



Report from Interagency Operations Advisory Group (IOAG) to ICG

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26th Meeting of the ICG Providers' Forum, 9 October 2022



IOAG ROLE

The IOAG (Interagency Operations Advisory Group) provides a forum for **identifying common needs across multiple international agencies** for coordinating space communications policy, high-level procedures, technical interfaces, and other matters related to interoperability and space communications. Its goals are to:

- Enable safe, secure, and efficient interoperable mission operations;
- Enable higher rate throughput for space missions;
- Enable responsive networks around the Earth, Moon, and Mars to enable future exploration and science missions.

The IOAG was founded by the Interoperability Plenary (IOP) to:

- Understand issues related to interagency interoperability and other space communications matters;
- Identify common solutions complying with IOP guidance;
- Recommend resolutions to the IOP for specific actions created by the IOP and put to the IOAG.



Members



Observers



WORKING GROUPS

IOAG members are divided into working groups that meet independently and deliver reports and updates to all delegates at IOAG meetings.

Coding and
Modulation Working
Group (C&MWG)

Low Earth Orbit
26 GHz Group
(LEO26WG)

Lunar
Communications
Architecture Working
Group (LCAWG)

Lunar-Mars
Working Group
(LMWG)

Mars and Beyond
Communication
Architecture Working
Group (MBC-AWG)

Mission Operations
Systems
Coordination Group
(MOSCG)

Mission Operations
Systems Strategy
Group (MOSSG)

Optical Link Study
Group (OLSG)

Service Catalog
Working Group
(SCWG)

Space Internetworking
Strategy Group (SISG)

Space Operations
Sustainability Working
Group (SOSWG)

Spacecraft
Emergency Cross
Support Working
Group (SECSWG)

Active
Dormant
Closed



Recent Meetings

- **25th IOAG annual meeting** held 23–25 May 2022
 - European Space Operations Center (ESOC), Darmstadt, Germany
 - Attended by ~40 delegates representing 8 members, 3 observers, and 4 liaisons
 - Meeting Minutes approved 13 Sep 2022; available to members at <https://www.ioag.org>
- **IOAG-25a teleconference** held 13 Sep 2022
 - Presentations available to members at <https://www.ioag.org>
 - Meeting Minutes under development
- IOAG-ICG liaison briefing provided at both meetings by Joel Parker/NASA and Werner Enderle/ESA
 - Overview of ICG
 - Activities of ICG WG-B Space Use Subgroup
 - Potential areas of coordination between ICG and IOAG
- Updates provided for GNSS Mission Tables (see backup)
- This report captures key content and outcomes



