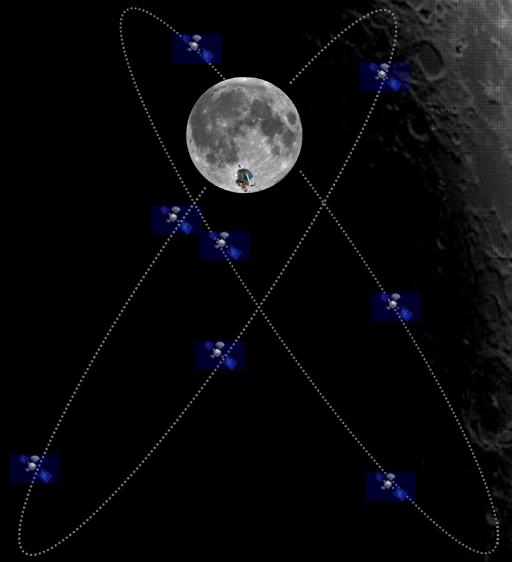
SPACE FOR INSPIRATION 2024

LUNAR COMMUNICATIONS AND NAVIGATION SESSION

Japan

Lunar Navigation Satellite System



# Lunar Navigation Satellite System & JAXA Lunar Exploration Roadmap

5th December, 2025

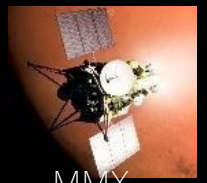
*Masaya Murata (Japan Aerospace Exploration Agency)*

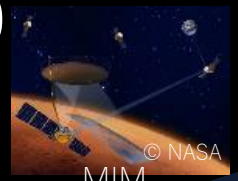
# Overview of JAXA Roadmap from LEO to Moon/Mars

2020 2030 2040

Expanding Human Presence

## MARS


MMX



MIM

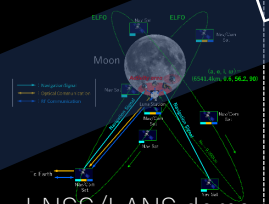
Robotic Tech Demo → Crewed Missions


Kaguya

Landed!


SLIM


LUPEX



LNSS/LANS demo


HTV-XG


Cargo Lander

## MOON

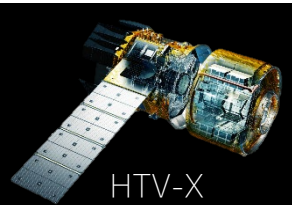
Gateway

Pressurized Crew Rover


Fuel-Plant (demo)


Lunar Base

Robotic Missions → Crewed Missions → Surface Infrastructure → Sustainable Exploration


