LEO PNT Panel at Munich Satellite Navigation Summit and CCSDS Lunar Interoperability Forum

Masaya Murata (JAXA)

Lunar Interoperability Forum

"GNSS meets friends in new orbits - potentials and synergies"

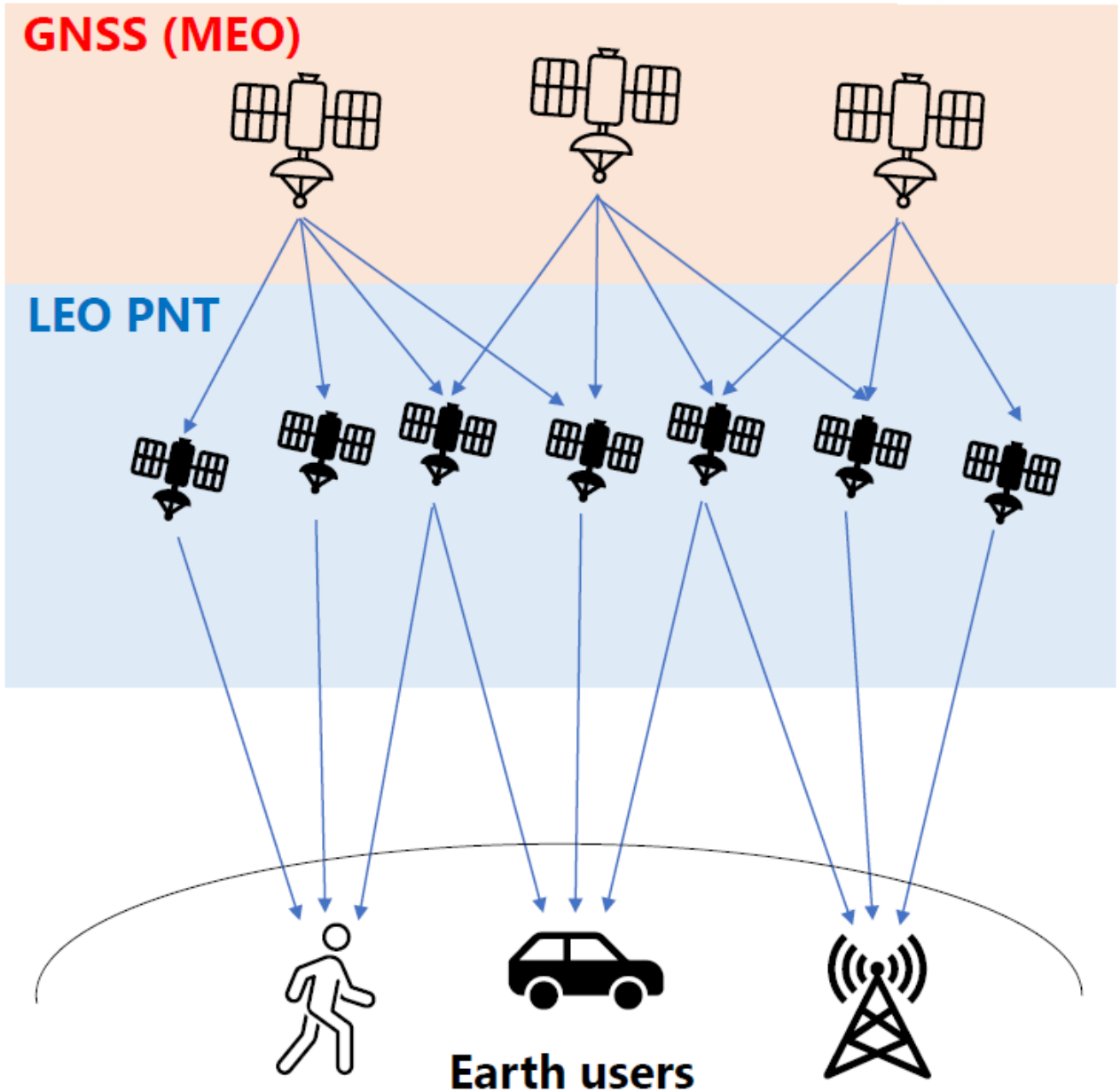
7 May 2024

Preliminary Study on JAXA LEO PNT System

Masaya Murata
Japan Aerospace Exploration Agency (JAXA)

Our LEO PNT Concept

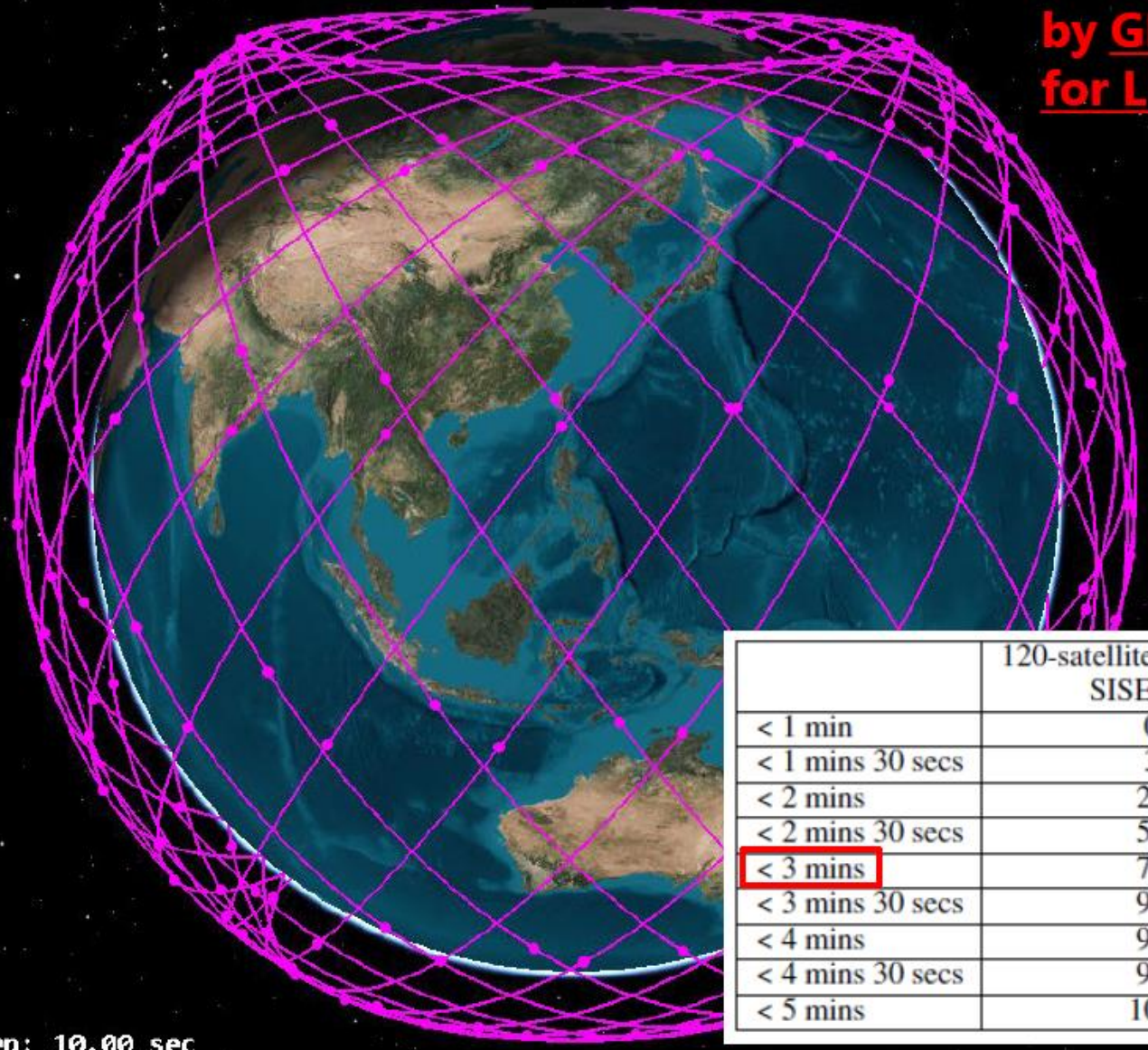
- LEO PNT augmentation for the existing GNSS
- Provision of an alternative PNT service to the GNSS
- Highly autonomous LEO PNT system driven by onboard GNSS navigation for LEO sats
- <u>Enabling the ultra-rapid precise point positioning (PPP) convergence service for Earth users</u>



Phase I (2030)

Our LEO PNT Constellation Plan Using 240 Satellites

Walker 55° :240/24/1 (Altitude = 975km)



