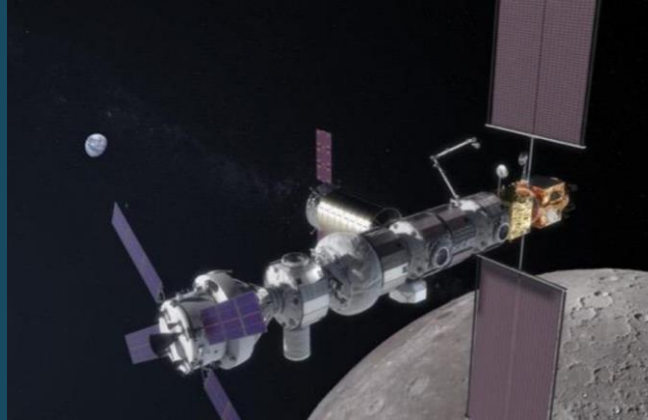
- Four minute video, developed as an outreach tool to:
 - Explain utility and benefits of a multi-GNSS SSV
 - Show how it will transform navigation use in space, and
 - Describe how it will impact humanity—in space and on Earth
- Co-Sponsors: NASA and National Coordination Office for Space-based Positioning, Navigation and Timing
- **Published at ICG-15, 2021**
- Available at: <https://www.unoosa.org/oosa/en/ourwork/icg/documents/videos.html>



Lunar Exploration: Roles for GNSS



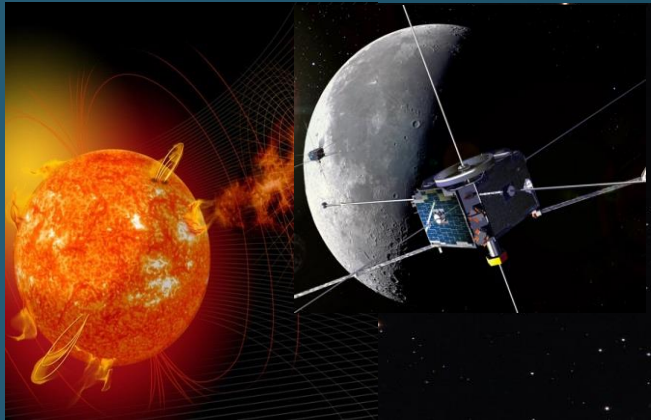
Lunar Surface Operations, Robotic Prospecting, & Human Exploration