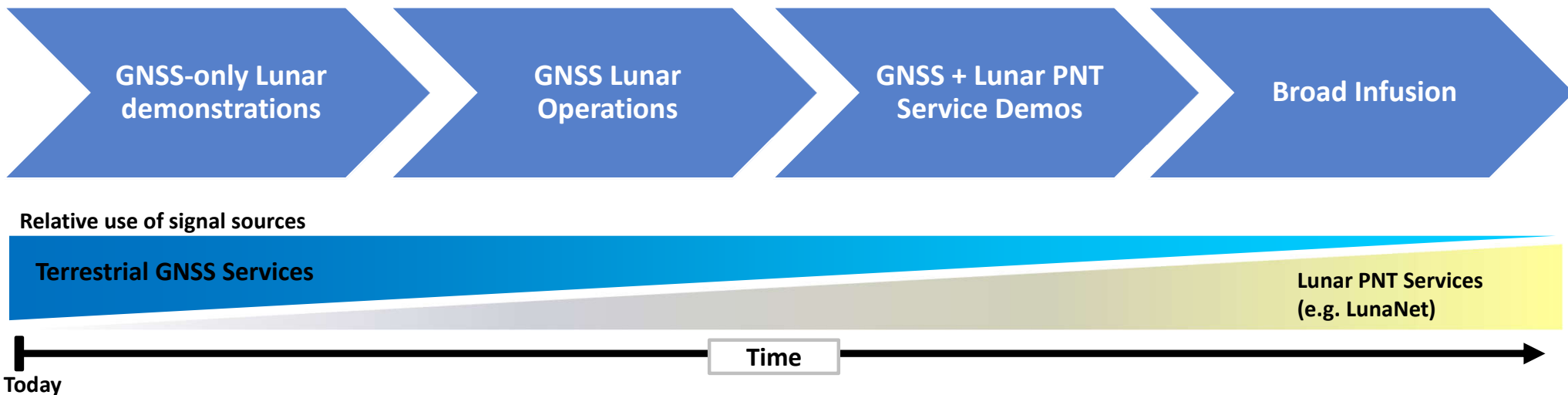
Chair: Pier Bargellini/ESA

ICG LIAISON REPORT

Background

- Different activities related to standards and definitions for GNSS usage for space applications are currently ongoing within various international groups which are partially overlapping
 - Within ICG WG-B Space Use Subgroup (SUSG):
 - WP3 – GNSS space user timing requirement analysis and space user operations recommendations
 - WP4 – Expansion of GNSS SSV to Support Lunar Operations
 - WP5 – GNSS Space User Standards
 - IOAG
 - Space Frequency Coordination Group
 - Lunar architecture definitions:
 - LunaNet
 - NASA LCRNS
 - ESA Moonlight
 - Others
- The objectives of this presentation are to:
 - To clarify the understanding of the roles of the ICG SUSG work packages and their contributions to international team coordination
 - To outline potential roles of ICG in coordination with other organizations (e.g. IOAG, SFCG)

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.

ICG WG-B SUSG Potential Areas of Coordination

- Continue current activities:
 - Liaison role with IOAG
 - Contribute to GNSS mission tables to support understanding of Earth-based GNSS use cases and mission applications
- Establish necessary liaison roles with SFCG, ISECG, etc.
- Collect and document lunar use cases
 - Contribute to expanded GNSS mission tables to include proposed missions that require lunar GNSS or PNT
- 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:
 - Coordination of frequencies and codes
 - Service volume definitions
 - Combined lunar PNT architectures
 - Signal compatibility and interoperability
 - Reference frames and timing

IOAG MEETING OUTCOMES

Lunar Communications and Navigation Working Group

Background (extracted from [1]):

- *IOAG Lunar Communications Architecture Working Group Study Report v1.3 was completed in January 2022*
(...)
- *Just as the LCAWG was communications-focused, it now makes sense to focus in more detail on PNT functions for future CisLunar network environment*
(...)
- *Different approaches need to be evaluated for the local lunar regime PNT architecture*
 - *Fundamental cislunar PNT standards: Lunar Reference System/Frame, gravity potential, lunar orbit, geodetic model, ephemeris → need equivalents for ITRF, WGS-84, J2000, UTC, TLE, SGP4, & transforms to tie terrestrial & lunar systems*
 - *Can “weak GNSS” signals from Earth be used in Cislunar? Should they be used? Will they interfere with a Lunar GNSS?*
(...)
- *More about options to be weighed and compared*
 - *Lunar GNSS concept of operations*
 - *Potential use of existing GNSS receivers if GNSS frequencies are utilized*
 - *Search and Rescue (SAR) compatibility*
(...)

[1] “Proposal for IOAG Communications and Navigation Working Group”, S. Lichten, M. Cosby, 24 May 2022

Lunar Communications and Navigation Working Group

(Extraction continued)

- **Proposal** here is to form a IOAG Lunar Communications and Navigation Working Group (LCNWG) to extend the work of LCAWG, incorporate results of development by members to study options, and make recommendations for future interoperable lunar PNT as well as communication/networking services
- **CHARTER:** the IOAG LCNWG is tasked to study and recommend the system definition and architecture for CisLunar navigation & communication services, leveraging previous IOAG work accomplished for CisLunar communications services, with interoperability to enable Cislunar users to utilize services from assets owned and/or operated by the IOAG member agencies and by the private sector.
 - (...)
 - Timeframe for the study: 1 year with progress reports at IOAG meetings

Discussion (from Meeting Minutes):

- Mr. Bargellini added that support from Mr. Enderle and Mr. Parker from the ICG would be much appreciated. As chair, he provided authorization for the LCNWG to proceed and invited the group to present TOR in more detail at the next IOAG meeting.