HTV-X


Resupply for ISS and Post-ISS


Concept study of Japanese Module

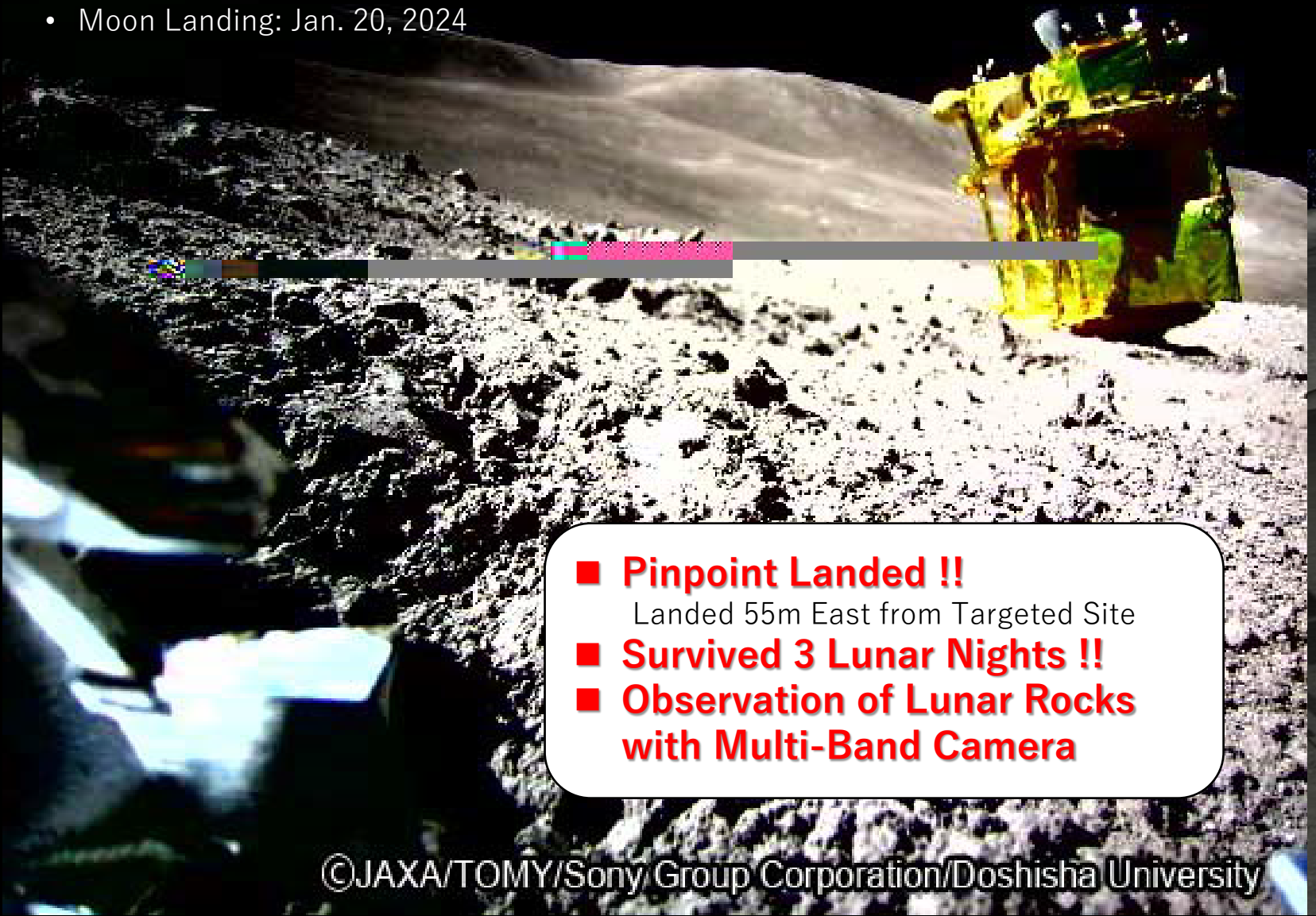
## LEO

ISS Operations → Sustainable LEO Commercializing Space Activities

# Lunar Surface: Pin-point Landing and South Pole Exploration

## Smart Lander for Investigating Moon (SLIM)

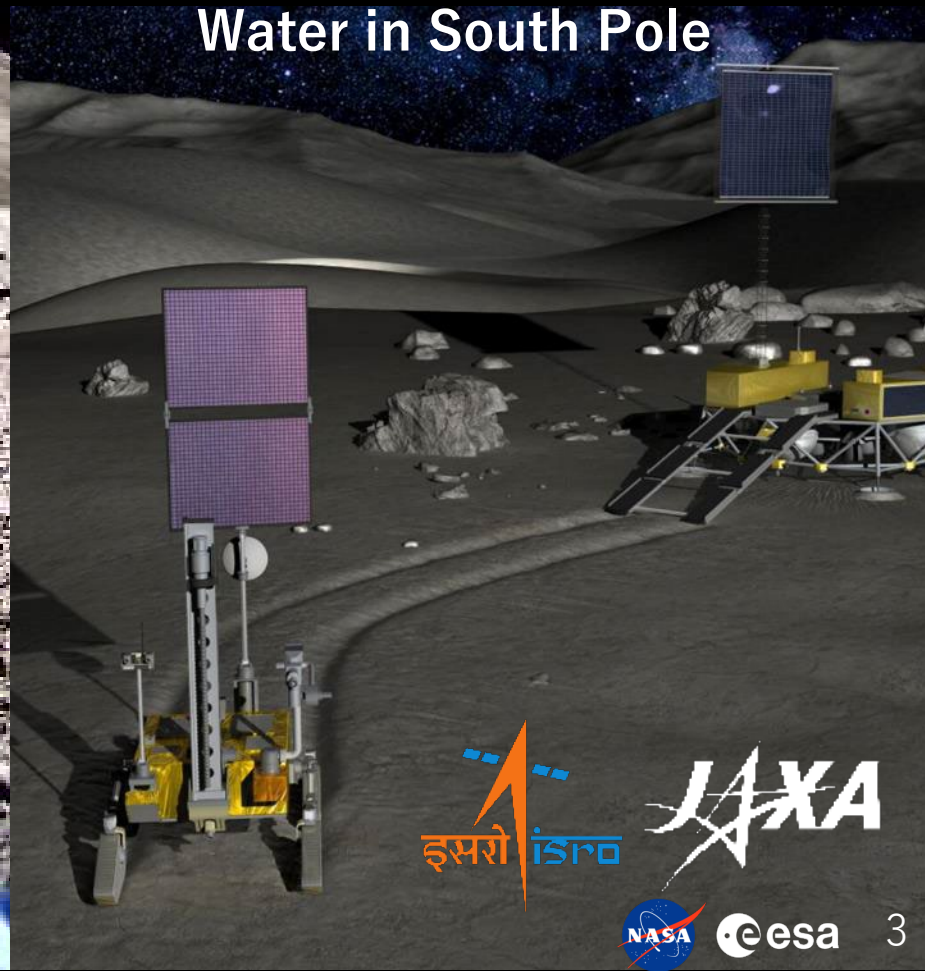
- Launch:  on Sept. 7, 2023
- Moon Landing: Jan. 20, 2024




## Lunar Polar Exploration (LUPEX)

- Target Launch: 2025-2026

## In-situ Observation of Water in South Pole



# The Pressurized Rover

**- Expected to take key role in Artemis missions -** Launch target: 2031

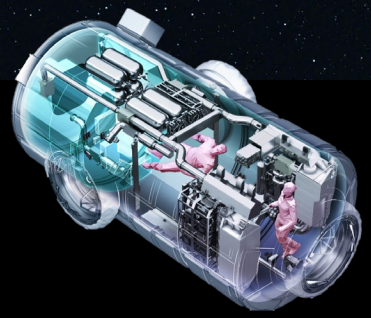
- **World first mobility system on the Moon boarded without EVA suit.**
- **Expands the exploration range on lunar surface**
- **Provides both crewed/uncrewed operation modes**


Signing of IA
(MEXT-NASA)
April 2024

✓ **Provision of a Pressurized Rover** by Japan

✓ **2 opportunities for Japanese astronauts** on the Moon's surface for exploration missions.

