Update on the Interoperable GNSS Space Service Volume

International PNT Activities of the ICG Space Use Subgroup

Mr. Juan Pablo Boyero (EC)
Mr. Joel Parker (NASA)
Dr. Masaya Murata (JAXA)

On behalf of the ICG WG-B Space Use Subgroup

CGSIC International Information Subcommittee
11 Sep 2023

International Committee on Global Navigation Satellite Systems

International Committee on GNSS (ICG)

- The ICG emerged from 3rd UN Conference on the Exploration and Peaceful Uses of Outer Space in July 1999
- The ICG brings together all six GNSS providers (United States–GPS, European Union–Galileo, Russia–GLONASS, China–BeiDou, India–NavIC and Japan–QZSS), as well as other members and observers to:
  - *Promote the use of GNSS and its integration into infrastructures*
  - *Encourage compatibility and interoperability among global and regional systems*
- Observers: International organizations and associations (BIPM, **IOAG**, ITU, IGS, etc.,)

https://www.unoosa.org/oosa/en/ourwork/icg/icg.html

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).

WG-S
Systems, Signals and Services

Major Topics
- Spectrum compatibility
- Interference detection & mitigation
- Service interoperability
- Performance standards & monitoring

WG-B
Enhancement of GNSS
Performance, New Services and Capabilities

Major Topics
- Development of interoperable, multi GNSS SSV
- GNSS hosted search and rescue payloads
- Space weather and atmosphere modelling

Applications Subgroup

Space Use Subgroup

WG-D
Geodetic Reference, Time Reference and Applications

Major Topics
- ITRF, geodetic reference frame
- Time standards & multi constellation time offsets
- High Accuracy applications (PPP)

WG-C
Information Dissemination and Capacity Building

Major Topics
- Training and Seminars
- Information Material

(Subgroups of WG-S, WG-D, WG-C not shown.) Terms of Reference: https://www.unoosa.org/oosa/en/ourwork/icg/meetings/ICG-2022.html

ICG WG-B Space Use Subgroup (SUSG)

- Founded at ICG-13, Nov 2018, in Xi'an, China to serve as the focal point for representing the needs of the space GNSS user community within the ICG.

- Terms of Reference (as adopted 15 Apr 2021)

  Objectives of Space Use Subgroup:

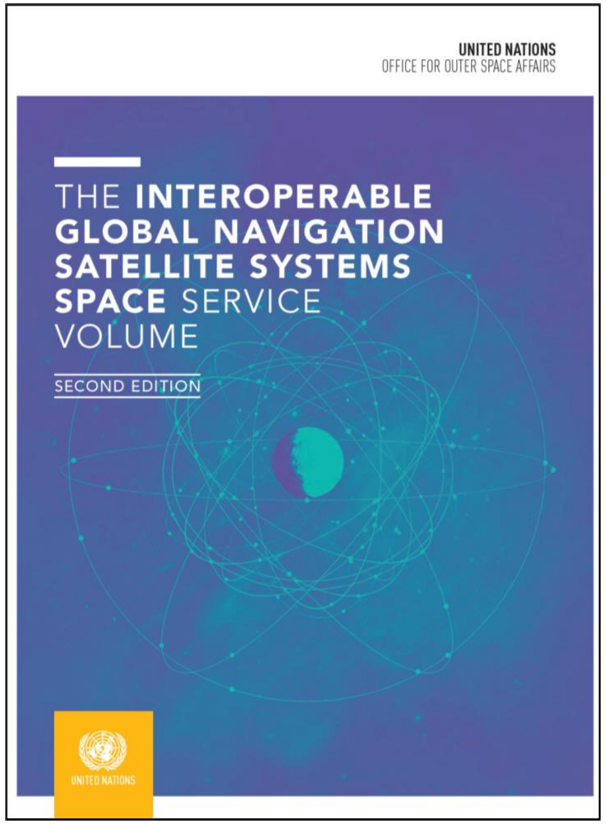
  - *Lead evolution of the Interoperable Multi-GNSS Space Service Volume including the use of GNSS for missions beyond the existing SSV (e.g. lunar).*
  - *Encourage developments of space-based user equipment and emerging user community.*
  - *Encourage coordination with Interagency Operations Advisory Group (IOAG) and International Space Exploration Coordination Group (ISECG).*
  - *Encourage development of new services and augmentations beneficial to space users.*
  - *Promote space user community needs within ICG.*

