What is LunaNet?
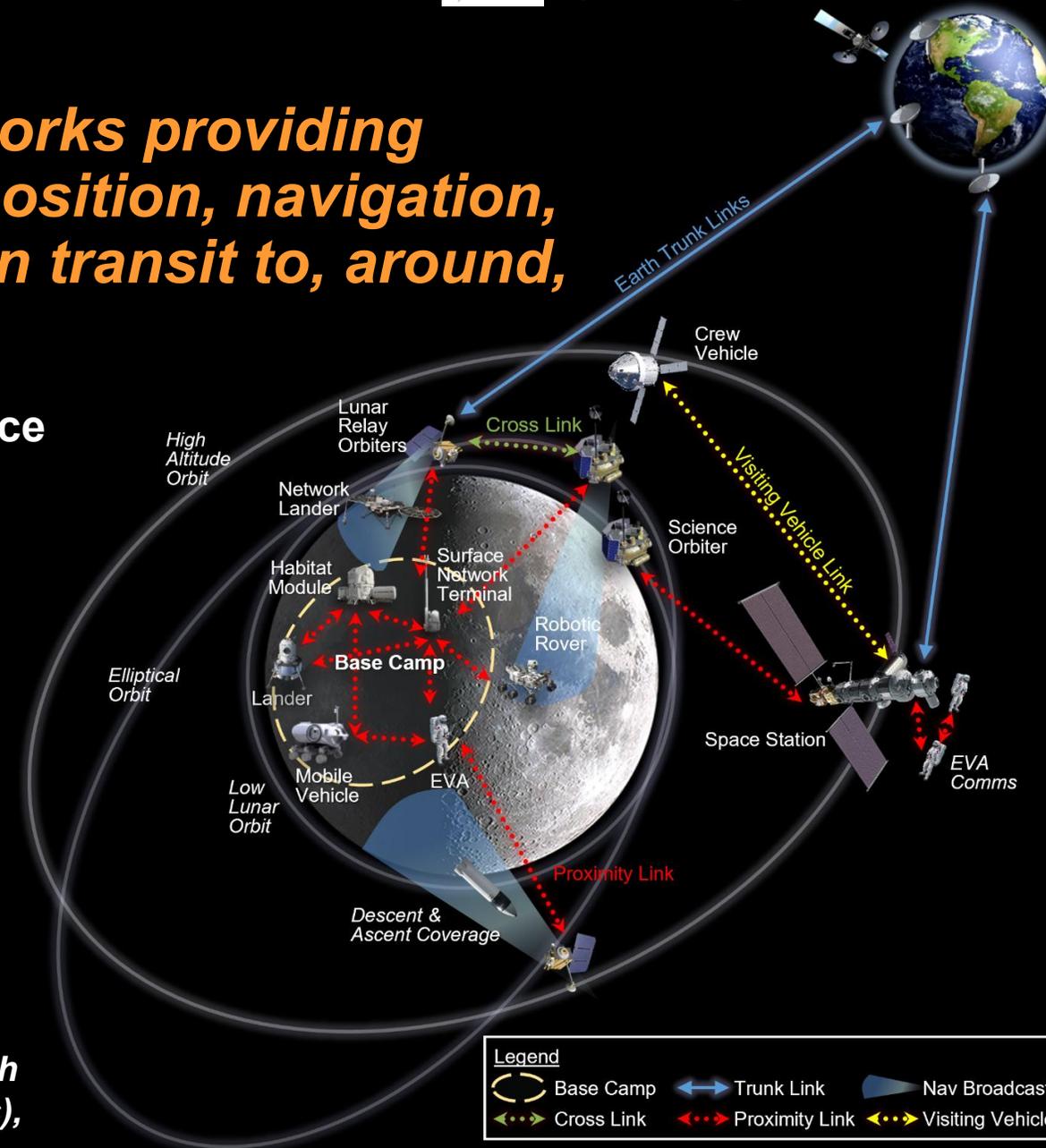
LunaNet is a set of cooperating networks providing interoperable communications and position, navigation, and timing (PNT) services for users in transit to, around, and on the Moon.