SISE of 20cm (RMS)
by GNSS onboard navigation
for LEO sats

10cm-level horizontal
PPP convergence less
than three minutes

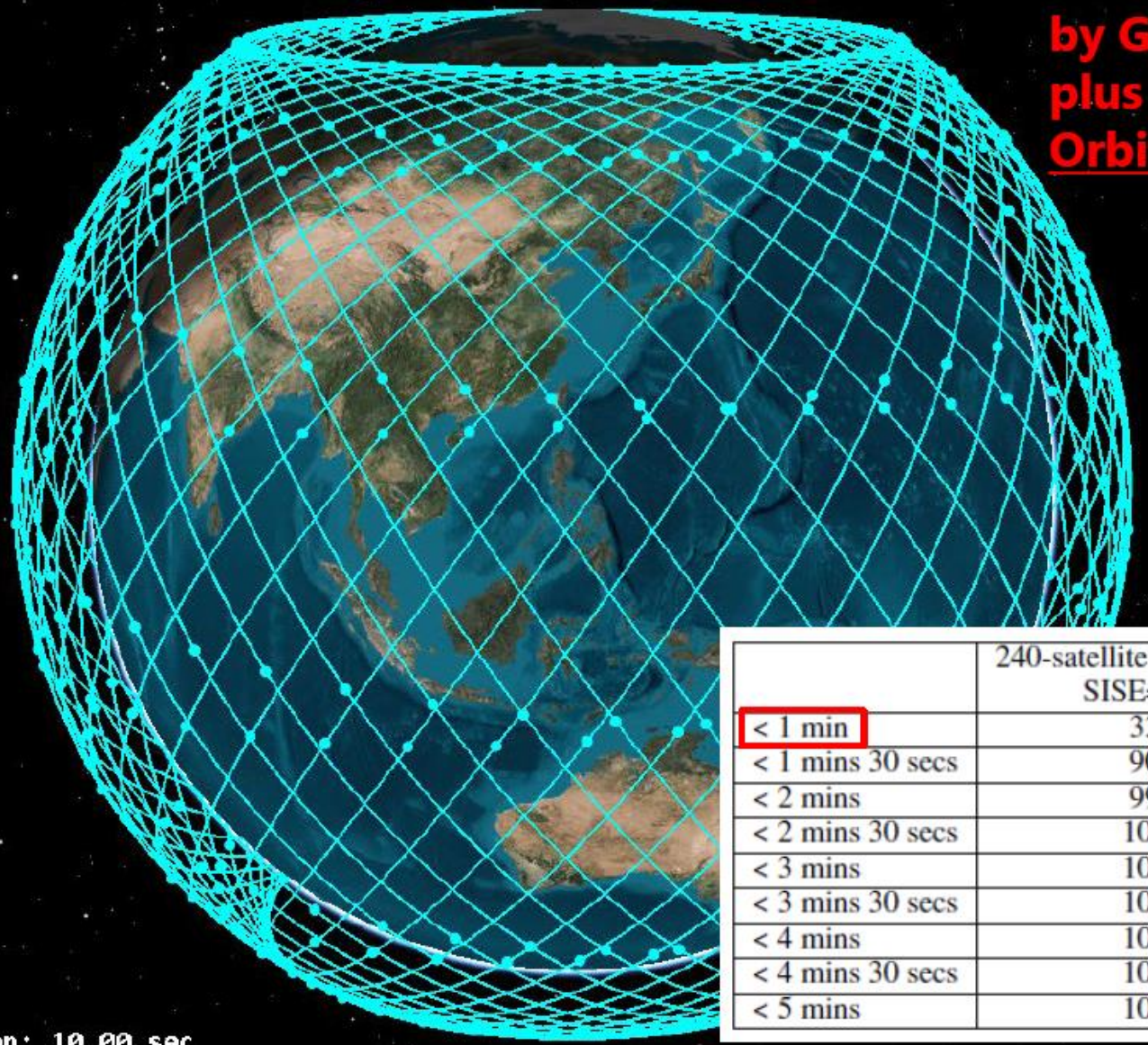
LEO PNT navigation
signal in C-band
(5030-5250 MHz)

	120-satellite constellation, SISE=20cm	240-satellite constellation, SISE=20cm
< 1 min	0%	1%
< 1 mins 30 secs	3%	22%
< 2 mins	23%	67%
< 2 mins 30 secs	57%	96%
< 3 mins	78%	99%
< 3 mins 30 secs	90%	100%
< 4 mins	96%	100%
< 4 mins 30 secs	99%	100%
< 5 mins	100%	100%

Phase II (2035)

Our LEO PNT Constellation Plan Using 480 Satellites

Walker 55° :480/48/1 (Altitude = 975km)



SISE of 10cm (RMS) by GNSS onboard navigation plus on-ground POD (Precise Orbit Determination)

10cm-level horizontal PPP convergence less than one minute

LEO PNT navigation signal in C-band (5030-5250 MHz)

	240-satellite constellation, SISE=10cm	480-satellite constellation, SISE=10cm
< 1 min	33%	77%
< 1 mins 30 secs	90%	99%
< 2 mins	99%	100%
< 2 mins 30 secs	100%	100%
< 3 mins	100%	100%
< 3 mins 30 secs	100%	100%
< 4 mins	100%	100%
< 4 mins 30 secs	100%	100%
< 5 mins	100%	100%

Takeaways

- JAXA started the design of the LEO PNT system and our initial design results were shown in this talk
- Our phase I LEO PNT system aims to provide the ultra-rapid PPP convergence service less than three minutes by the onboard GNSS navigation for the LEO satellites
- At phase II, we aim to provide the PPP convergence service less than one minute by also using the LEO PNT-dedicated ground stations and the on-ground POD results
- We design our system to be interoperable and compatible with the other LEO PNT systems under development. ESA-JAXA collaboration discussion is already ongoing

LUNAR INTEROPERABILITY FORUM

全講演資料とプレゼン動画は以下ページで
公開されている
https://public.ccsds.org/LunarForum.aspx

TUESDAY, 7 MAY 2024

Panel 1: Space Agencies & Organizations

Chair: S. W. Asmar

- IOAG (9:15 AM)
  - Jim Schier: "Cislunar Infrastructure: The Convergence of Architecture, Governance, and Interoperability"
- JAXA (9:30)
  - Masaya Murata: "Japan Lunar Navigation Satellite System and Its Contribution Towards Lunar Augmented Navigation Service"
- ESA (9:45)
  - Javier Ventura-Traveset: "Moonlight, LCNS, and Lunar Pathfinder: European contribution to lunar Communication and Navigation Services"
- CNES (10:00)
  - Jean-Luc Issler: "CCSDS frequency band recommendations related to lunar in-situ 3GPP 5G, WIFI and PNT"

CCSDS-IOAG Lunar Interoperability Forum
Washington, D.C.

INTERAGENCY OPERATIONS ADVISORY GROUP

Cislunar Infrastructure: Convergence of Architecture, Governance and Interoperability