- Members: China*, EU (EC, ESA*), US*, India, Japan, Russia

*co-chairs

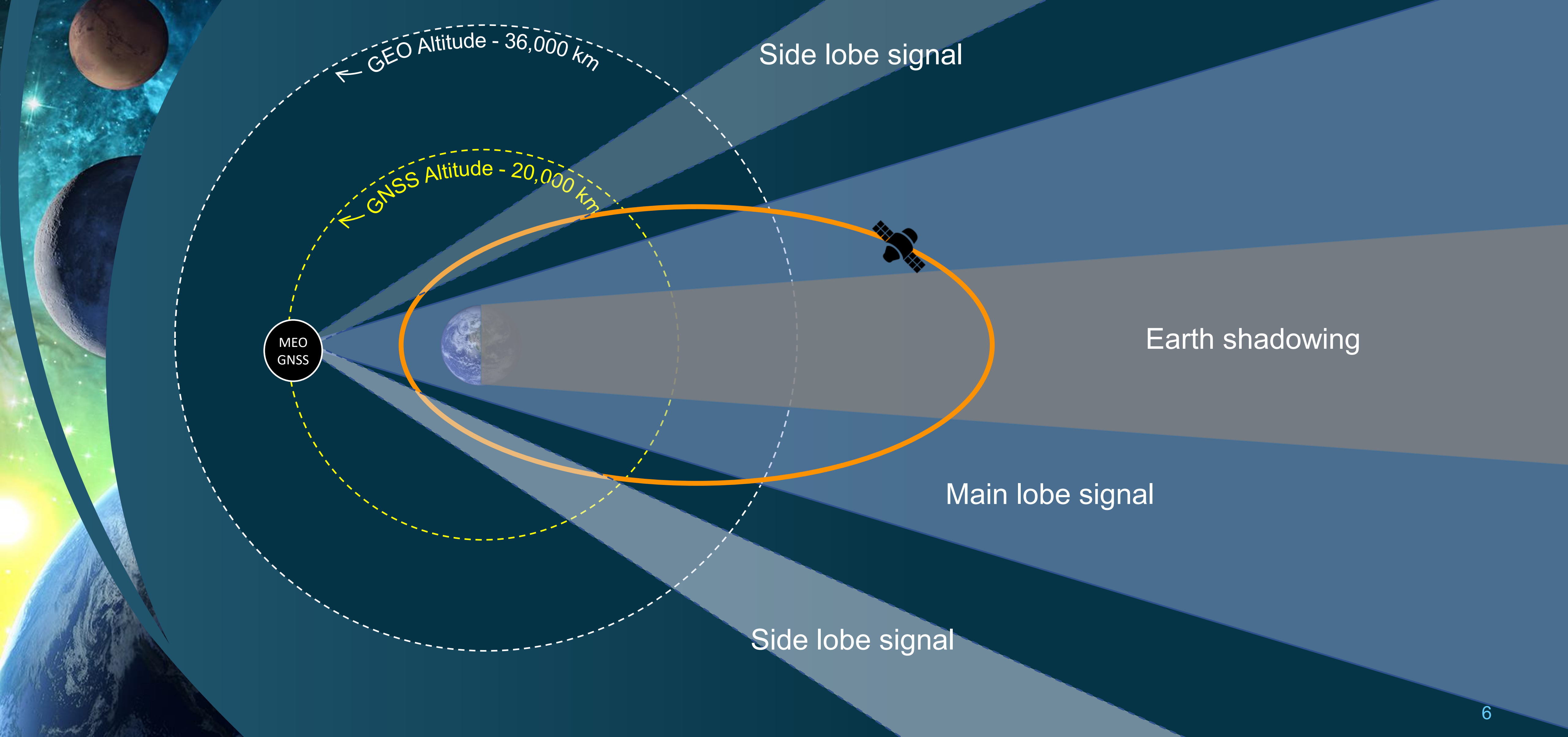
Space Use Subgroup (SUSG) – Accomplishments

- **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
  - Summary publications are underway