# Japan's Contribution to the Gateway and Beyond



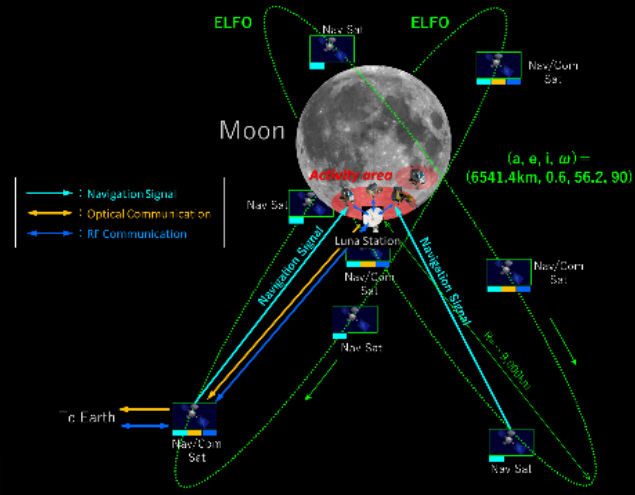
## Habitation Functions
ECLSS for I-HAB

- Environment Control and Life Support Capability in I-HAB
- Batteries for HALO

## Logistics Module
HTV-X (HTV-XG)

- Logistic Resupply capability
- 4,000kg of pressurized cargo to Gateway within 30 days

## Lunar Comm & Nav (CPNT) system




## Small Lander

## Medium Cargo Lander

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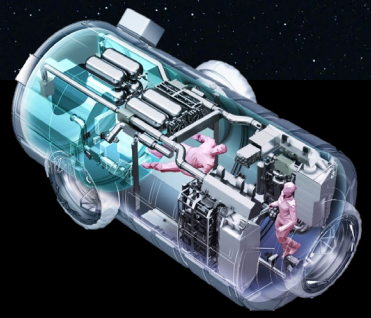

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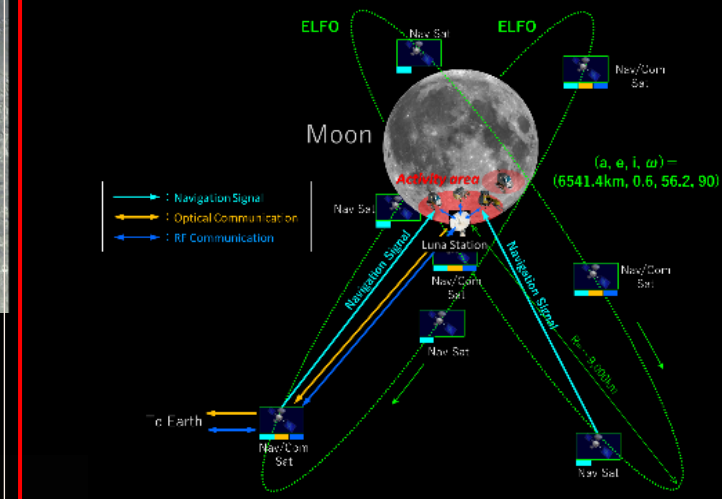
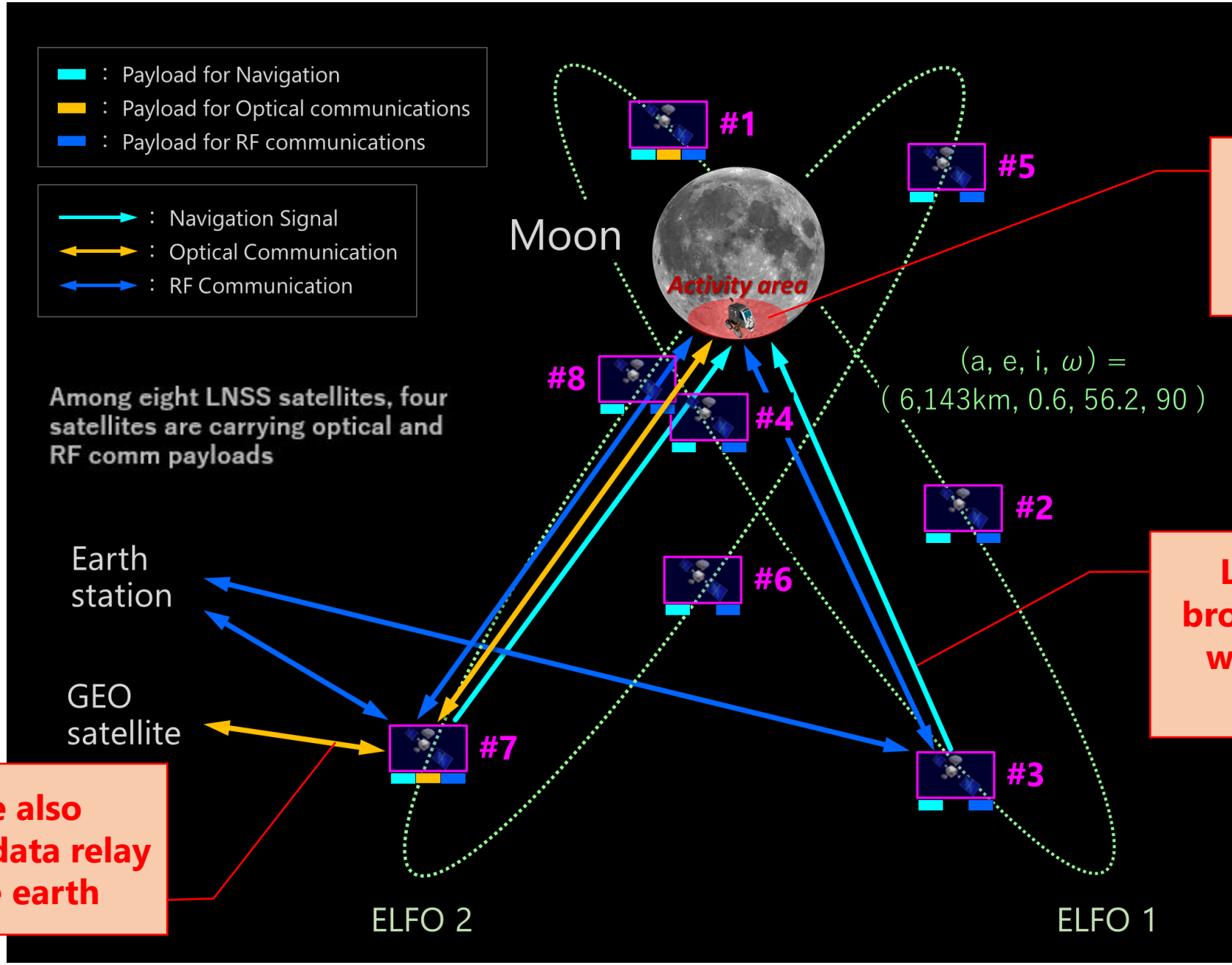