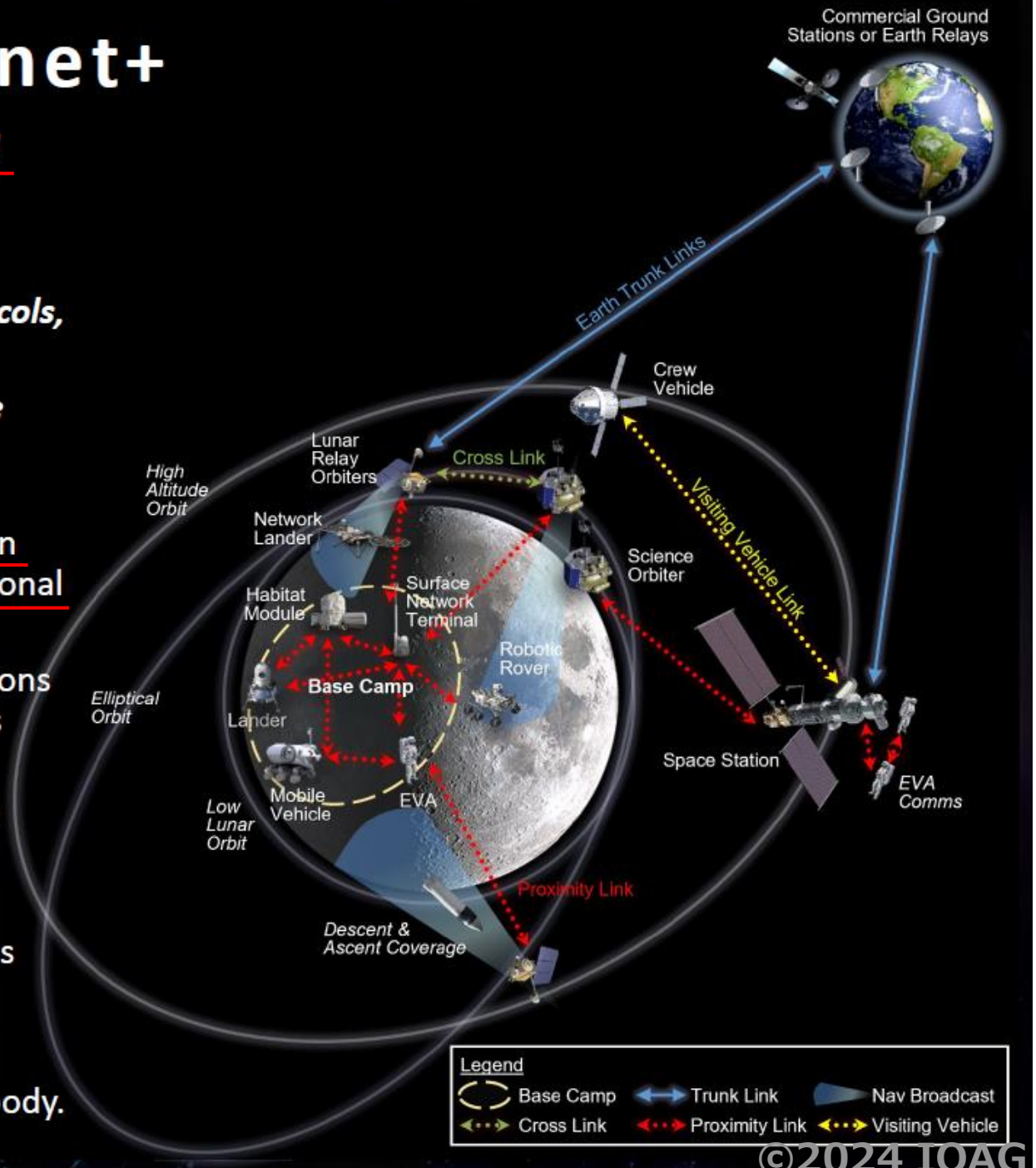
Presented by:
Jim Schier, IOAG Chair

May 7,2024

LunaNet, the Lunar Internet+

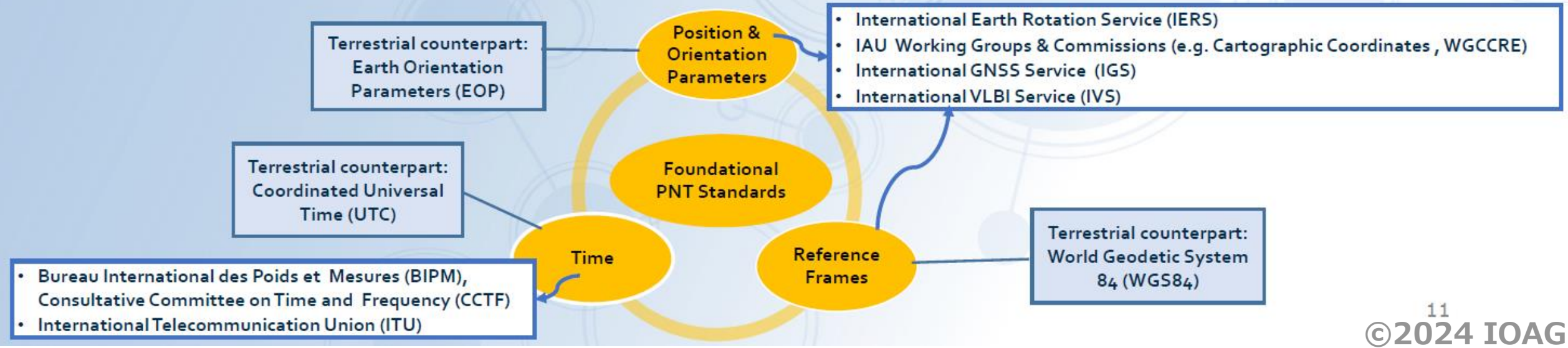
LunaNet is a set of cooperating networks providing interoperable communications and navigation services for users on and around the Moon.

- ***Based on a framework of mutually agreed-upon standards, protocols, 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:** LunaNet services can include data transmission and distribution of position, navigation, timing (PNT), and situational awareness information.
  - **Scalable**: LunaNet can be introduced as part of the earliest missions and accommodate expansion as new users and service providers come online.
  - **Open**: LunaNet is based on open international standards like the Internet
  - **Resilient**: As LunaNet grows into many networks and users, it becomes steadily more resilient to individual failures and outages
  - **Secure**: LunaNet protects sensitive and proprietary data while preventing or rapidly recovering from cyber threats
  - **Extensible**: The LunaNet concept is applicable to any planetary body.



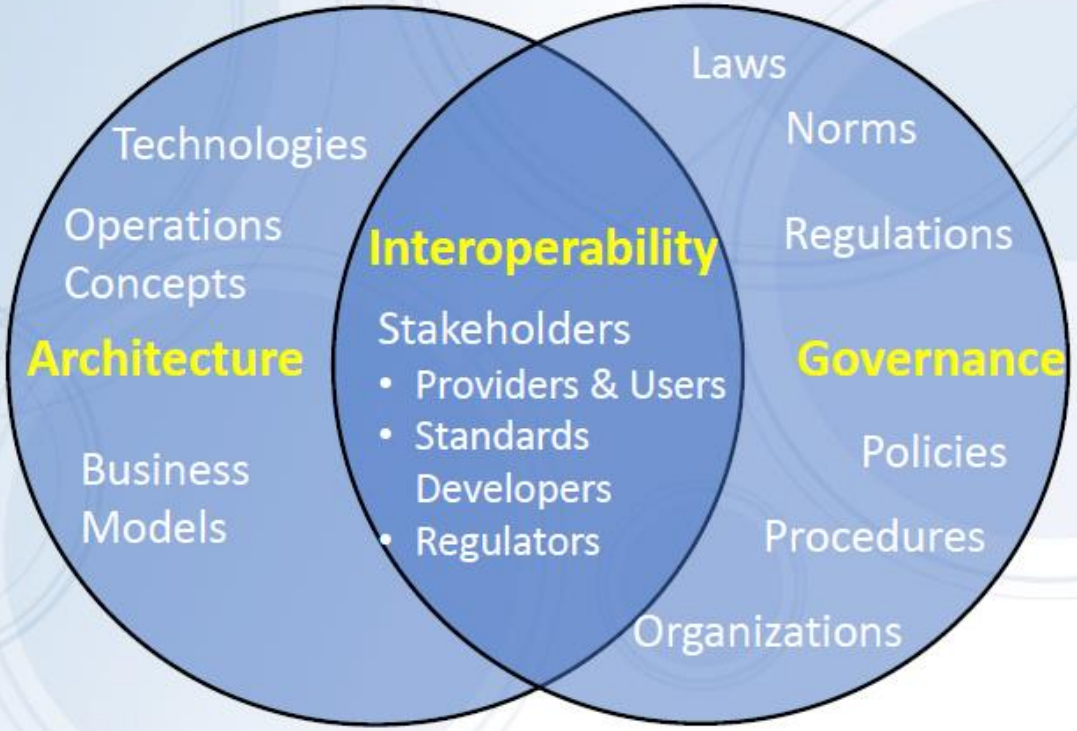
Foundational PNT Standards

- Humankind has enacted international standards for International Celestial Reference System (ICRF) & Int'l Terrestrial Reference System (ITRS)
- New Int'l Lunar Reference System (ILRS) is needed
- National positions need to be integrated into int'l standards
  - Ex: OSTP issued position on Coordinated Lunar Time (LTC)



Conclusion

- Achieving interoperability across cislunar Communications, Position, Navigation & Timing (CPNT) infrastructure (services & capabilities) will require adoption of common:
  - Architecture (& concepts of operation),
  - Development and operations coordination within the community of service providers, users, and other stakeholders
  - Interaction with national & international means of establishing laws, regulations, policies, norms, and standards
- These processes will take years to unfold



- ICG-IOAG Multilateral Cislunar PNT Workshop, February 2025 in Vienna, Austria
  - "The workshop shall: (1) serve as a mechanism to better understand the scope and depth of lunar PNT systems being developed, (2) propose recommendations that may be taken up by lunar PNT developers, and (3) facilitate refinement of interoperable, compatible, and available lunar PNT systems of the future." [ICG-17 Recommendation]

Joint ICG-IOAG Multilateral Cislunar PNT Workshop at Vienna International Centre in February 2025

Organization Committee

ICG:

China/CAST: Xinuo Chang

Europe/ESA: Javier Ventura-Travese

India/ISRO: Ashish Shukla

Japan/JAXA: Masaya Murata

USA/NASA: Joel Parker

SFCG Liaison: Catherine Sham (NASA)

LNIS WG Liaison: Cheryl Gramling (NASA)

IOAG:

Jim Schier (NASA, IOAG Chair)

Stephen M. Lichten (NASA JPL)

Matthew Cosby (UK Space Agency)

Corali Roura (NASA, IOAG CSLG)

Angela D. Peura (NASA, IOAG Secretariat)

Jidesh Jidesh（ISRO）

Shri Madhav Nakhani（ISRO）

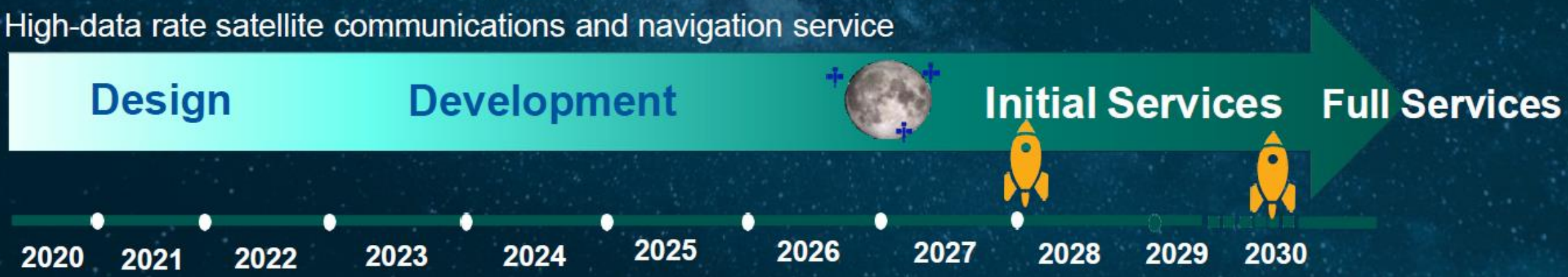
European Roadmap under coordination with ESA