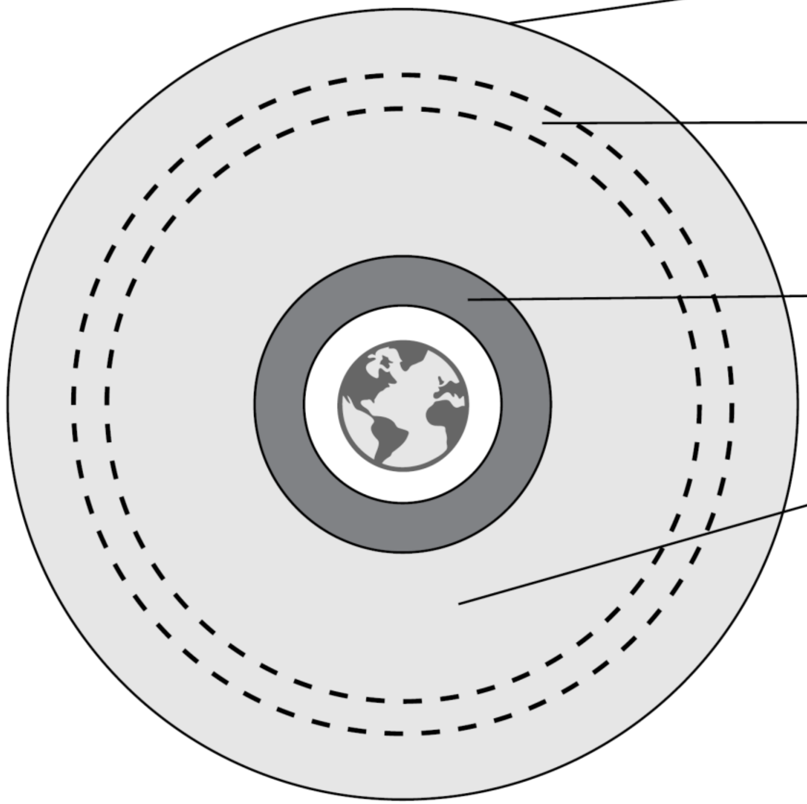


- **SSV Video**
  - Four minute video, developed as an outreach tool to:
    - Explain utility and benefits of a multi-GNSS SSV
    - Show how it will transform navigation use in space, and
    - Describe how it will impact humanity—in space and on Earth
  - Co-Sponsors: NASA and National Coordination 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

Signal Reception in the GNSS Space Service Volume (SSV)



Space Service Volume Definition



The GNSS Space Service Volume is defined as the region of space between **3,000 km** and **36,000 km** altitude from Earth.

Service in the SSV is defined by three key **parameters**…

- Pseudorange accuracy
- Minimum received power
- Signal availability

…across two **regions**:

- Lower SSV, up to 8,000 km
- Upper SSV, up to 36,000 km

SSV Characteristics for All GNSS Providers

Expected performance data (extracted sample shown here) was requested via a “template” for each:

- GNSS constellation
- Civil signal
- SSV parameter

Data was requested for nominal constellations, and for primary main lobe signals only.

Supplied data represents minimum performance **expectations** for each signal; specification and requirement status varies by provider.

Data is intended to provide a **conservative baseline performance level** for mission planning activities. See the SSV Booklet for details constellation-specific information.

Data includes expected **signal availability** for each signal in each SSV region.

*New in 2nd edition

Band	Constellation	Minimum Received Civilian Signal Power	
		0dBi RCP antenna at GEO (dBW)	Reference off-boresight angle (°)
L1/E1/B1	GPS	-184 (C/A) -182.5 (C)	23.5
	GLONASS	-179	26
	Galileo	-182.5	20.5
	BDS	-184.2 (B1I MEO) -185.9 (B1I I/G) -184.2 (B1C MEO)* -185.9 (B1C IGSO)*	25 19 25 19
	QZSS	-185.5	22
L5/L3/E5/B2	GPS	-182	26
	GLONASS	-178	34
	Galileo	-182.5 (E5b) -182.5 (E5ABOC)* -182.5 (E5a)	22.5 23.5 23.5
	BDS	-182.8 (MEO) -184.4 (I/G)	28 22
	QZSS	-180.7	24
	NavIC	-184.54	16