- **Based on a framework of mutually agreed-upon standards, protocols, frequency bands, and interface requirements that enable interoperability.**

- **Allows many lunar mission users to engage the services of diverse commercial and government service providers in an open and evolvable architecture.**

    - **Service-Oriented**
    - **Scalable**
    - **Open**
    - **Resilient**
    - **Secure**
    - **Extensible**

LunaNet consists of Earth Ground Stations (for Direct with Earth links), lunar orbital relays (lunar proximity and Earth trunk links), and surface assets.

Ground Stations or Earth Relays

Earth Trunk Links

Crew Vehicle

Lunar Relay Orbiters

Cross Link

High Altitude Orbit

Network Lander

Habitat Module

Surface Network Terminal

Science Orbiter

Visiting Vehicle Link

Robotic Rover

Elliptical Orbit

Base Camp

Lander

Low Lunar Orbit

Mobile Vehicle

EVA

Space Station

EVA Comms

Proximity Link

Descent & Ascent Coverage

Legend
- Base Camp
- Cross Link
- Trunk Link
- Proximity Link
- Nav Broadcast
- Visiting Vehicle

LunaNet Interoperability Specification Document

Version 5

Published by NASA-ESA-JAXA 29 January 2025

LNIS V005

LunaNet Signal-In-Space Recommended Standard - Augmented Forward Signal (LSIS - AFS) VOLUME A

Version 1

Noted as Applicable Document 1 [AD1 Vol-A] in LNIS V5

LSIS V1.0   29 January 2025   1

The LNIS and its *Applicable Document* includes:

· **Concept of the LANS, message format of the Augmented Forward Signal (AFS), signal frequency, power, signal modulation, etc.**

· **Signal-In-Space-Error (SISE) requirement for LunaNet Service Providers (LNSPs)**

· **Lunar Reference System and Lunar Time System Standard (forthcoming)**

JAXA/ESA/NASA comply with the LNIS to become interoperable LNSPs

JAXA, ESA, and NASA continue developing the LNIS documents and to ensure the success of the LANS. The LNIS Version 6 will be published soon

ESA Moonlight
LCNS
(2028～)

Contractor:
Telespazio

NASA LCRNS
(2026～)

Contractor:
Intuitive
Machines

Japan LNSS
(2029～)

Contractor:
ArkEdge
Space

Among eight LNSS satellites, four satellites are carrying optical and RF comm payloads
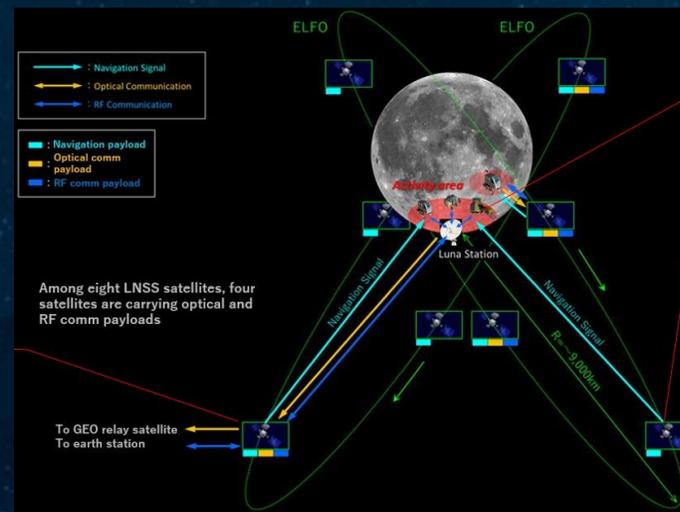
LCNS:
Lunar Communications and Navigation System

LCRNS:
Lunar Communications Relay and Navigation Systems

LNSS:
Lunar Navigation Satellite System

4

IOAG AND WORKING GROUP (CSLG)

- ## What is IOAG?