## Small Lander

## Medium Cargo Lander

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

## LNSS: Lunar Navigation Satellite System

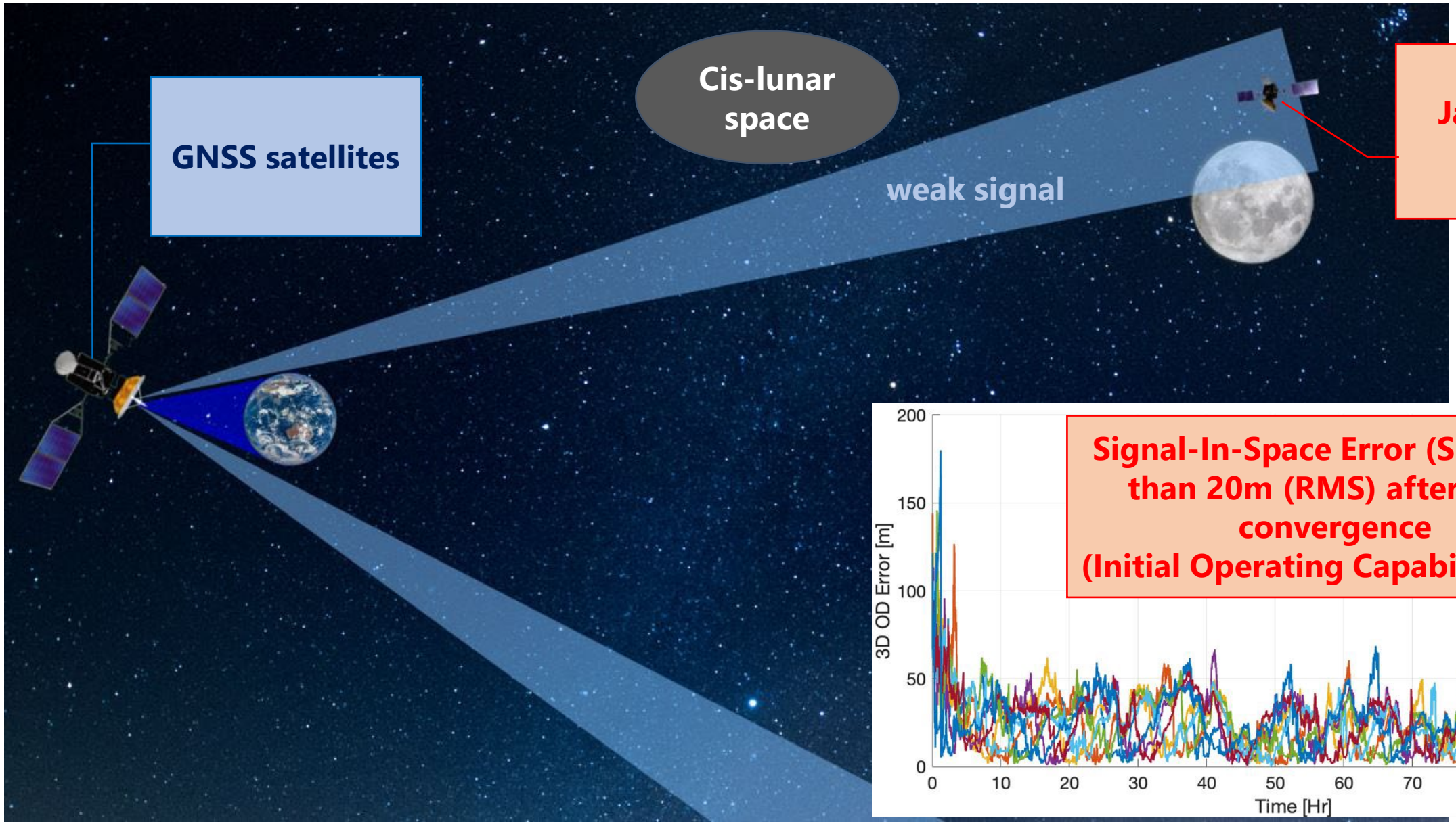



**Target: South Pole region**

**LNSS satellite broadcasting one-way navigation signal**

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