Benefits of the Interoperable GNSS SSV

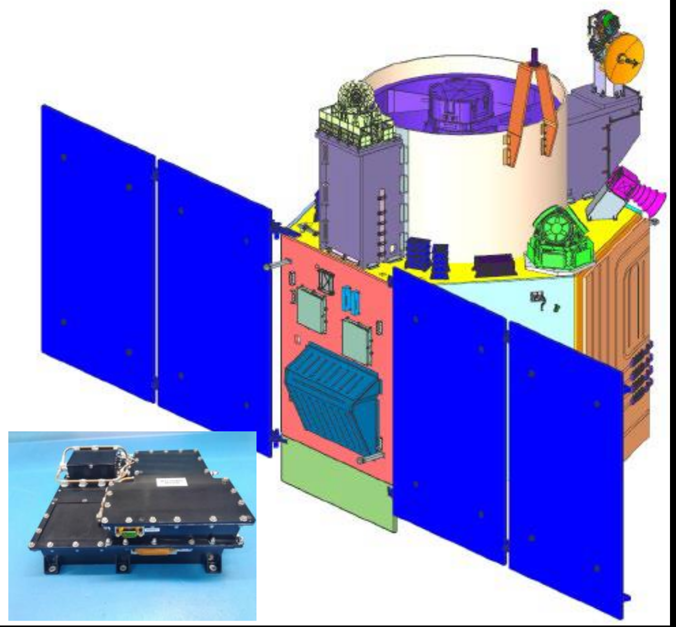
- **Improve navigation performance:**
  - Increase number of usable signals over individual constellations alone
  - Improve geometric diversity by using multiple constellations in different regimes
  - Reduce or eliminate periods of outage, reducing the need for highly stable on-board clocks

- **Enable new mission types and operations concepts:**
  - Improved availability of navigation signals enables increased satellite autonomy, reducing the need for ground interactions and enabling reduced operations costs.
  - Increase operational robustness via diversity of independent constellations, signals, geometries, etc.
  - Reduce the navigation burden on ground-based communications assets, simplifying mission architectures.

- **Encourage development of the high-altitude GNSS user community**
  - Adoption of the Multi-GNSS SSV indicates GNSS provider support for the high-altitude user community, encouraging development of specialized receivers and new mission applications.
  - Established UN ICG process provides a forum for further development.

Image: Southeastern USA at night, from ISS (NASA)