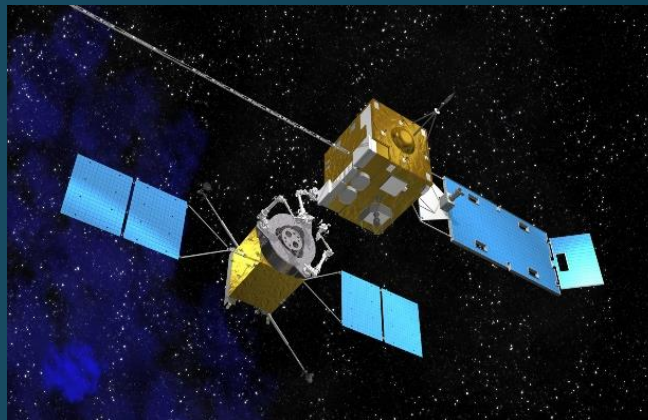
Human-tended Lunar Vicinity Vehicles



Robotic Lunar Orbiters, Resource & Science Sentinels



Earth, Astrophysics, & Solar Science Observations

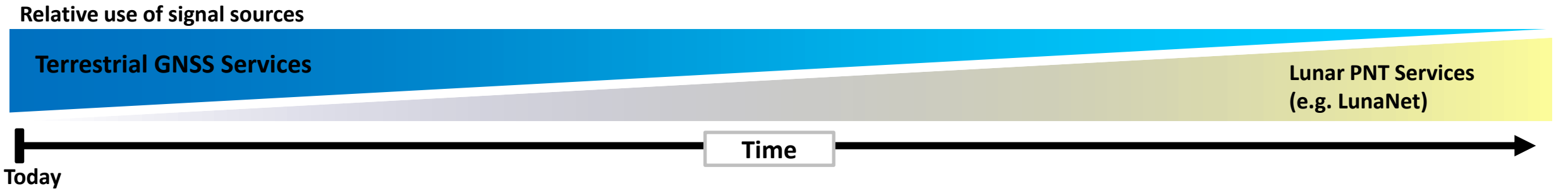
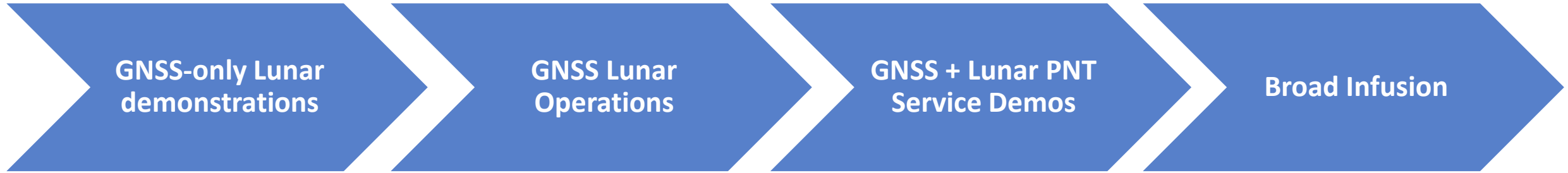


Satellite Servicing

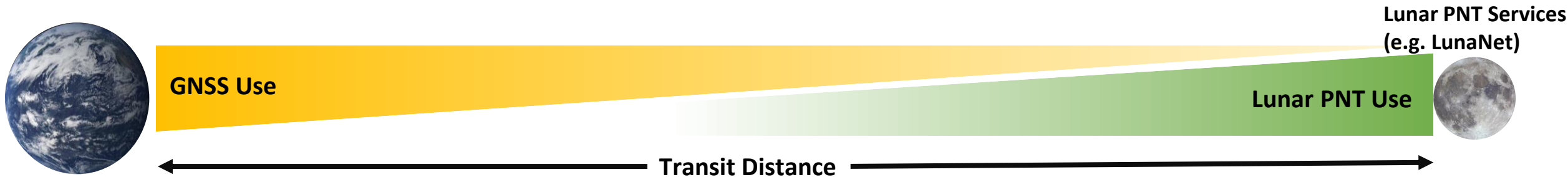


Lunar Exploration Infrastructure

Phased Expansion of Lunar PNT Services



Transit use of GNSS and Lunar PNT Services



ICG Member Lunar PNT Activities

Space Use Subgroup has received briefings on four lunar PNT activities by ICG members.

CAST/China – Earth-Moon Communication-Navigation System

- Step 1: Earth-Moon navigation system based on enhanced GNSS
- Step 2: Communication-navigation system for near-Moon space mission
- Step 3: Communication-navigation system for cislunar space mission

ESA/Europe – Moonlight

- Lunar Pathfinder – low-rate satellite communications service + Moon GNSS receiver - 2025
- Moonlight Programme – high-data-rate satellite communications and navigation service - 2027

JAXA/Japan – Lunar Navigation Satellite System

- Eight-satellite constellation in elliptical lunar frozen orbits
- Lunar PNT demonstration mission currently targeting around 2028