# LNSS satellite orbit and clock real-time, onboard estimation using GNSS weak signals



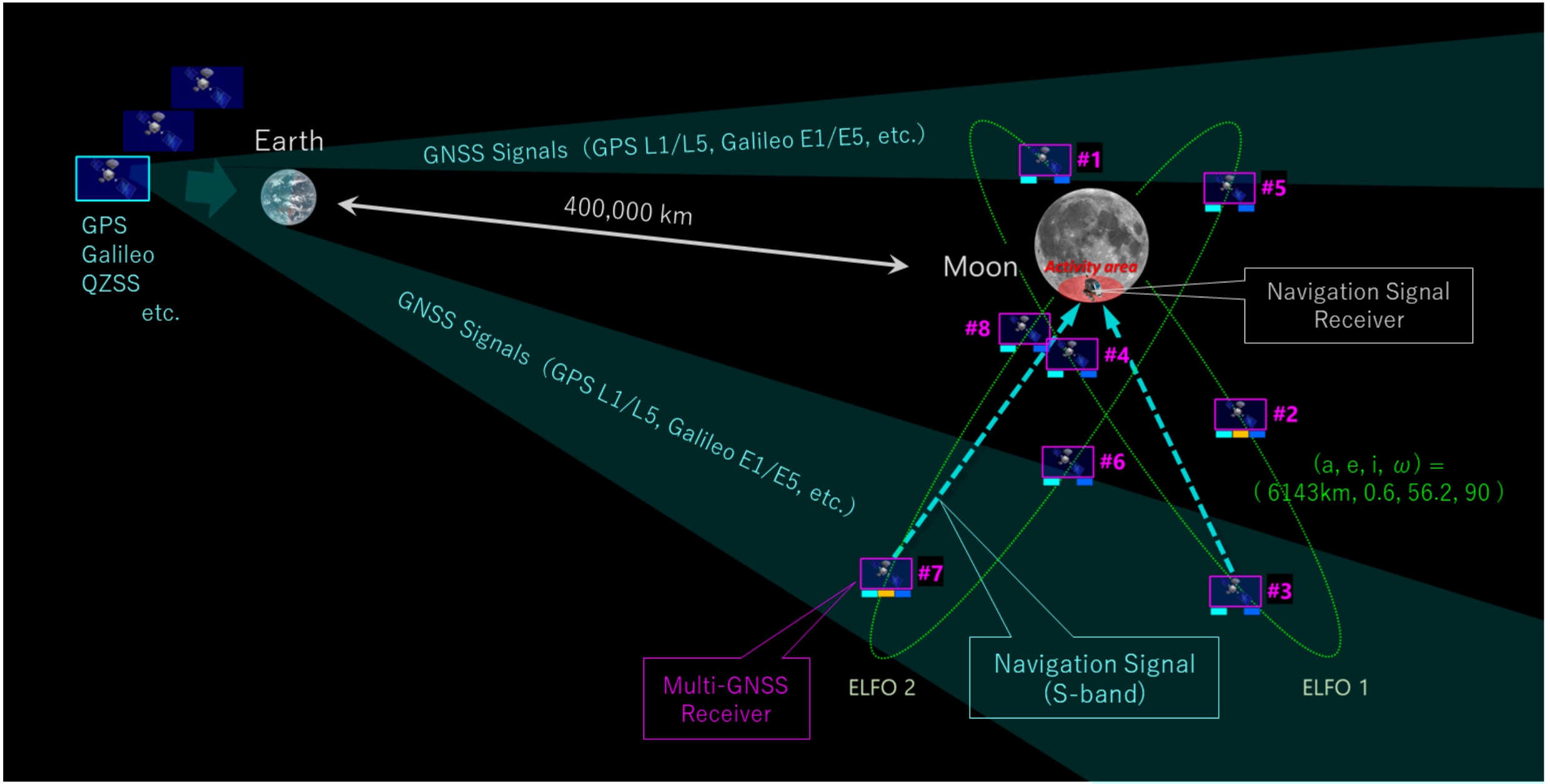




**Signal-In-Space Error (SISE) less than 20m (RMS) after filter convergence (Initial Operating Capability, IOC)**

JAXA's plan

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