  - The **Interagency Operations Advisory Group (IOAG)** is a collaborative organization that facilitates coordination between international space agencies to enhance interoperability and cooperation in space operations. It serves as a forum for space agencies to discuss and develop recommendations on issues related to cross-support, communication, and network interoperability for space missions

- ## What is CSLG?

  - Working group of IOAG called Committee to Study LunaNet Governance
  - As the name indicates, the CSLG studies and recommends governance items and structure for the LunaNet

IOAG MEMBERS

LUNANET GOVERNANCE REPORT: CHAPTERS AND STATUS

IOAG PRELIMINARY REPORT ON LUNANET GOVERNANCE

Coordination and Governance in the Initial Phase

Section	Title	Status
1	Executive Summary	Draft complete
2	Introduction	Draft complete
2.1	Problem Statement	Draft complete
2.2	Scope	Draft complete
2.3	Background	Draft complete
3	Methodology and Analysis Process	Draft complete
4	Analysis	Draft complete
4.1	Existing Governance Relevant to CPNT	Draft complete
4.2	Existing Governance Other than CPNT	Draft complete
4.3	LunaNet Characteristics that Need Governance	Draft complete
4.4	Gap Analysis: LunaNet Needs & Existing Governance	Draft complete
5	Preliminary Findings	Draft complete
5.1	Governance Options	Draft complete
5.2	Criteria for Assessing Options	Draft complete
5.3	Findings: Spectrum (Layer 1)	Draft complete
5.4	Findings: Communications (Layer 2)	Draft complete
5.5	Findings: Networking (Layer 3)	Draft complete
5.6	Findings: PNT	Draft complete
5.7	Findings: Orbits	Draft complete
6	Summary of Findings and Issues	Draft complete

ABSTRACT AND PUBLICATION

- **Abstract**
  - This report is issued from the IOAG's CSLG and captures its recommendations for an initial multi-stakeholder organizational governance structure, approach, and functions to develop guidelines, policies, and practices to help achieve a publicly available (open) architecture to provide communications, networking, position, navigation, and timing (CPNT) services to cislunar Users (LunaNet)