STEP 1: LUNAR PATHFINDER

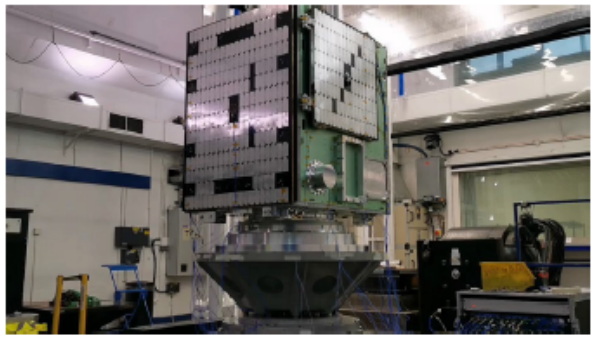
Low-rate satellite communications service + Moon GNSS Receiver

STEP 2: MOONLIGHT LCNS CONSTELLATION

High-data rate satellite communications and navigation service



Moonlight – Lunar Pathfinder – Quick facts



Lunar Pathfinder Structure under test

Lunar Pathfinder & CLPS-CS3 stack

Provides data relay services as of Q1 2026

- ✓ Flight-patchable SBand Prox1 link, follows SFOG42-1
- ✓ Adaptative Communication Rates [1;4096] ksps
- ✓ Follows LNISv5 subset, precursor to new Lunar CCSDS, designed to maximize interoperability with LunaNet

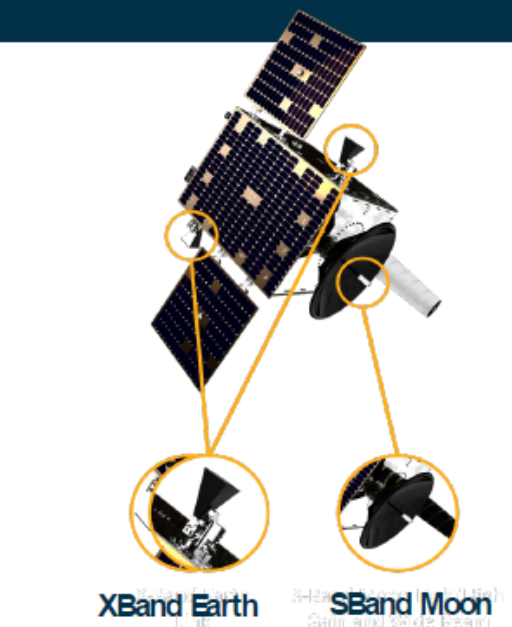
ESAPartnership with SSTL, strategic partnership with NASA:

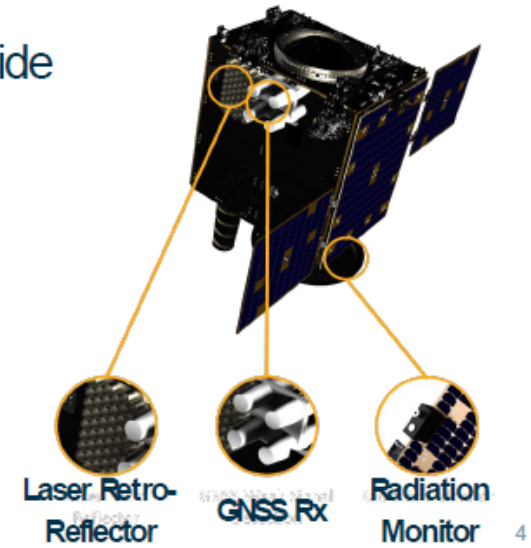
- ✓ Launch date: Dec 2025 (Firefly's Blue Ghost)
- ✓ Exploitation phase (8 years): Q1 2026 up to Q3 2034
- ✓ Will provide DTE to US LuSEE-NIGHT mission from lunar far side

Demonstrates Navigation technologies

- ✓ First ever GPS/GALI LEO reception on lunar orbit
- ✓ NASA Laser Retro-Reflector experiment

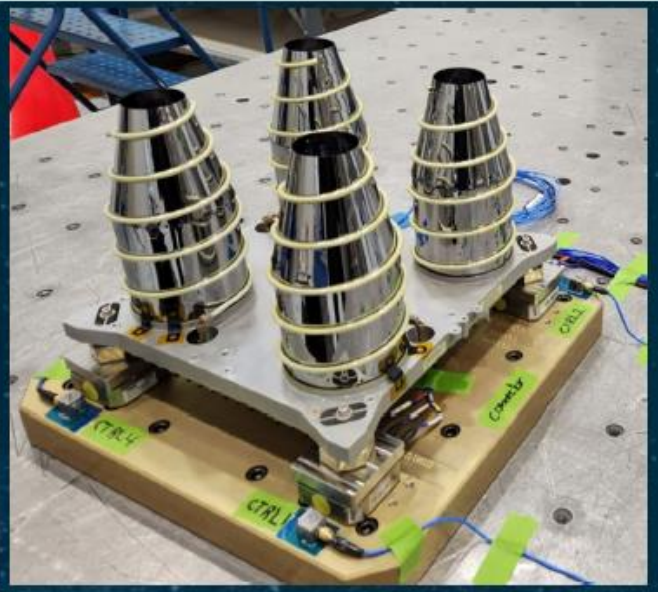
Hosts a radiation monitor





Lunar Pathfinder will also test First ever GPS/GALILEO reception on lunar orbit and precise autonomous Lunar orbit determination (cooperation with NASA)

GNSS High-sensitive receiver
Flight unit



GNSS High-gain Antenna
Flight unit

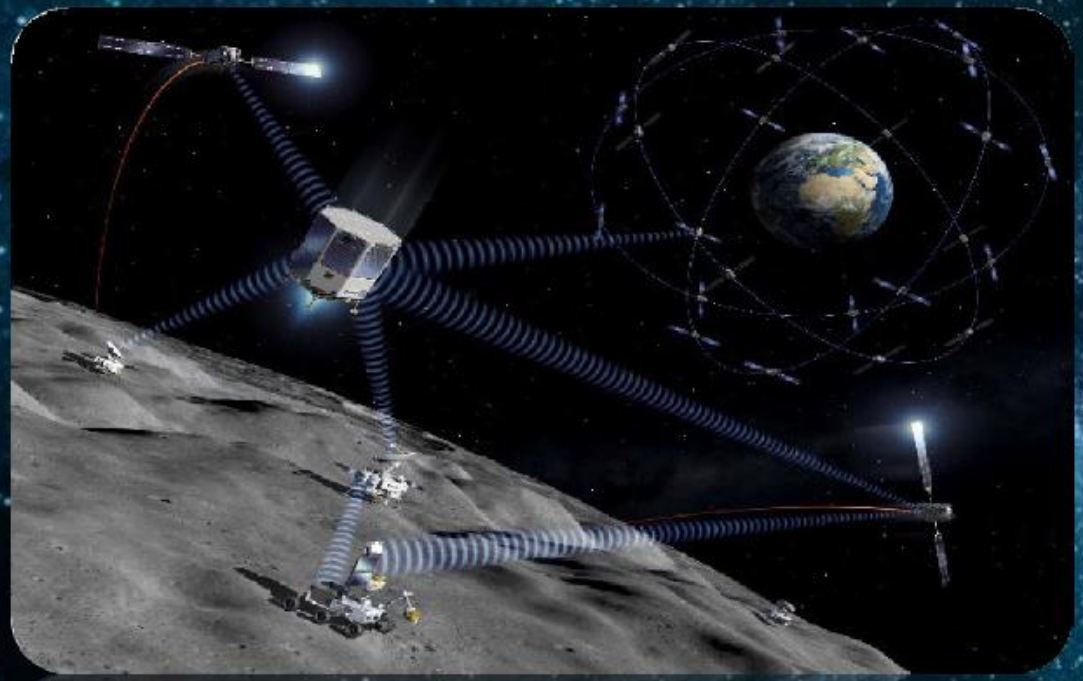
Laser Retroreflector
Flight unit (NASA)

Demonstration of GPS/Galileo PNT on a Lunar orbiting satellite

First time ever three ranging techniques (GNSS, Laser and X-band ranging) are used simultaneously on lunar orbit

Moonlight Approach & Services

Public-Private Partnership: Private sector as service provider
ESA supporting infrastructure development and acting as Anchor customer