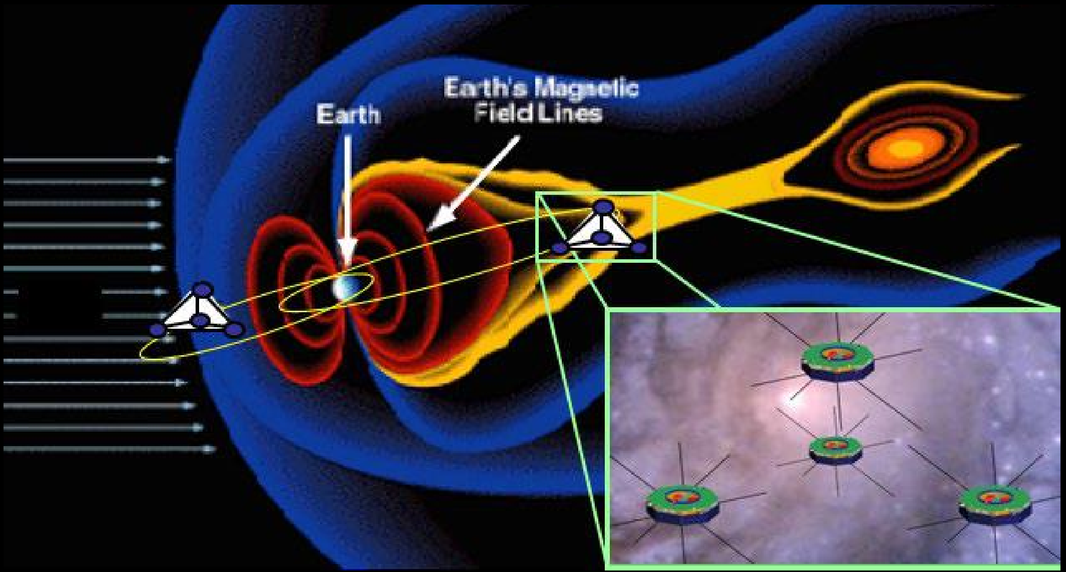
Real-World Mission Examples



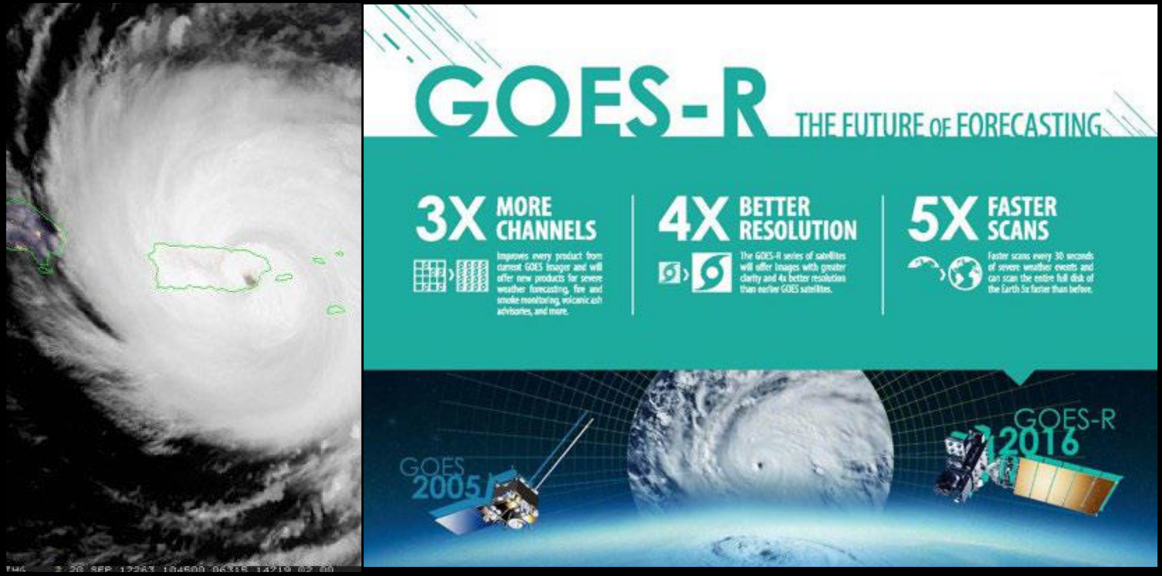
CARTOSAT-3 (ISRO)
GPS+NavIC, LEO Sun-Sync

Proba-3 (ESA)
GPS+Galileo, Highly Elliptical Earth Orbit

GARISS (NASA+ESA)
GPS+Galileo, ISS payload



MMS (NASA)
GPS, Highly Elliptical Earth Orbit



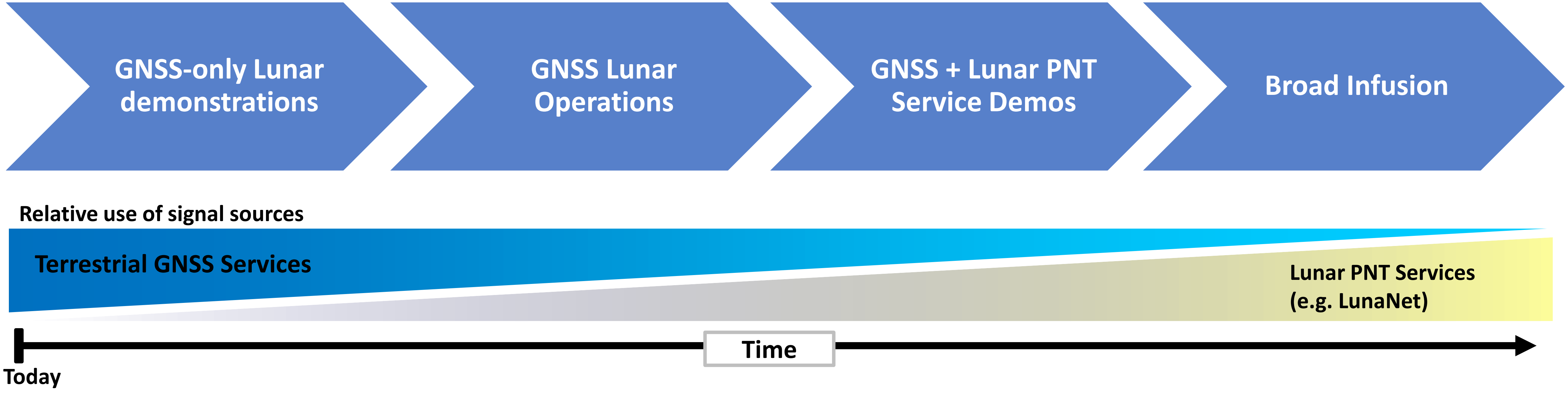
GOES-R (NASA/NOAA)
GPS, Geostationary Orbit