- **Target publication schedule**
  - Publication at IOAG Webpage in April 2026

CONTRIBUTORS

- **Co-chairs**
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  - Jim Schier (CSLG founder)
- **Members**
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  - Keith Scott – NASA
  - Catherine Sham – NASA
  - Marco Lanucara – ESA
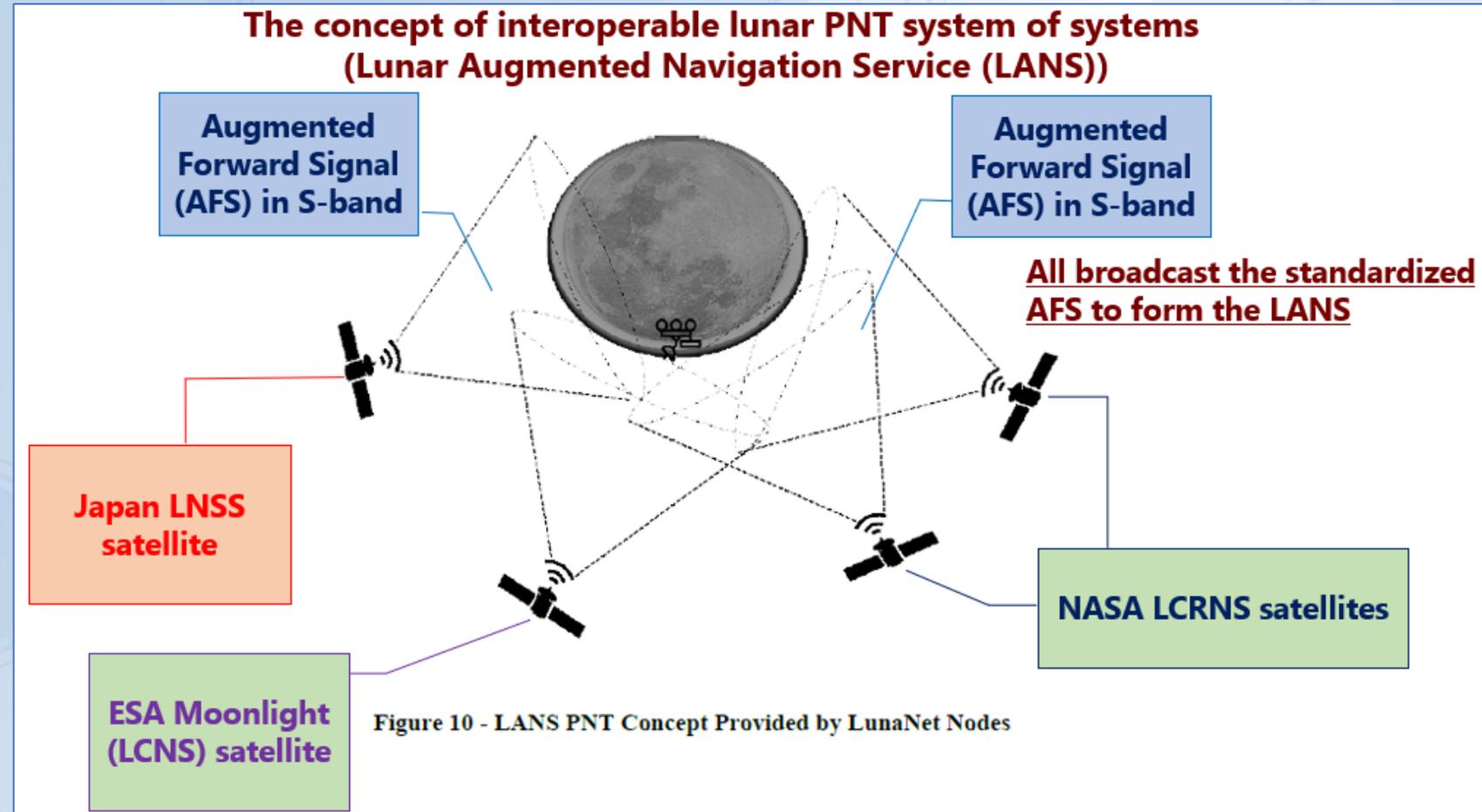 - Javier Ventura-Traveset - ESA

EXECUTIVE SUMMARY (EXCERPT)

- The present report has been produced by the IOAG-CSLG inter-agency committee with the core aim of defining a multi-stakeholder organizational governance structure and related processes to achieve and maintain interoperability among stakeholders and facilitate the secure and efficient operational delivery of LunaNet services by LunaNet providers to LunaNet users.

- **LunaNet relationship to Internet and GNSS**
  - **To Internet:** LunaNet will consider the Internet in terms of its architecture because of the similarity in architecture and services, and therefore lessons learned from Internet governance should also be leveraged to achieve the governance of LunaNet
  - **To GNSS:** LunaNet will consider the governance of various GNSS such as Global Positioning System (GPS), Galileo, Global Navigation Satellite System (GLONASS), BeiDou, Quasi-Zenith Satellite System (QZSS), and Navigation with Indian Constellation (NavIC) that have separate national governance approaches in formulating a unified lunar PNT governance approach

COORDINATION NEEDS IDENTIFIED FOR LUNANET LUNAR AUGMENTED NAVIGATION SERVICE (LANS)

- Allocation and assignment of Pseudo Random Noise (PRN) Codes to LunaNet Service Provider (LNSP) nodes

- Allocation and assignment of AFS Frame ID 0 (in SB3, SB4) among LNSP nodes

- Necessary data sharing among LNSP

- Service and Signal-in-Space-Error (SISE) monitoring

- Reference orbits or orbital adjustment to maximize the LANS performance

- Provision of LNSP-specific ICDs for receiver manufacturers

The concept of interoperable lunar PNT system of systems (Lunar Augmented Navigation Service (LANS))