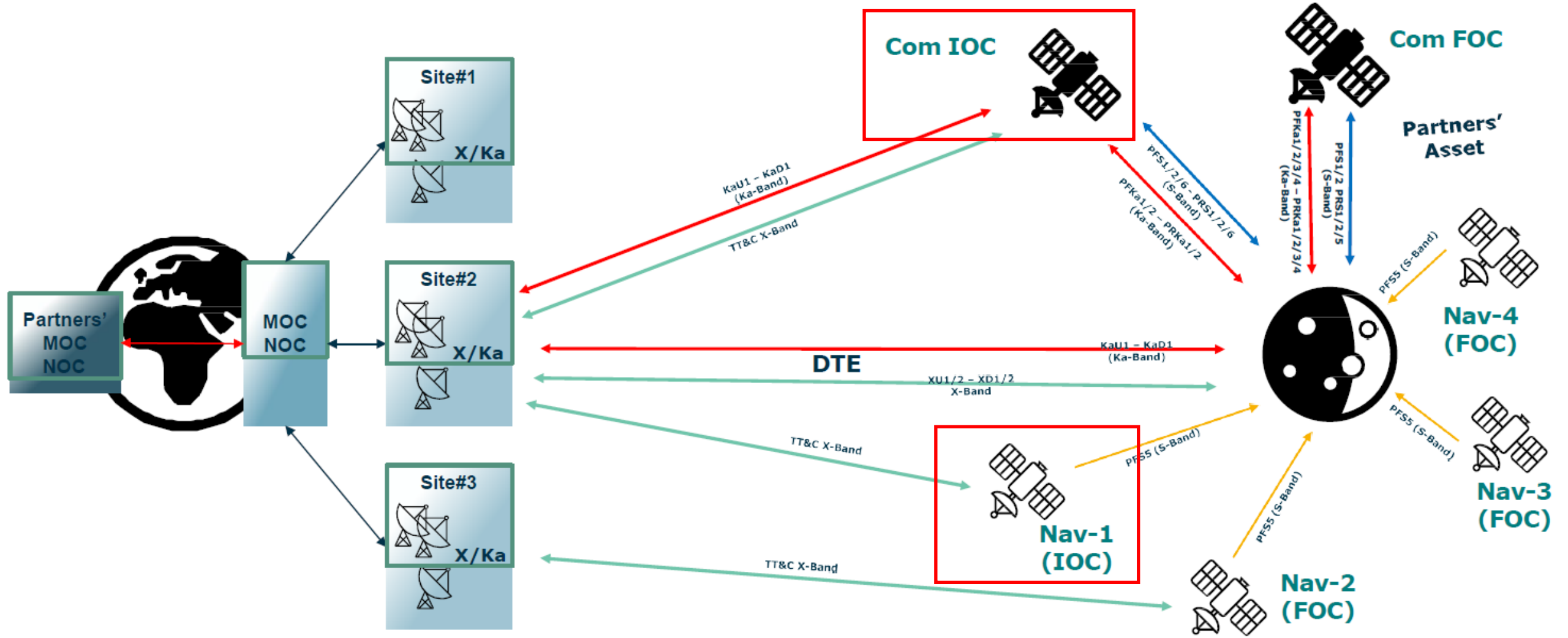


Data transport	Absolute Position
Tele-operations	Absolute Velocity
Audio/Video streaming	Universal time

Direct To Earth Service	Post-processing PVT
Over-the-top Services	LunaSAR return link

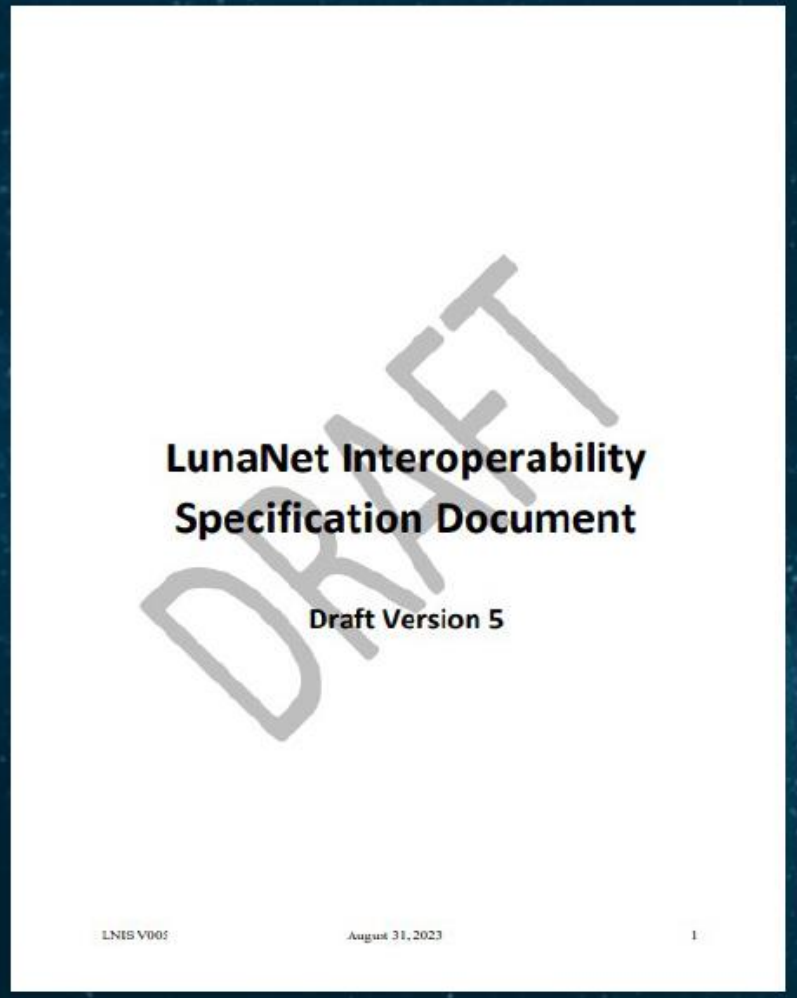
- A dedicated constellation of satellites around the Moon providing commercial lunar communication and navigation services in two steps IOC (2028) and FOC (2030).

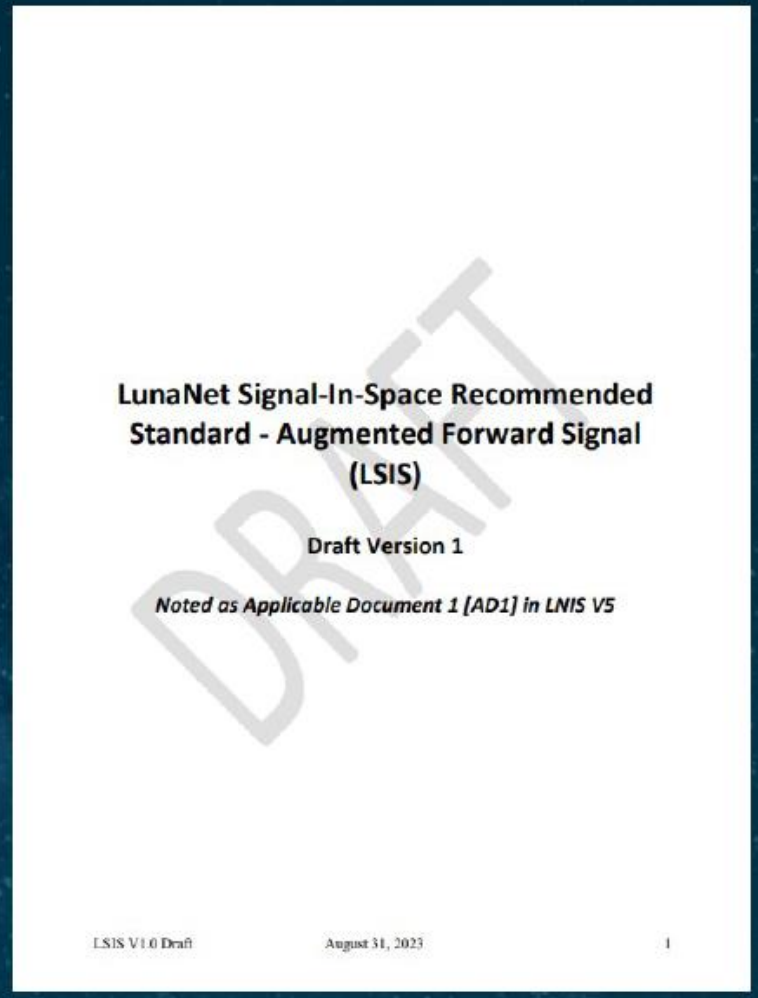
Moonlight: Mission Architectural Concept
(notional)



Links are named in-line with LunaNet spec

MOONLIGHT will comply with LunaNet Interoperability Specifications (last update LNIS v5, Sept 2023)