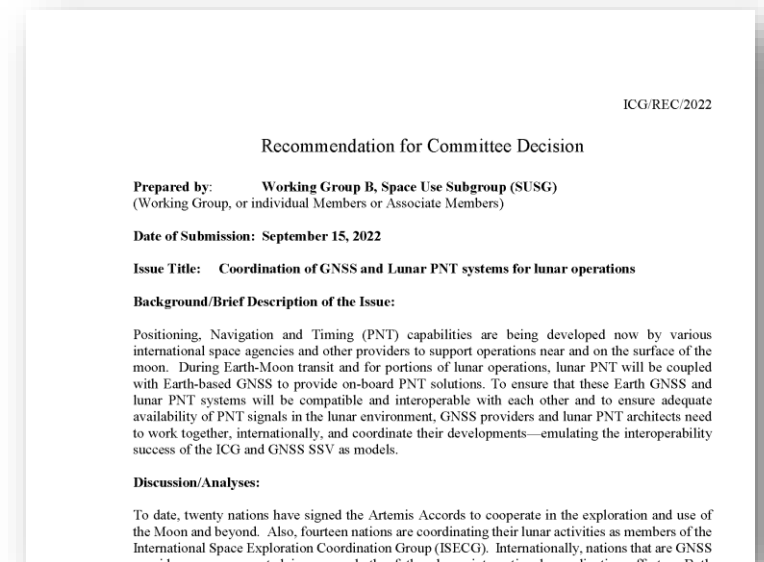
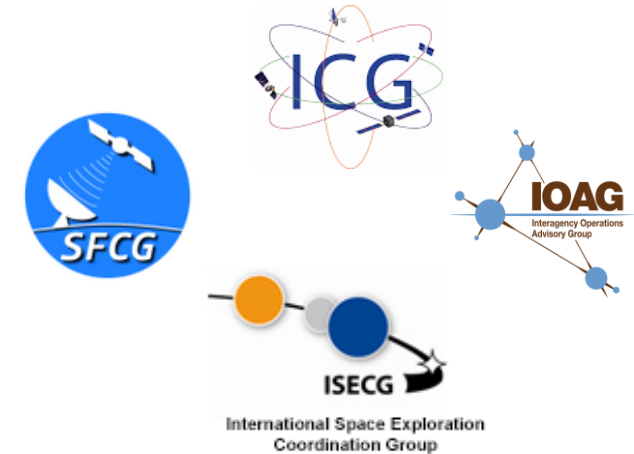
NASA/USA – Lunar Communications Relay and Navigation Systems (LCRNS)

- Enables an interoperable approach for lunar communications and PNT via LunaNet Interoperability Standards
- Preliminary requirements document released May 2022; LunaNet Interop. Spec v4 released Dec 2022
- Lunar GNSS Receiver Experiment (LuGRE) will demonstrate GNSS-based PNT at the Moon in 2024

ICG Lunar PNT Coordination Approach

- Coordinate with relevant multilateral organizations, e.g.:
 - Interagency Operations Advisory Group (IOAG) - operations, communications, navigation
 - International Space Exploration Coordination Group (ISECG) – roadmaps, tech needs
 - Space Frequency Coordination Group (SFCG) - radiofrequency coordination
- ICG role includes:
 - Collect and document lunar use cases
 - Encourage and consolidate results of lunar flight experiments using GNSS and lunar PNT systems
 - Study and make recommendations to maximize **compatibility, interoperability, and availability** of combined GNSS + lunar PNT “system of systems”, including:
 - Combined lunar architectures; service volume definitions
 - Frequencies and codes; signal interoperability and compatibility
 - Reference frames and timing
 - Per ICG Terms of Reference, ICG provides recommendations; other organizations (e.g., IOAG, SFCG, space agencies) act on recommendations at their discretion.
- ICG-16 WG-B Recommendation #1: “Coordination of GNSS and Lunar PNT systems for lunar operations”

The ICG encourages international GNSS providers and lunar PNT developers to work together via the appropriate multilateral fora, such as the IOAG, to ensure the future attainment of an interoperable, compatible, and available PNT system of systems that can support the world’s ever-expanding human and robotic space operations around and on the surface of the moon. [...]



Conclusions

- **GNSS use in space is widespread and routine** across a variety of active use cases, including real-time spacecraft navigation, time synchronization, Earth sciences, and many others.
- The **Interoperable Multi-GNSS Space Service Volume** framework offers enormous benefits for high-altitude space users and can be seen as an enabler for future advanced missions via improved signal availability and navigation performance.
- With advanced GNSS equipment, GNSS signals can be tracked and used for navigation **even for Lunar missions**
- GNSS will play **a key role in the combined Earth-Moon PNT environment** as lunar-focused services are developed.
- **Coordination of international activities** is essential to ensure interoperability, compatibility, and availability of PNT systems within the Space Service Volume and beyond in the Earth-Moon system.