# Typical LNSS PNT accuracy for fixed receiver and moving object at the South Pole

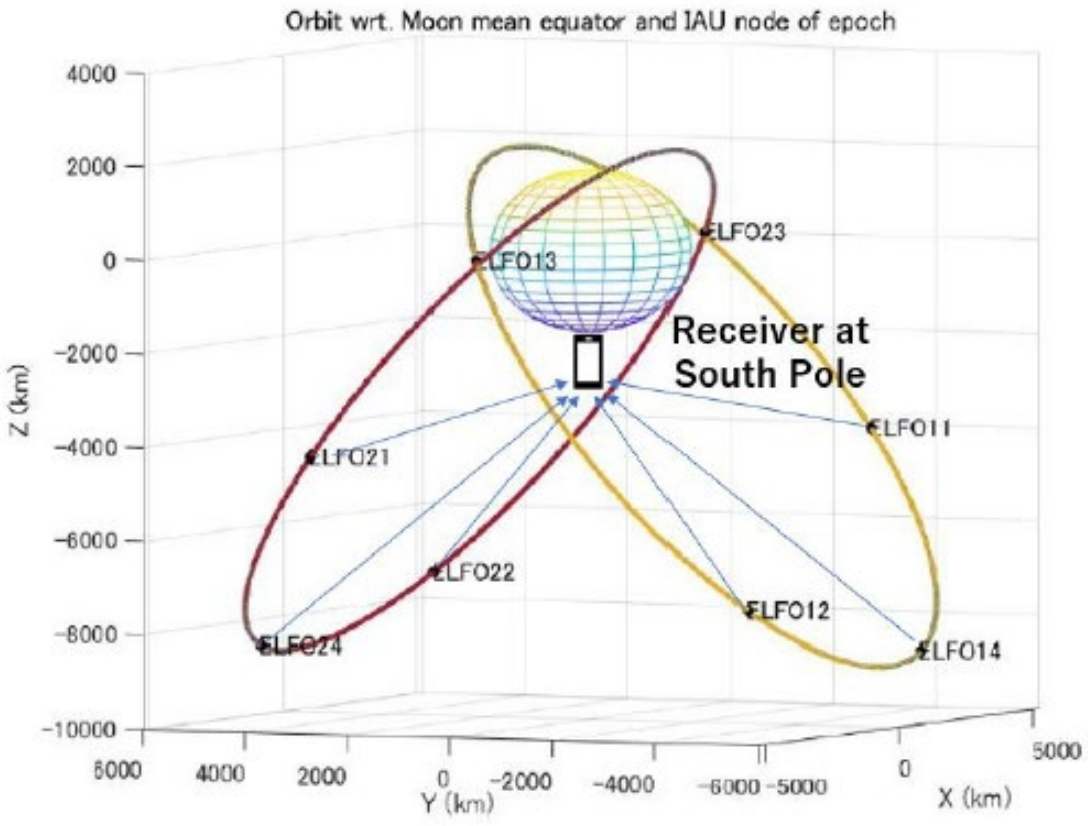


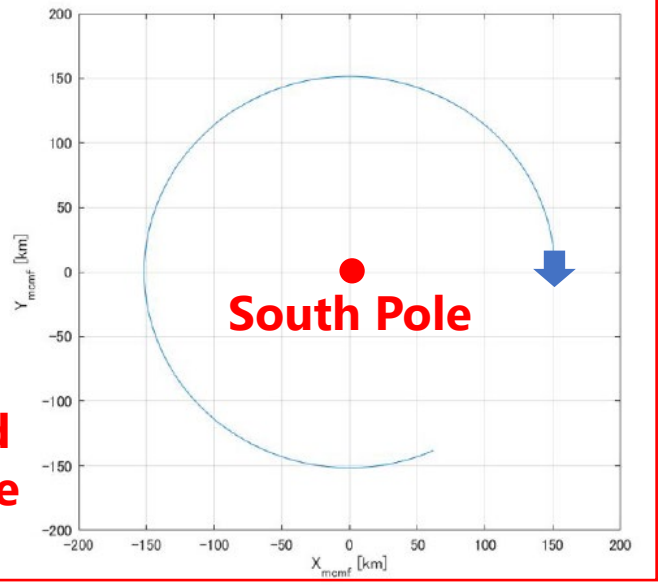

Figure 2: LNSS satellite constellation and receiver at South Pole.

- **Average SSP errors:**

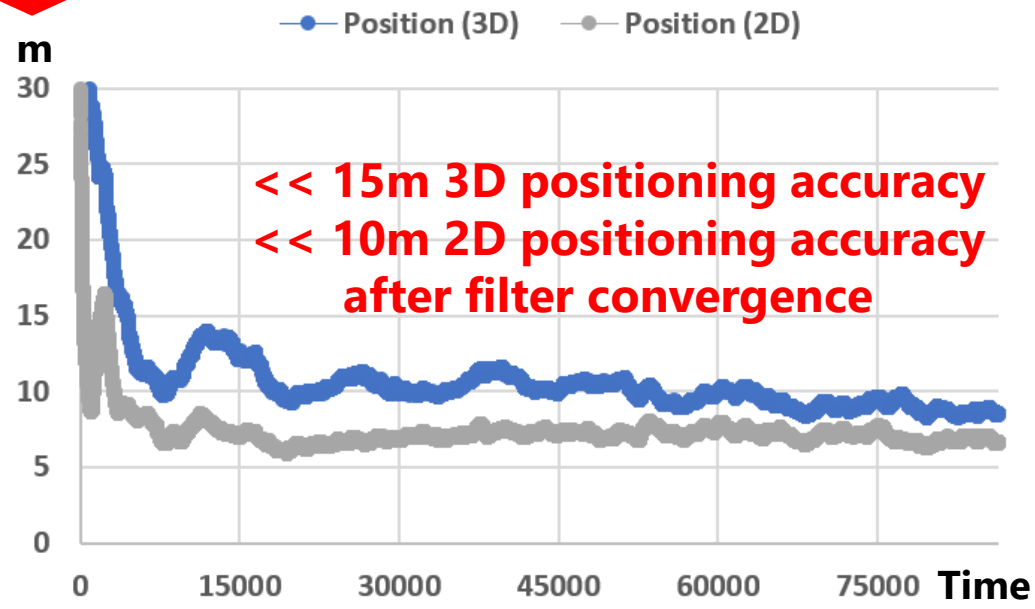
**3D position 37.7m,**
**2D position 13.8m,**
**Vertical 32.8m,**
**Clock bias 6.6E-08s**