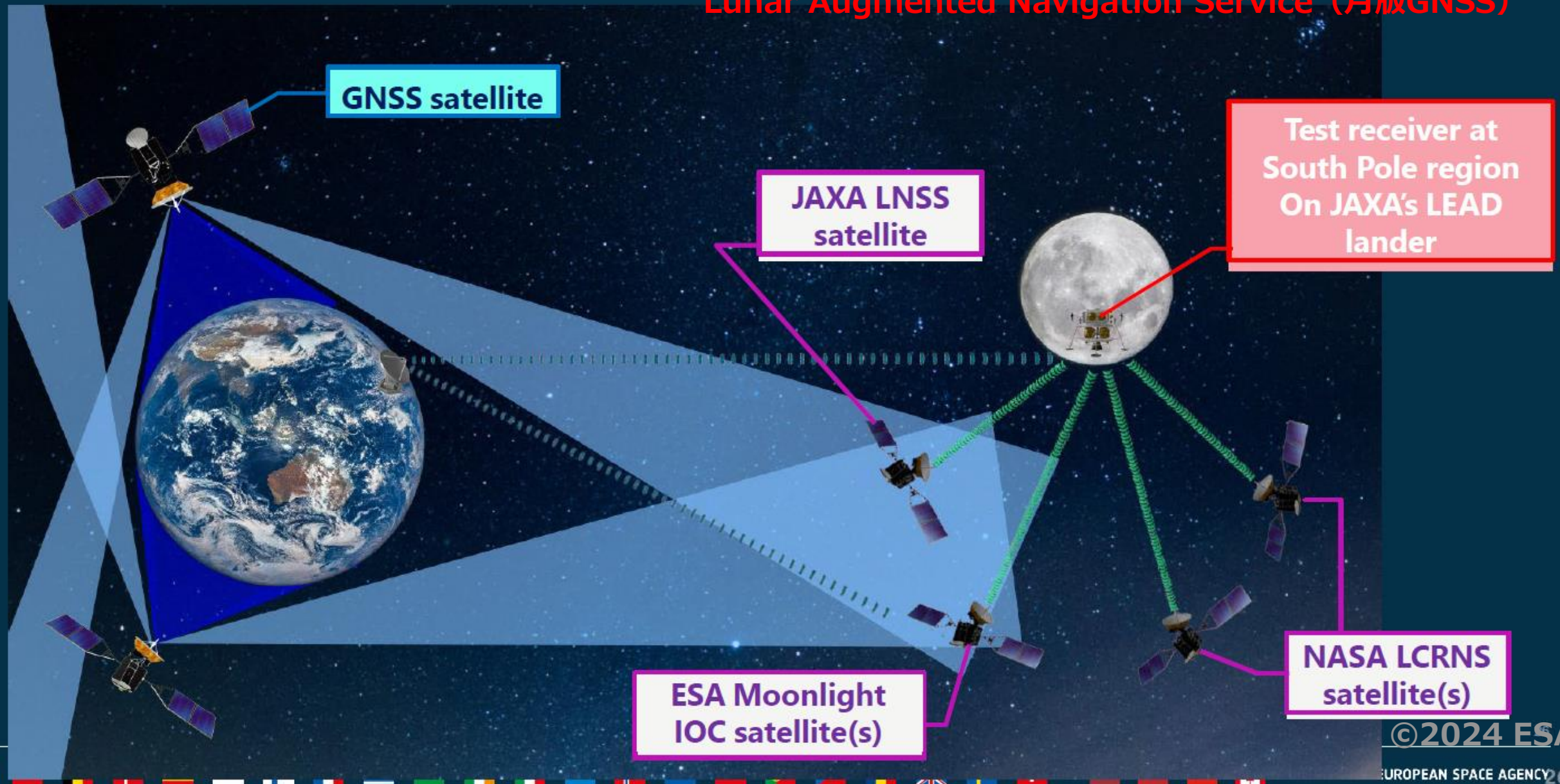


Joint NASA, ESA and JAXA cooperation: LunaNet dedicated WGs established and active

LNIS v5 is currently being updated, taking into account feedback received (incl. notably IOAG and CCSDS)

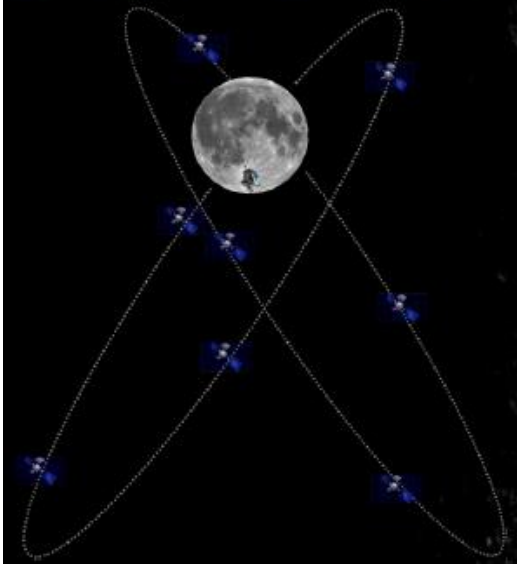
First-ever lunar PNT interoperability demonstration planned for 2028
ESA / NASA / JAXA: Towards an international LANS System

Lunar Augmented Navigation Service（月版GNSS）



Japan Aerospace Exploration Agency

Lunar Navigation Satellite System

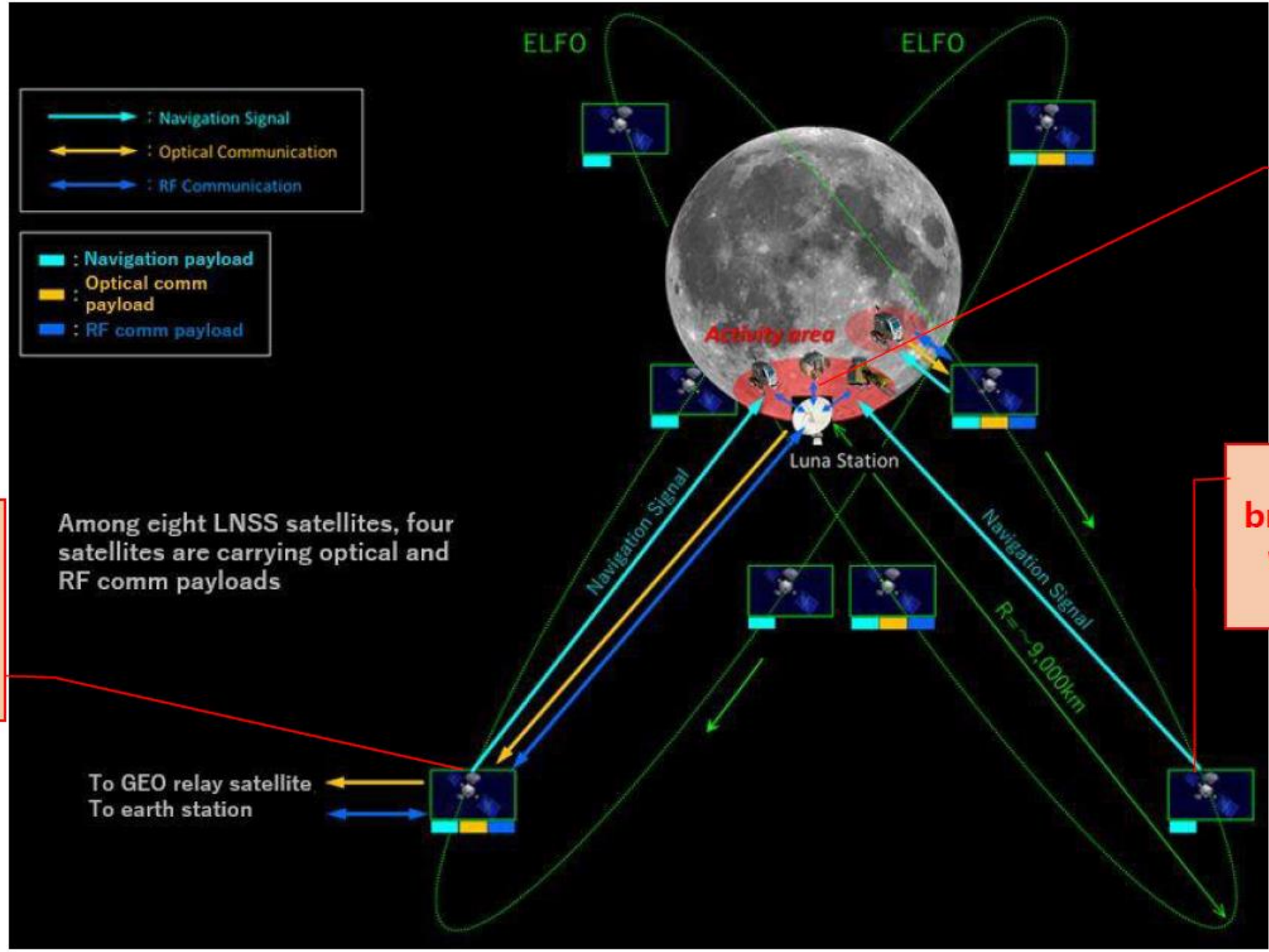


Japan Lunar Navigation Satellite System (LNSS) and Its Contribution Towards Lunar Augmented Navigation Service

Masaya Murata (JAXA)