Augmented Forward Signal (AFS) in S-band

Augmented Forward Signal (AFS) in S-band

All broadcast the standardized AFS to form the LANS

Japan LNSS satellite

NASA LCRNS satellites

ESA Moonlight (LCNS) satellite

Figure 10 - LANS PNT Concept Provided by LunaNet Nodes

How to certify a LNSP is compliant with LunaNet?
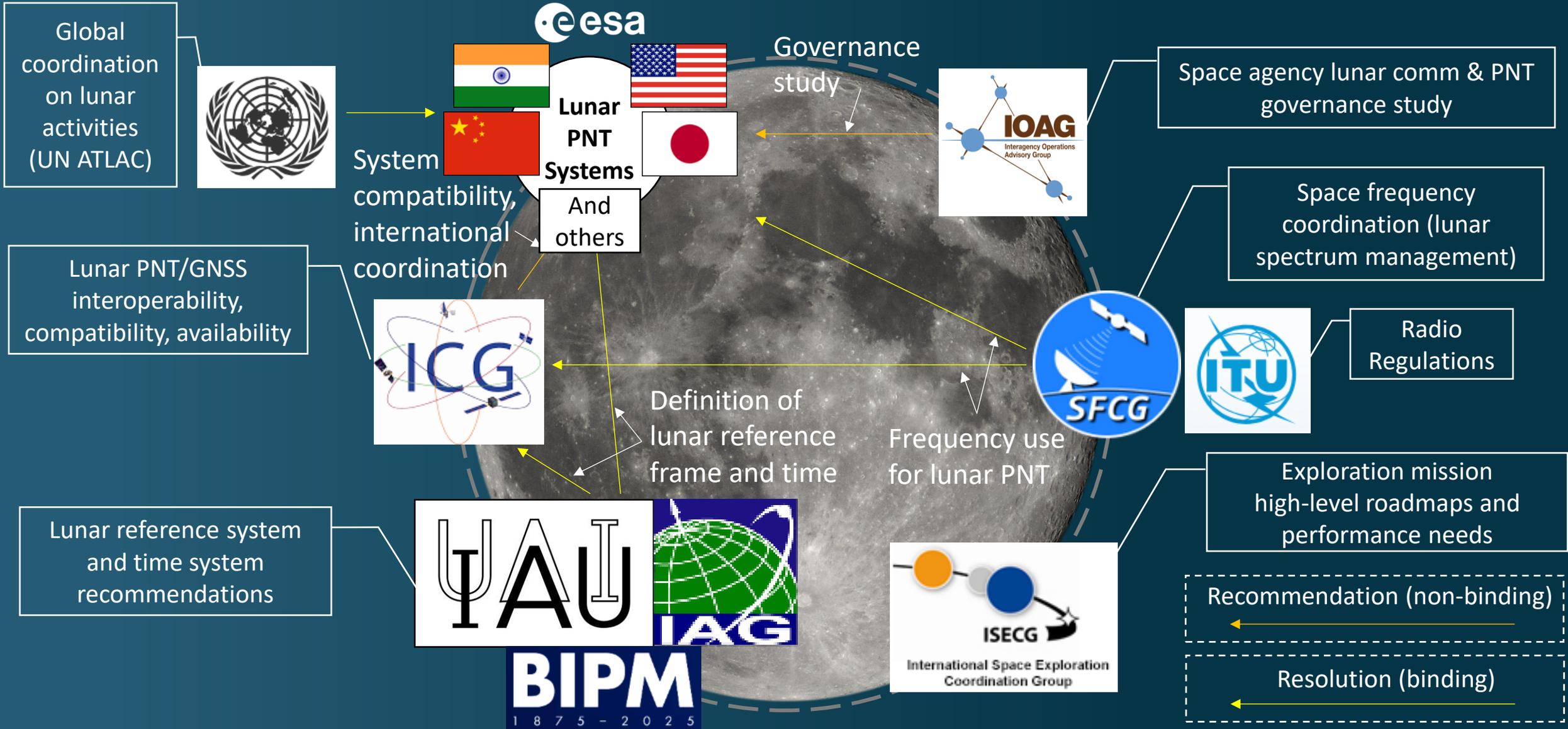
EXECUTIVE SUMMARY (EXCERPT)