**Our LNSS was designed to achieve the high 2D (horizontal) PNT accuracy**

**Assumed circular movement with velocity of 3 m/s at south altitude of 85 degrees**




**Applying onboard filtering technique (EKF)**



# Collaboration with ESA and NASA and LunaNet Interoperability Specification (LNIS)

# Lunar Comm & Nav (CPNT) systems by US, Europe, Japan

**ESA Moonlight LCNS (2028～)**

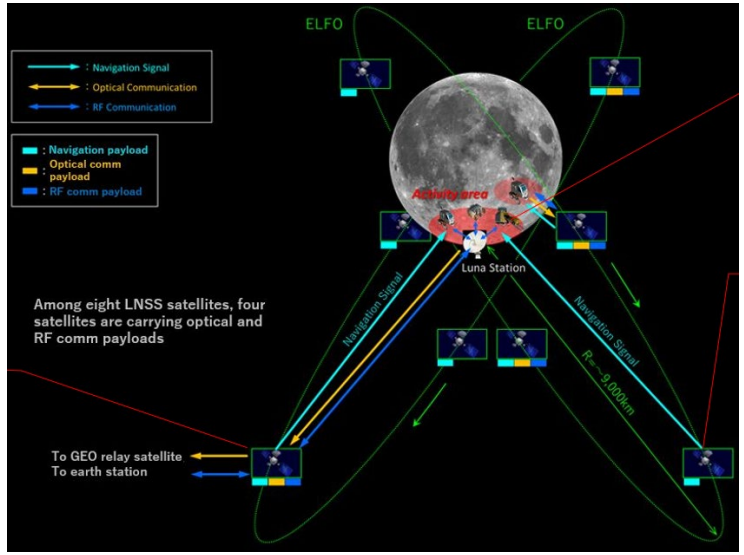
**Contractor: Telespazio**

**NASA LCRNS (2026～)**

**Contractor: Intuitive Machines**

**Japan LNSS (2028/2029～)**

**ArkEdge Space was recently selected**
**※PNT only**




**LCNS:**
**Lunar Communications and Navigation Services**

**LCRNS:**
**Lunar Communications Relay and Navigation Systems**

**LNSS:**
**Lunar Navigation Satellite System**

# LunaNet: Lunar CPNT International Framework


Ensuring interoperability among lunar CPNT systems from the get-go

Joint establishment of “moon GNSS" called LANS

LunaNet: Bringing terrestrial internet capabilities to astronauts, rovers, and orbiters.
NASA / Reese Patillo