Lunar Communications and Navigation Working Group

IOAG-25a update (extracted from [2]):

- Kickoff meeting held w/ 16 participants representing 8 organizations
- Proposed expanded membership for PNT focus: 30 members representing 10 organizations
 - Includes ICG liaisons
- Focus areas for 2022–2023:
 - *Assemble an international working group to define Lunar PNT Architecture (...)*
 - *Add Position, Navigation, and Timing (PNT) to the Lunar Architecture defined in Jan 2022 Report and make recommendations for integration of PNT with Communications*
 - *Focus on one reference frame*
 - *Build on the work from parallel activities and not “reinvent the wheel”*
- Actions proposed for each agency to:
 - Indicate if they anticipate providing or playing a role in commercial lunar comm/nav services
 - Provide updates to mission tables
 - Provide agency prioritization of needed PNT analyses for lunar, Incl. “Utilization of Earth “far GNSS” versus local lunar GNSS-like network”
- Still needing resolution: Potential coordination between IOAG LCNWG and LunaNet

[2] “Lunar Communications & Navigation Working Group (LCNWG) Report”, S. Lichten, M. Cosby, 13 Sep 2022

Early Lunar Communications and Navigation Architecture Concept



Gateway

Additional relay capability

Orbital Relays

LINKING LUNAR USERS TO EARTH
& TO EACH OTHER

Diverse, evolving constellation
with multiple users and
providers



LunaNet

Framework of standards for
open, interoperable networks
- Data, PNT & other services

Earth Stations

Upgraded DSN and
other assets including
commercial stations



Orbiting
Spacecraft
Users

Far Side
missions

SOUTH
POLE

Artemis surface
missions

Other robotic
missions

Surface communications
and navigation assets

Communication and navigation infrastructure lowers the barriers to entry for new missions and capabilities and supports expanding robotic and human activities on the Moon.

Draft proposed LunaNet standards: <https://go.nasa.gov/3BQrCOK>

Committee to Study LunaNet Governance

- **IOAG-25** (summarized from [3]):
 - Proposed draft ToR for Interim Committee to Study LunaNet Governance
 - Vision:
 - Establish the Interim Committee
 - Produce preliminary LunaNet governance deliverables
 - Interim Committee General Objective: *To undertake activities related to the multi-stakeholder organizational governance structure to achieve interoperability among stakeholders and facilitate the secure and efficient delivery of LunaNet services to LunaNet users.*
 - Outcome: *“Mr. Bargellini summarized the consensus to proceed with the study to propose governance.”*
- **IOAG-25a** (summarized from [4]):
 - All comments to ToR have been dispositioned
 - *Recommend IOAG approval of ToR after accepting all changes*
 - ICG liaisons proposed as members of Interim Committee

[3] “Proposed Draft Committee to Study LunaNet Governance Terms of Reference (ToR)”, J. Schier, 23 May 2022

[4] “Committee to Study LunaNet Governance: Status and Terms of Reference (ToR)”, J. Schier, 13 Sep 2022