Space Use Subgroup Work Plan

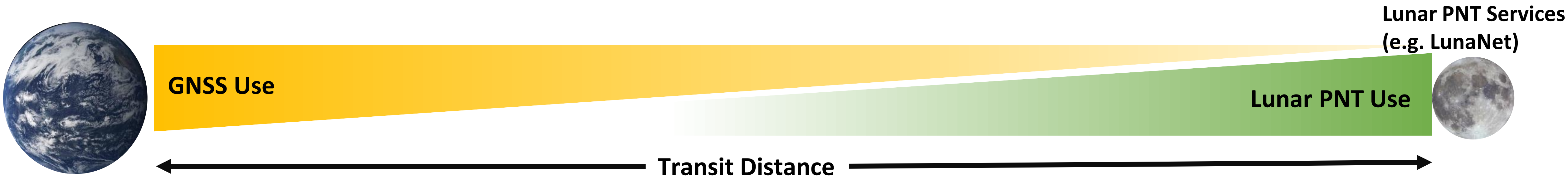
Work Plan, adopted on 16 Feb 2023, consists of 5 work packages focused on key activities:

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

Phased Expansion of Lunar PNT Services



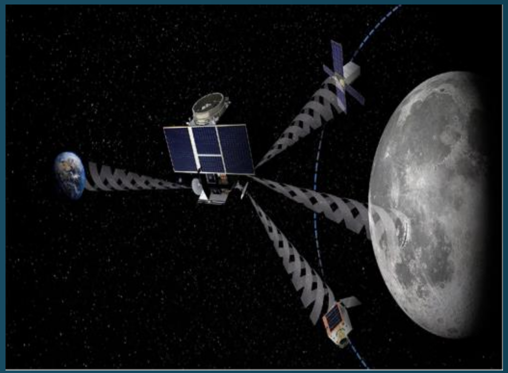
Transit use of GNSS and Lunar PNT Services



Use of GNSS and lunar PNT services are considered as a key part of the broader navigation ecosystem including ground-based on on-board sources.

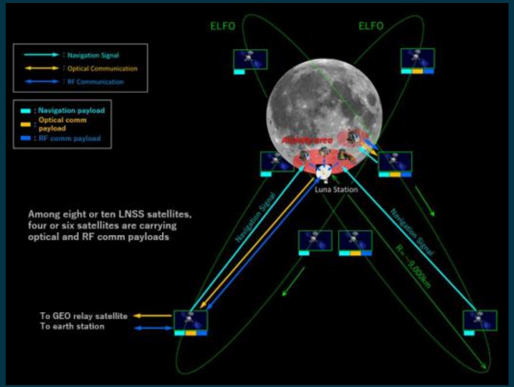
International Lunar PNT Efforts

SUSG WP4 team received presentations from China, Europe, Japan and the USA on Lunar PNT demonstrations, architectures and systems being planned or in development including:



Lunar Pathfinder
(ESA Demo)

LuGRE
(NASA Demo)



Lunar Navigation Satellite System (LNSS)
(JAXA Nav System)

LunaNet
(international architecture)

ICG-16 WG-B Recommendation 1

ICG/REC/2022

Recommendation for Committee Decision

Prepared by: **Working Group B, Space Use Subgroup (SUSG)**
(Working Group, or individual Members or Associate Members)

Date of Submission: **September 15, 2022**

Issue Title: **Coordination of GNSS and Lunar PNT systems for lunar operations**

Recommendation

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.

The collaborative efforts of the ICG, including the GNSS Space Service Volume initiative, should serve as a model for this promising international exploration initiative.

The ICG will analyse planned lunar PNT systems and their interactions with GNSS and propose recommendations that may be taken up by GNSS providers and lunar PNT developers.

Conclusions

- The ICG, via its WG-B Space Use Subgroup (SUSG), is working for greater representation of space user PNT needs.
- SUSG has published the 2nd edition of the Interoperable Multi-GNSS SSV booklet, which updates constellation data, adds example missions, and expands technical analysis.
- SUSG has adopted a Work Plan that features significant efforts in areas that need coordination:
  - Constellation Technical Data
  - User Mission Profiles
  - GNSS Space User Requirements for Timing
  - GNSS Space User Standards
  - Expansion of GNSS SSV to Support Lunar Operations
- ICG is working toward robust multilateral coordination to enhance the overall lunar PNT architecture and all aspects of interoperability.