- **Toward a LunaNet governance structure**
    1. The LunaNet PNT WG team, should be recognized in the LunaNet Governance as the PNT Interface Design authority, constituted by engineers of each agency providing at least parts of LunaNet orbital infrastructure and related ground segment on Earth (currently NASA, ESA and JAXA) as a minimum
    2. The LunaNet C&PNT team would be advised by a High Level Committee gathering various institutions and/or national and/or space agencies representatives (IOAG, ITU, SFCG, ICG, CCSDS, feedbacks from industry, etc)
    3. The spectrum access will require coordination at agency level under, in particular, the SFCG guidance
    4. For IP networking, the current governance bodies such as IETF, ICANN, RIRs and NOGs should be used for LunaNet
    5. As part of its current duty, it is suggested to use SANA and IANA for any lunar DTN networking new policies and governance.

EXECUTIVE SUMMARY (EXCERPT)

- **Toward a LunaNet governance structure**

  6. Lunar PNT capabilities should enable compliance with "NASA's Recommendations to Space-Faring Entities: How to Protect and Preserve the Historic and Scientific Value of U.S. Government Lunar Artifacts", (July 20, 2011)

  7. Lunar PNT capabilities should enable safety of navigation for lunar missions from all countries and companies. A reinforcement of Space Situation Awareness in the Lunar vicinity will be required, as not covered within the current frameworks

  8. Use of common lunar reference frame and lunar time to avoid operational confusion. These are currently being defined by the IAU, IAG, and BIPM

  9. There will also be a need for a certification process to check and verify the compliance to the LunaNet, either to be managed through the LNSPs or from a centralizing body

INTERNATIONAL BODIES RELATED TO LUNAR PNT

Global coordination on lunar activities (UN ATLAC)

Lunar PNT/GNSS interoperability, compatibility, availability

Lunar reference system and time system recommendations

System compatibility, international coordination

Lunar PNT Systems

And others

Governance study

Definition of lunar reference frame and time

Frequency use for lunar PNT

Space agency lunar comm & PNT governance study

Space frequency coordination (lunar spectrum management)

Radio Regulations

Exploration mission high-level roadmaps and performance needs

Recommendation (non-binding)

Resolution (binding)

COLLABORATION WITH UN ICG, ATLAC IS NECESSARY

- International Committee on GNSS (ICG) WG-L (Lunar PNT) studies international cooperation beyond the scope of LunaNet
  - WG-L facilitates development of interoperable, compatible, and available lunar PNT systems
  - WG-L tasks include Lunar PNT international cooperation models: Work with appropriate international organizations to investigate and recommend international cooperation models that enable sustainable development and operations of lunar PNT systems.
  - The international coordination could cover items such as PRN allocation, monitoring, provider joint activities, and standardization
    - If another space agency uses and complies with the LunaNet, could we adjudicate PRN assignments in an ICG forum?