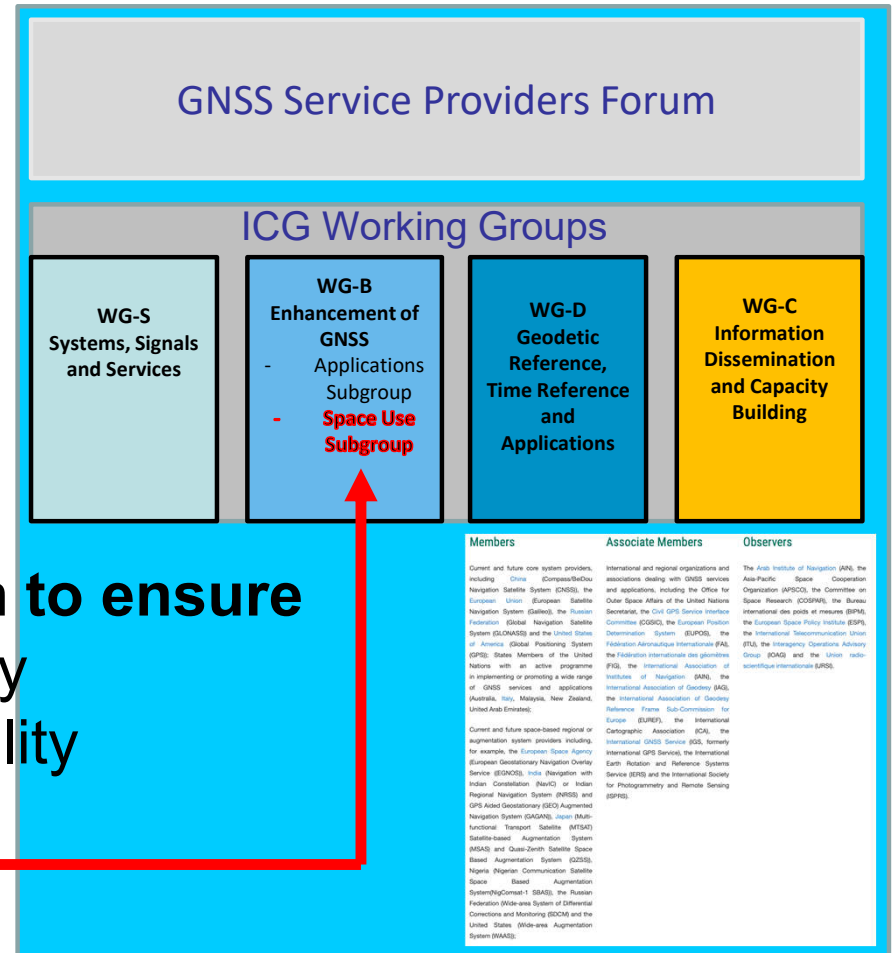
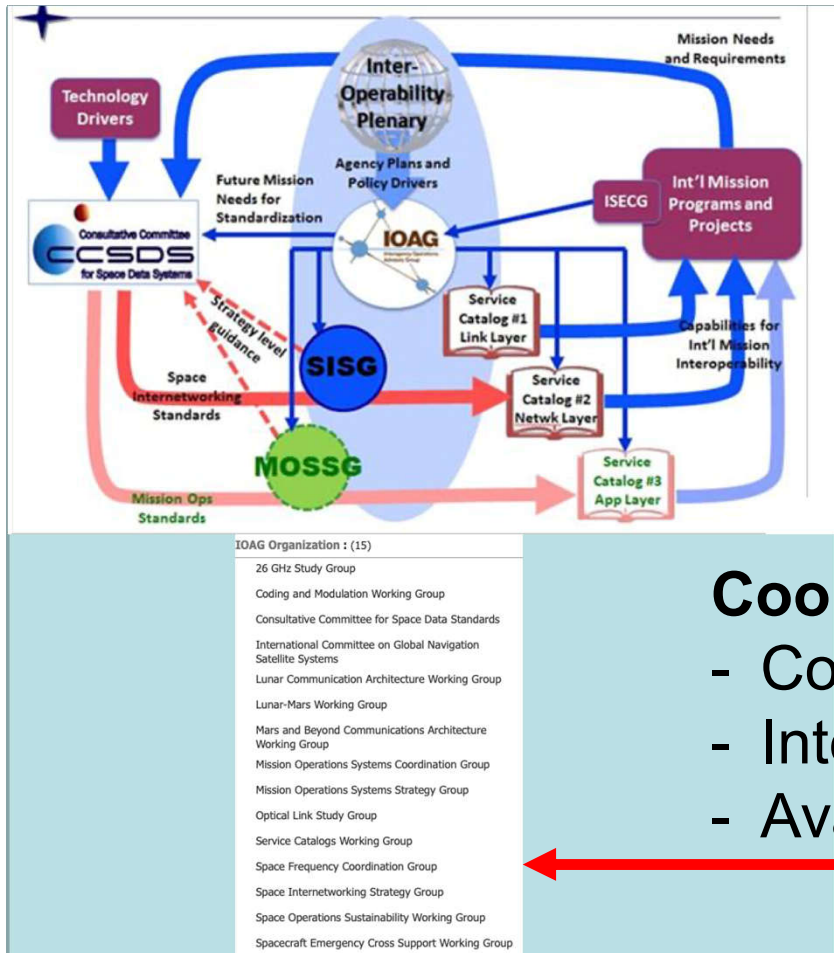
Conclusions

- IOAG held 25th annual meeting and intersessional teleconference
- ICG-IOAG liaisons presented potential areas of coordination, focused on space user timing, standards, and lunar PNT activities in the WG-B SUSG
- IOAG created Lunar Communications and Navigation WG with charter to study/recommend lunar comm & PNT architectures
 - Scope includes study of utilization of GNSS SSV as part of larger architecture
 - Chartered Interim Committee to Study LunaNet Governance to study governance aspects of common lunar comm/PNT architecture
- ICG participation was well received. ICG-IOAG liaisons are accepted as members in both activities.
- ICG sees coordination between GNSS and lunar PNT architecture as critical to ensure interoperability, compatibility, and availability of combined “system of systems” for space users.