JAXA's plan

LNSS is GPS-like satellite constellation for the Moon designed by JAXA



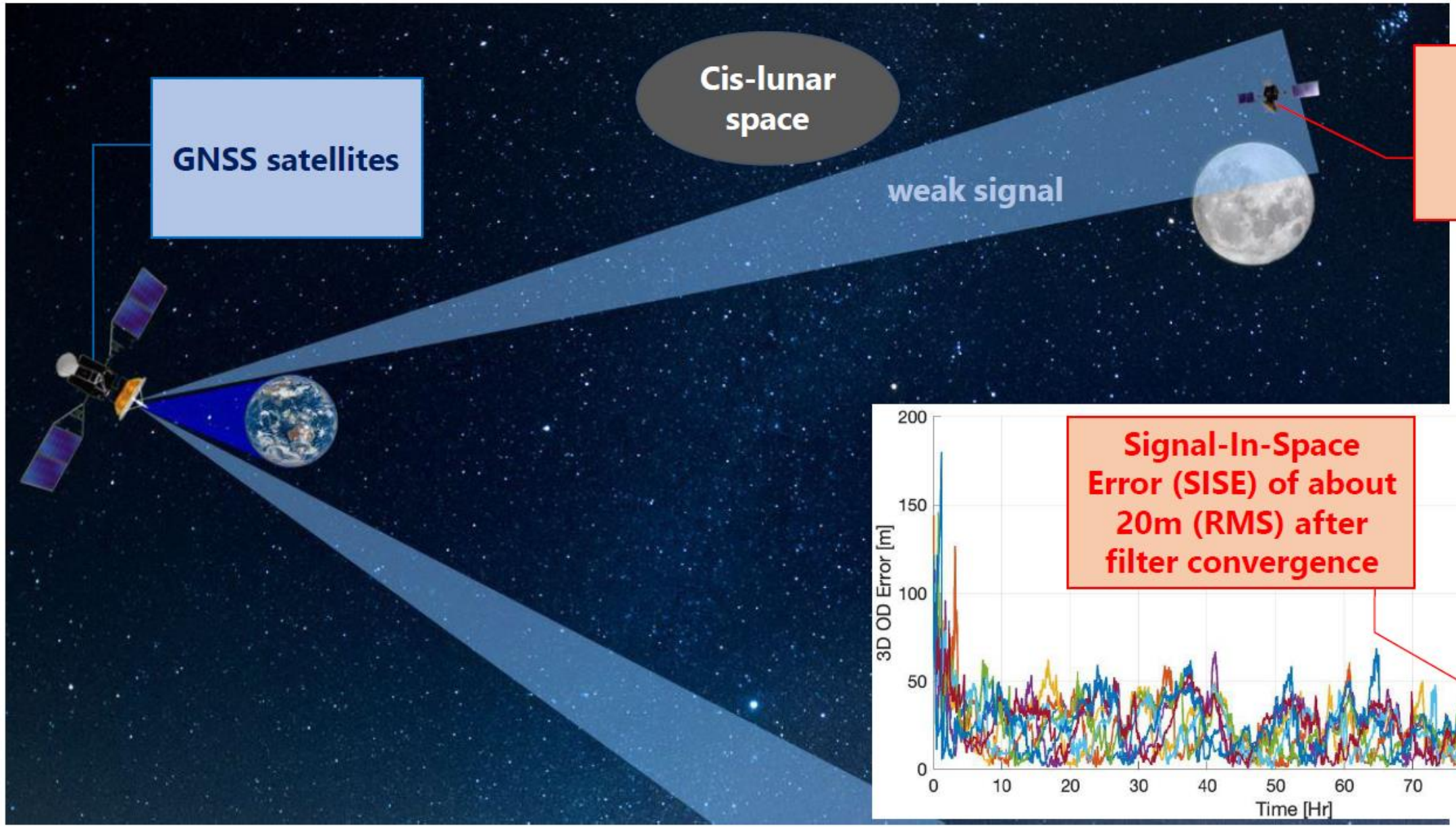
Target: South Pole region

LNSS satellite broadcasting one-way navigation signal

LNSS satellite also functioning as a data relay satellite to the earth

JAXA's plan

GNSS weak signal navigation for LNSS satellites, making the lunar PNT autonomous



Towards the establishment of 'Moon GNSS' called LANS

The concept of the Moon GNSS called the Lunar Augmented Navigation Service (LANS)

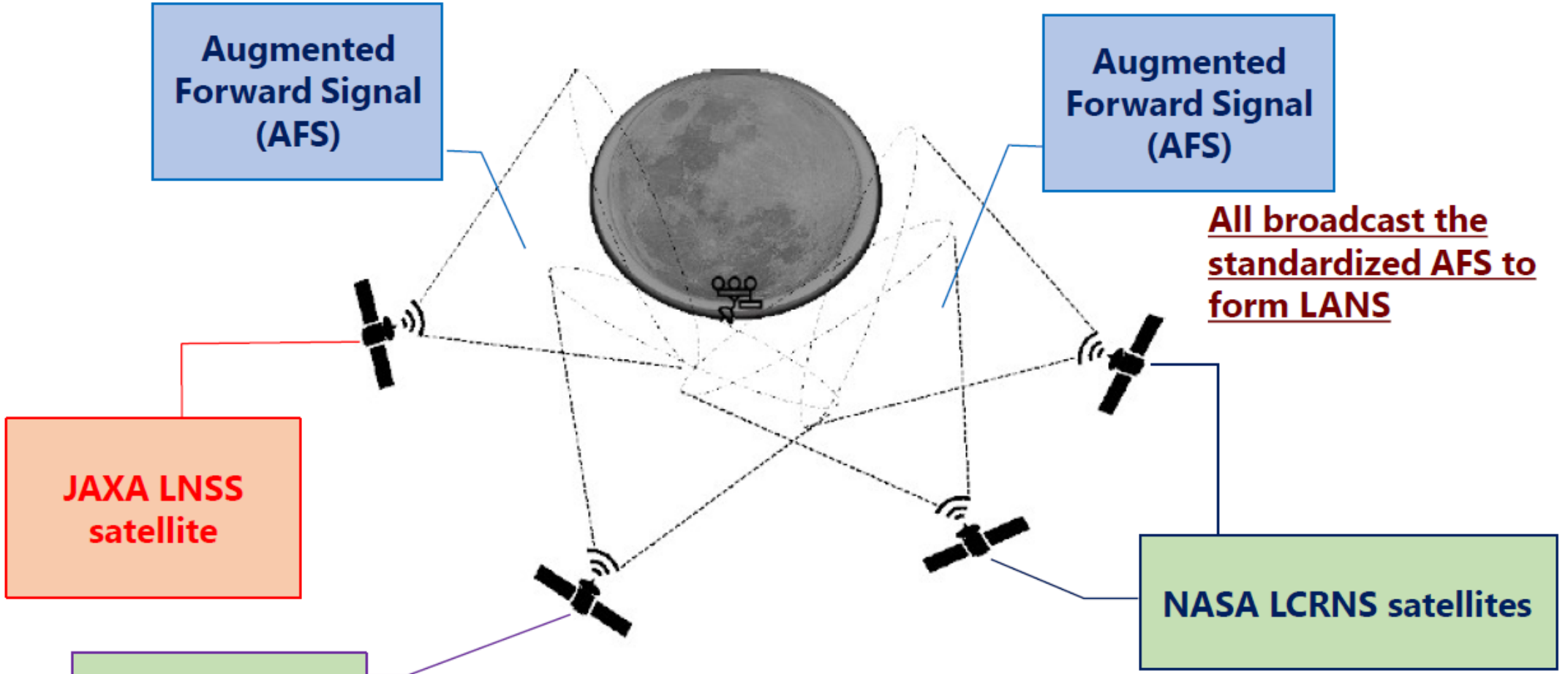
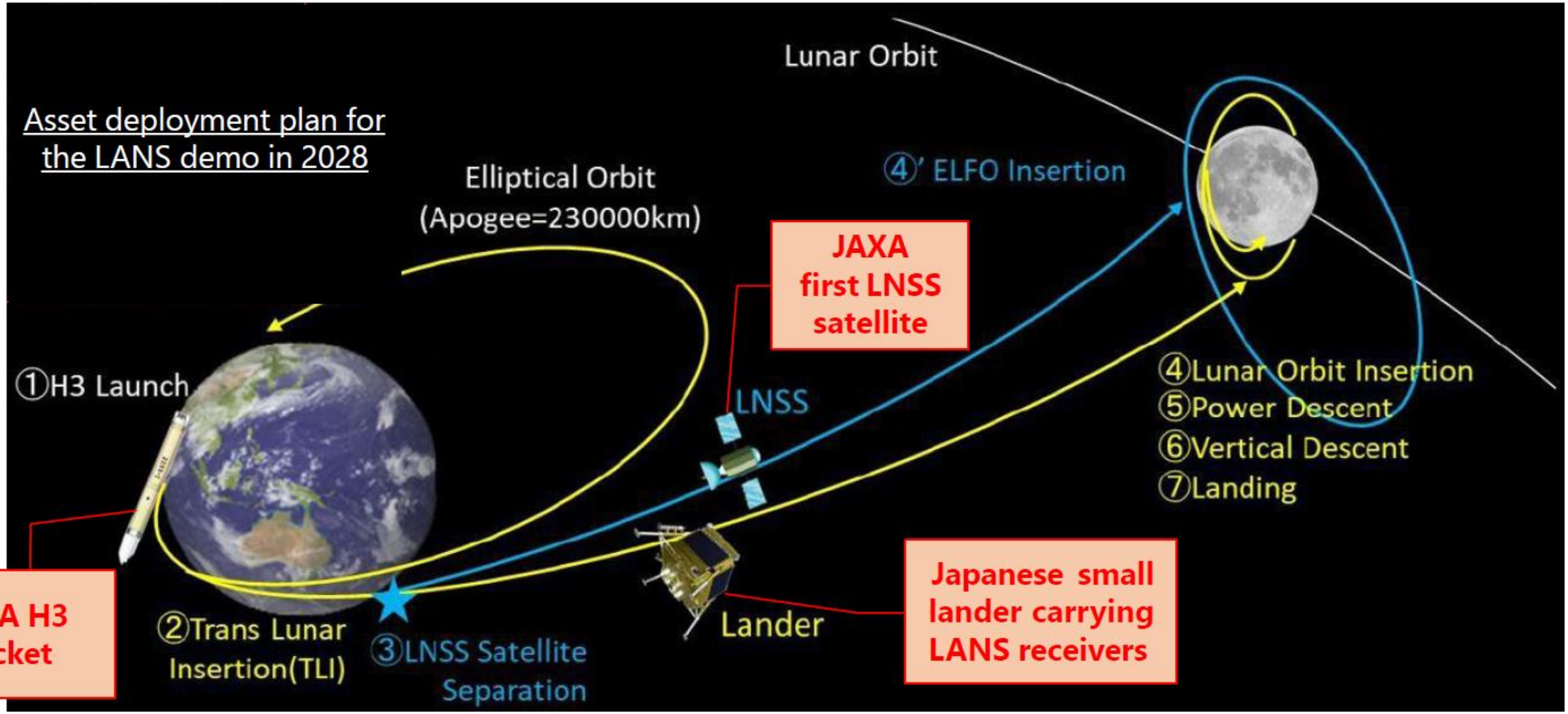