- ATLAC (Action Team on Lunar Activities Consultation) studies the global coordination on lunar activities such as policy development, international cooperation, identification of areas of collaboration to drive sustainable lunar exploration
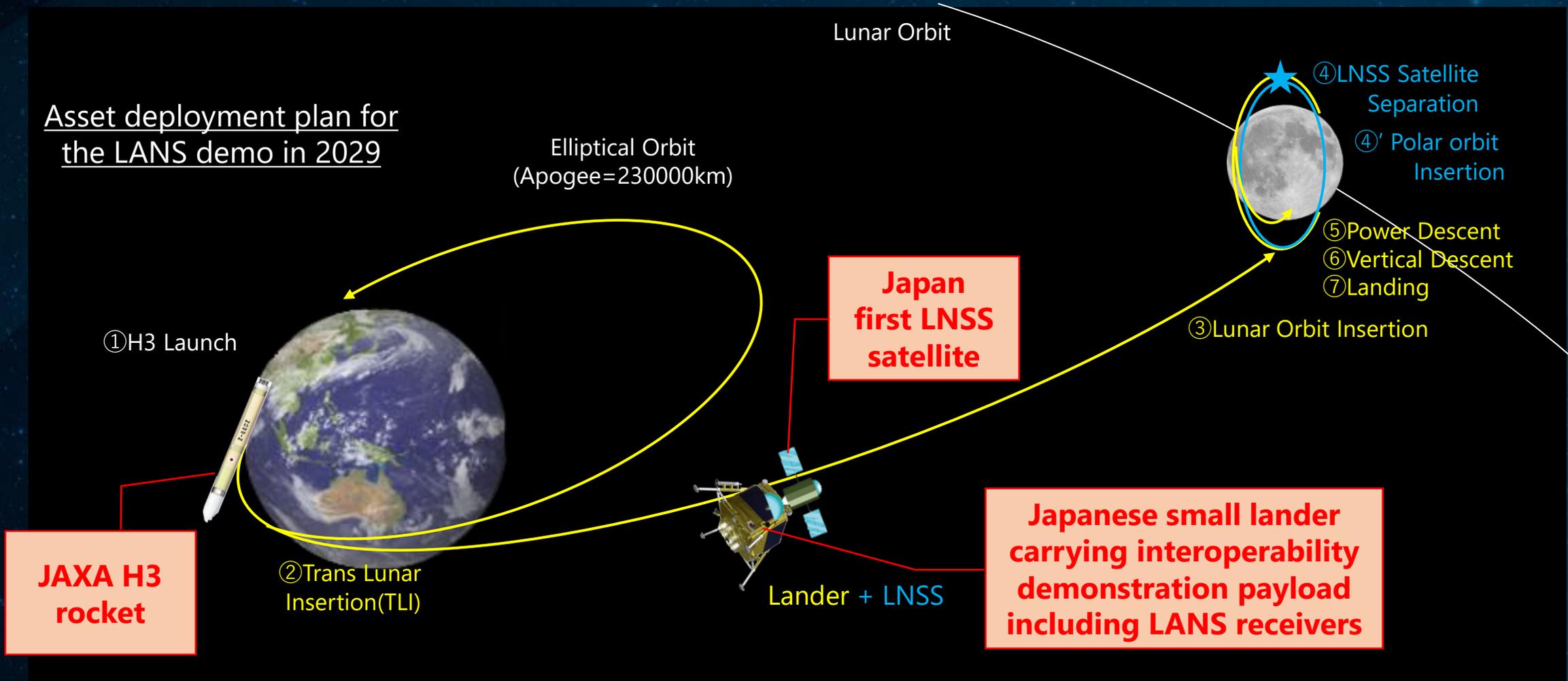
NEXT STEPS AND PLANS (MAIN GAPS)

- Rationalize and monitor the compliance of LNSPs to the LunaNet framework through the monitoring of increments, statement of compliances and service deliveries including <u>a process of certification with respect to the LunaNet framework</u>.

- This can be done at different levels:
  - In relation with LunaNet or through specific cross-interoperability programs led by partner agencies (<u>as for instance the LANS initiative for the navigation aspects</u>)
  - LunaNet is not covering, as of today, the certification aspects of the LNSPs toward LunaNet standards but the LunaNet working groups could verify the compliance status of the LNSPs to LunaNet through the verification of test reports and statements of compliance/applicability from industry

# For instance, the LANS demonstration initiative for the navigation aspects

Lunar Orbit

Asset deployment plan for the LANS demo in 2029

Elliptical Orbit
(Apogee=230000km)

④LNSS Satellite Separation
④' Polar orbit Insertion
⑤Power Descent
⑥Vertical Descent
⑦Landing
③Lunar Orbit Insertion

①H3 Launch

Japan first LNSS satellite

Japanese small lander carrying interoperability demonstration payload including LANS receivers

JAXA H3 rocket

②Trans Lunar Insertion(TLI)

Lander + LNSS

NEXT STEPS AND PLANS (MAIN GAPS)