BACKUP

Need for Coordination between IOAG and ICG-Space Use Subgroup



Coordination to ensure

- Compatibility
- Interoperability
- Availability

IOAG GNSS Mission Table



Microsoft Excel
Worksheet

Aggregate IOAG Missions Using GNSS
2022-05-20 (IOAG-25).xlsx



Microsoft Excel
Worksheet

Aggregate IOAG Missions Using GNSS
2022-09-13 (IOAG-25a).xlsx

WP 3 - GNSS Space User Timing Requirements

Activity objective:

- Perform analysis to develop a GNSS space user timing requirement analysis and develop GNSS space user timing operational recommendations

Approach:

- a) Work to collect space user requirements for timing interoperability
- b) Work with WG-D and develop proposed timing interoperability solutions
- c) Present to SUSG for approval, rejection or modification
- d) Socialize ideas with international providers
- e) Action: Include/coordinate with other ICG time-related WGs

Activity outcome:

- Development of space user timing capabilities and requirements; space user operations recommendations

WP 5 - GNSS Space Use Standards

Activity objective:

- Work with other organizations (e.g, IOAG/CCSDS) on space user standards that will improve GNSS SSV interoperability and acceptance as an international standard

Approach:

- Collect requirements from different space users communities
 - Space agencies, Scientific, Commercial, Institutional/Governmental (none military), Mega Constellations, Universities, Regulations for Space Debris
- Review of existing standards in different domains related to GNSS space usage
 - CCSDS (space agencies)
 - NMEA – maritime applications
 - IGS (Scientific, Institutions/Organizations/Government, Industry)
 - RINEX for off-line processing
 - State Space Representation (SSR) – Real Time processing (used for RT high accuracy positioning)
- Develop proposals for GNSS Space User Standards
- Socialize ideas with international providers
- Work requisite standards organizations to determine their interest in in proposed standards;
- Identify joint projects/opportunities in order to conduct tests/demonstrations in space (e.g. usage of Cubsats)
- Present proposed standards to SUSG for approval, rejection or modification;
- Submit formal proposal for GNSS Space User Standard to selected standardization body and support implementation of standard

Activity outcome:

Proposal for GNSS space user Standards

WP 4 - Expansion of GNSS SSV to Support Lunar Operations

Primary goals:

- Maximize interoperability, compatibility and availability of **all** internationally developed Positioning, Navigation and Timing (PNT) resources on and in the vicinity of the moon
- Leverage expertise of GNSS SSV space use team to research, analyze and recommend definitions, user base, capabilities and architectures for lunar operations
 - System of systems approach needed to optimally employ Earth-centric GNSS capabilities with an expanding, evolving lunar-centric PNT capability
 - Operational use of GNSS and Lunar PNT systems during transit operations for robust PNT continuity will require special attention

ICG Terms of Reference:

- ICG provides recommendations; other organizations (e.g., IOAG, SFCG, space agencies) act on recommendations at their discretion.

WP 4 - Expansion of GNSS SSV to Support Lunar Operations

- **WP4 Activities**

- **Lunar PNT Frequency and Code Coordination:** Work with the Space Frequency Coordination Group (SFCG) to coordinate use of existing Earth-based GNSS L-band receive frequencies and transmit bands/frequencies and planned signal codes for proposed Lunar-based PNT systems, beacons and augmentations
- **Lunar Use Cases:** Collect international lunar PNT use cases encompassing key present and expected future cis-lunar region missions and develop initial set of user performance needs for lunar PNT missions
- **Lunar SSV Definition:** Develop a draft Lunar SSV definition and other relevant lunar PNT definitions; coordinate effort with international standards bodies (e.g. IOAG)
- **Lunar PNT flight experiments:** Encourage lunar flight experiments employing Earth-based GNSS and/or Lunar PNT capabilities to gain an understanding of the performance and limitations of these systems; publish results and lessons learned
- **Lunar PNT Architectures:** Research, analyze and recommend PNT system architectures, employing Earth-based GNSS and Lunar PNT capabilities, that are interoperable, compatible, available and support current and future user needs; highly leverage already performed work
- **Lunar reference frame:** Work with international organizations to develop and coordinate Lunar reference frames