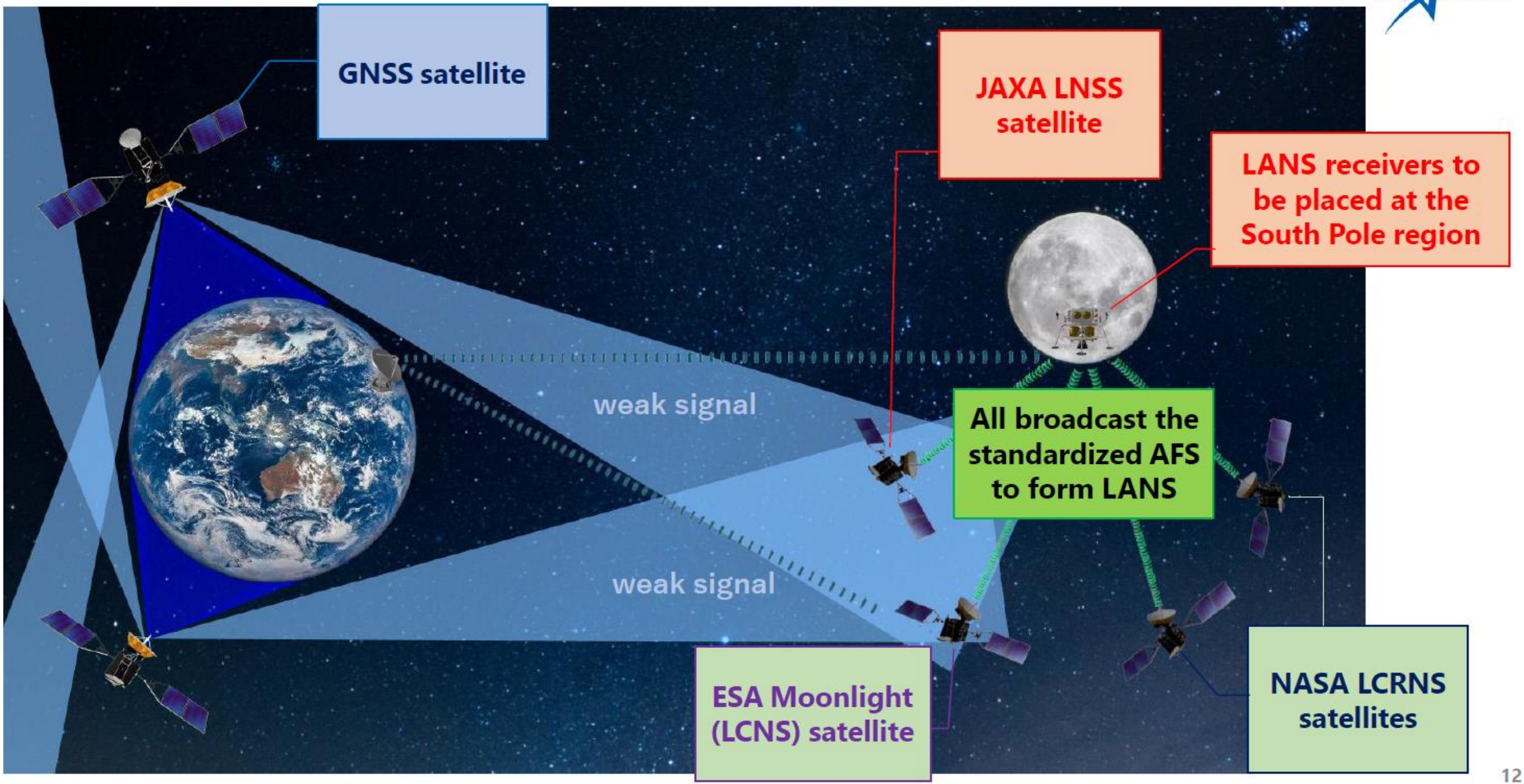
Figure 10 - LANS PNT Concept Provided by LunaNet Nodes

This figure was copied from the LunaNet Interoperability Specification (LNIS)
※LNIS is the standardization document for the LunaNet

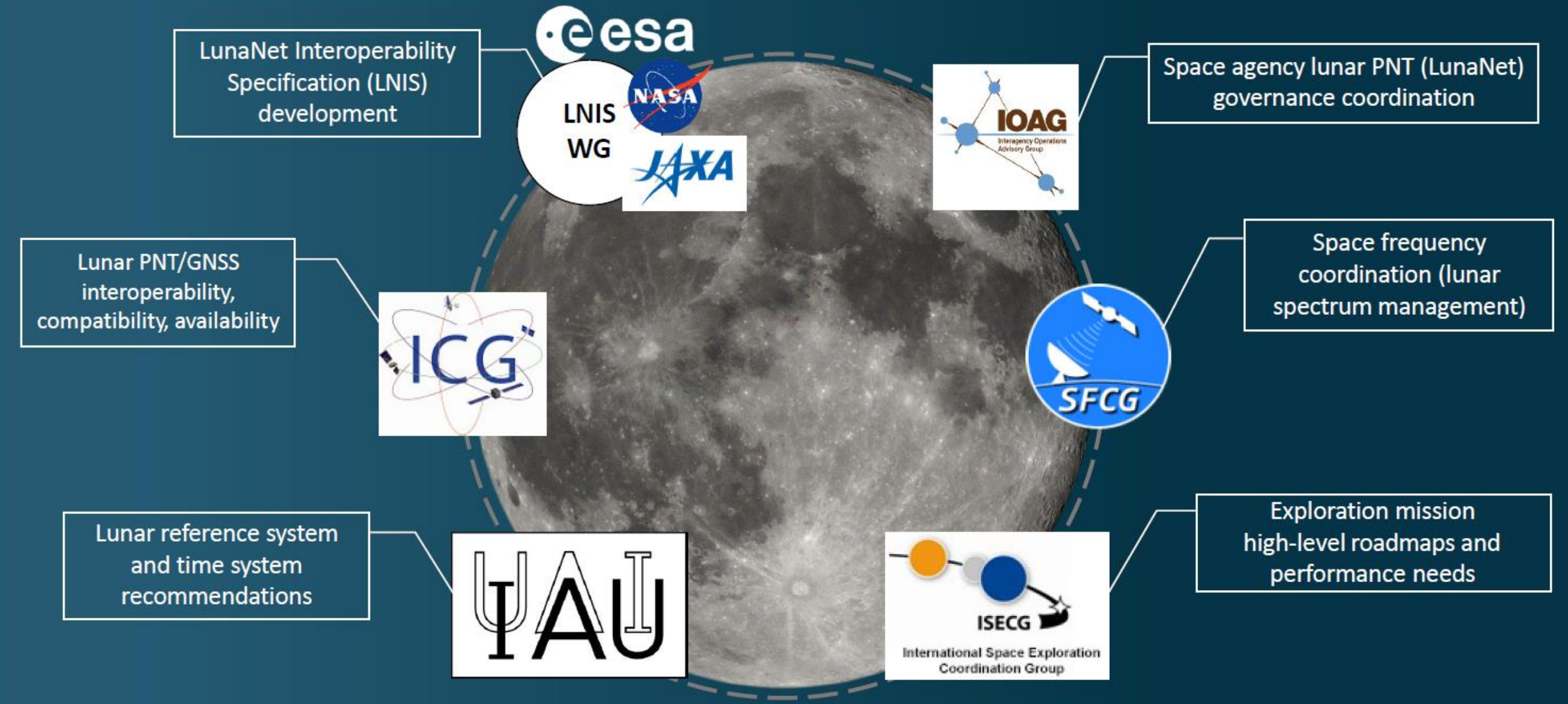
Launching and deploying our first LNSS satellite and LANS receivers to the moon



Proposing the first-ever ESA-NASA-JAXA LANS interoperability and PNT demonstration



International Organizations Currently Involved in Lunar PNT



Session F4: PANEL: International Civilian Agency Lunar PNT Systems

Panel Members:

1. Dr. Javier Ventura-Traveset, European Space Agency (ESA)
2. Cheryl Gramling, National Aeronautics and Space Administration (NASA)
3. Dr. Masaya Murata, Japan Aerospace Exploration Agency (JAXA)
4. Dr. Cosimo Stallo,Thales Alenia Space
5. Dr. Mauro Cardone, Italian Space Agency (ASI)
6. ISRO Representative (TBD)
7. Dr. Jungmin Joo, Korea Aerospace Research Institute (KARI)

This year, the number of the lunar PNT panelists grows from three of last year to seven! Besides the panel, this year's ION GNSS+ again holds the lunar PNT technical session

Takeaways

・The international collaboration between the JAXA LNSS, ESA LCNS, and NASA LCRNS is ongoing on the LunaNet Interoperability Specification (LNIS). The Lunar Augmented Navigation Service (LANS) becomes the “Moon GNSS” and lunar users will enjoy the interoperable lunar PNT system of systems from the get-go

・JAXA is proposing the joint LANS interoperability demonstration mission in 2028 and ESA and NASA are currently assessing their respective participation through the collaborative discussion

・The international coordination becomes much more important from this year onwards and I greatly thank the CCSDS for organizing this Lunar Interoperability Forum. The interoperability and compatibility among the respective systems become a key issue for the successful, international lunar PNT system of systems