- Coordinate the allocation of the LunaNet specific resources among the LNSPs in the operational lifetime of the services. This includes the analysis of interference patterns and the frequency/polarization scheduling among LNSPs to their Users
  - This can be done in relation with SFCG in charge of coordinating the allocation of frequencies to specific missions yet currently not covering the operational coordination aspects

- Lunar trajectories coordination, registration and monitoring: the current orbit/debris management bodies are not covering beyond-Earth space, and would require specific framework extensions to cover cislunar space
  - This could be done through the extension of working groups already performing such activity for Earth orbits to include the cislunar missions or thought the creation of a specific entity

BEYOND LUNANET GOVERNANCE

Lunar PNT Systems

And others
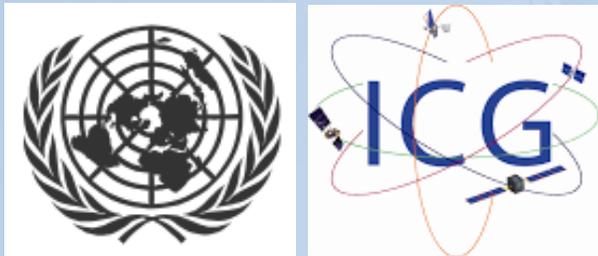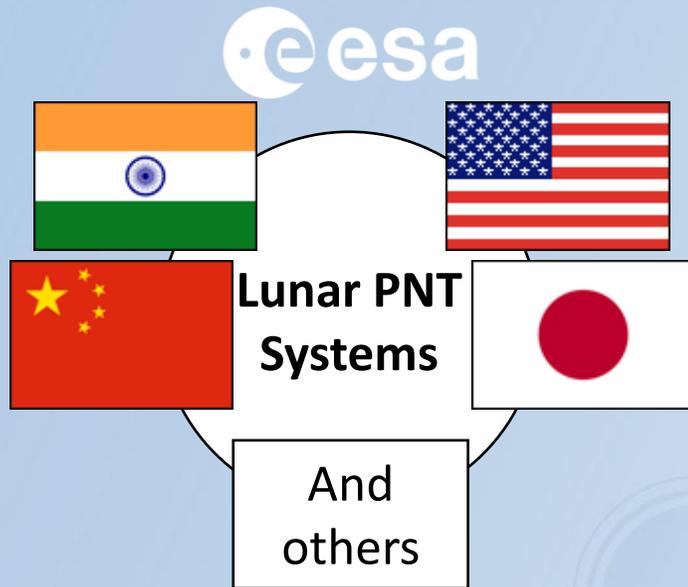
- The CSLG has been so far focusing on the governance for the LunaNet C&PNT capabilities, but there was also a discussion or suggestion to include lunar C&PNT systems that are not "LunaNet"

- For the frequency perspective, the SFCG and ITU have been providing international recommendations and radio regulations. However, the necessary coordination items are also including
  - in-orbit collision avoidance (space traffic management),
  - signal power coordination (interference prevention),
  - single-access bands coordination during the operational phases of the relay services

- Moreover, the interoperability is also important from user perspective, and even a basic-level technical coordination with non-LunaNet providers such as the alignment to a common lunar reference frame and time should significantly enhance overall lunar C&PNT user experience

CONCLUSIONS

- The global coordination for the Moon including the lunar PNT is now being investigated by the ICG WG-L and the IOAG CSLG
  - International organizations such as the SFCG, ITU, IAU, IAG, and BIPM are also working on their specific foundational aspects such as the lunar spectrum, reference frame, and time definition

- The IOAG CSLG members have been writing the "IOAG Preliminary Report on LunaNet Governance" to contribute to the governance mechanisms that becomes necessary for the LunaNet service operation
  - We are aiming for the report publication this April and the report is currently under review and its final polishing stage

- The governance session of this cislunar PNT workshop is an important place to discuss the governance issues related to the lunar PNT
  - The presentation slides last year available at https://ioag.org/meetings/cislunar/