# Towards the establishment of 'Moon GNSS' called LANS

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

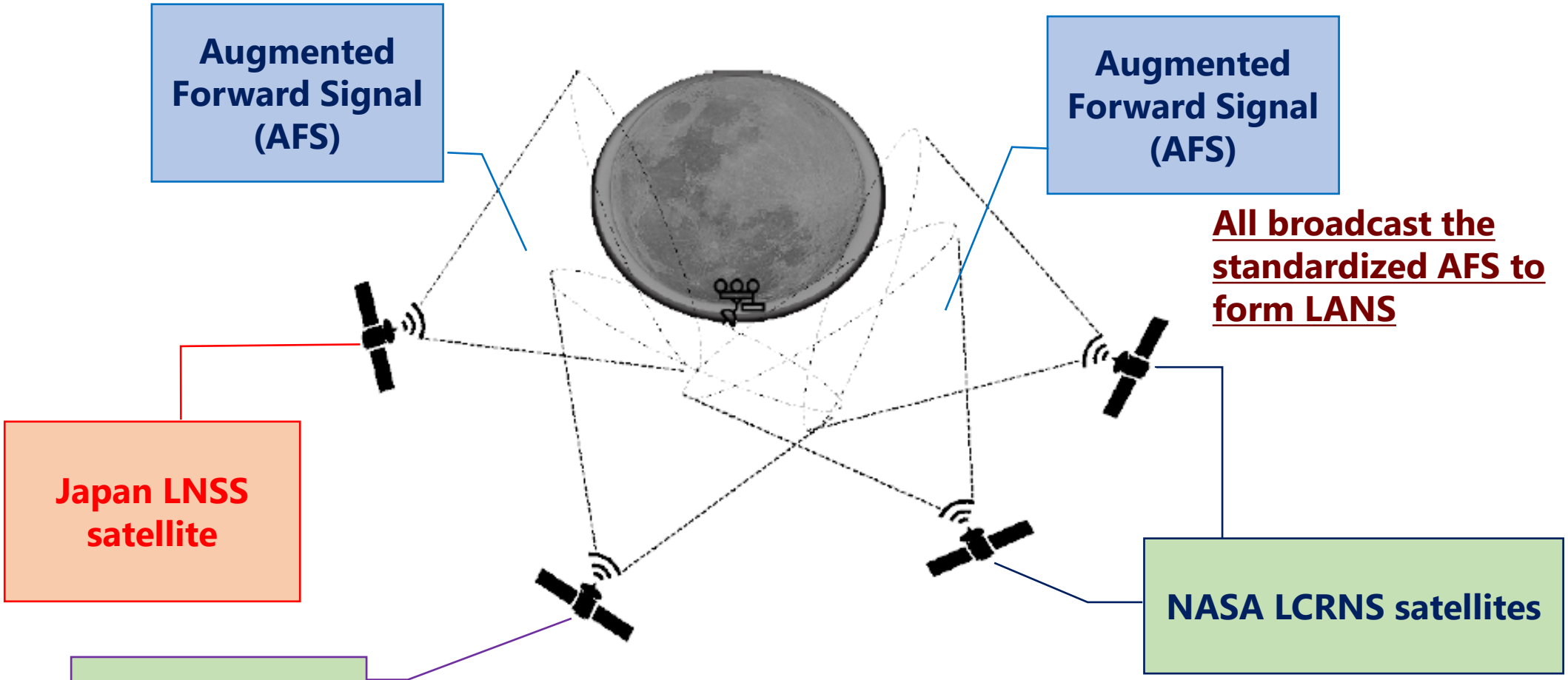
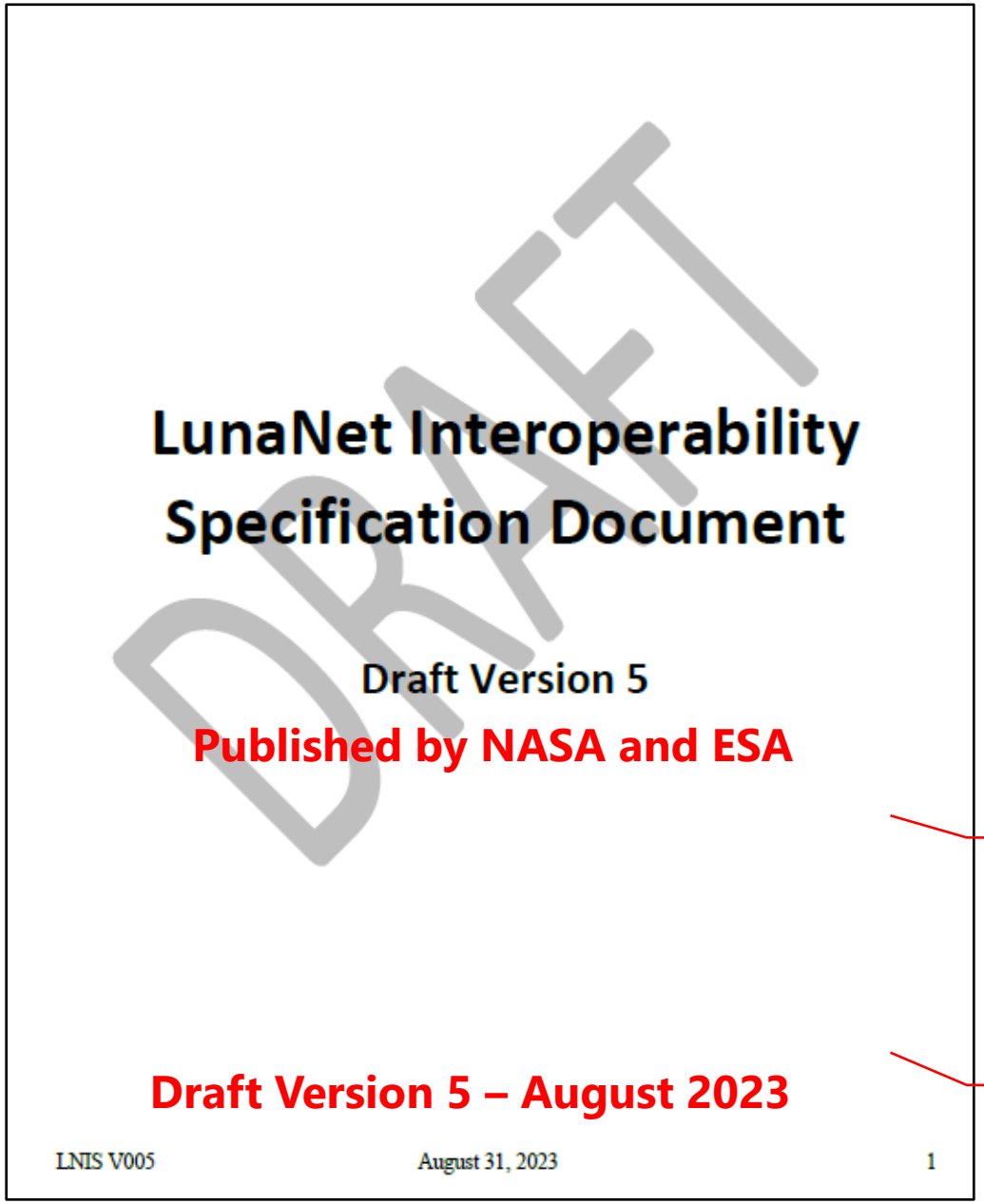



Figure 10 - LANS PNT Concept Provided by LunaNet Nodes

This figure was copied from the LunaNet Interoperability Specification (LNIS)

※LNIS is the standardization document for the LunaNet

# LunaNet Interoperability Specification (LNIS) Draft Version 5 now available on the internet




## The LNIS and its applicable document includes:

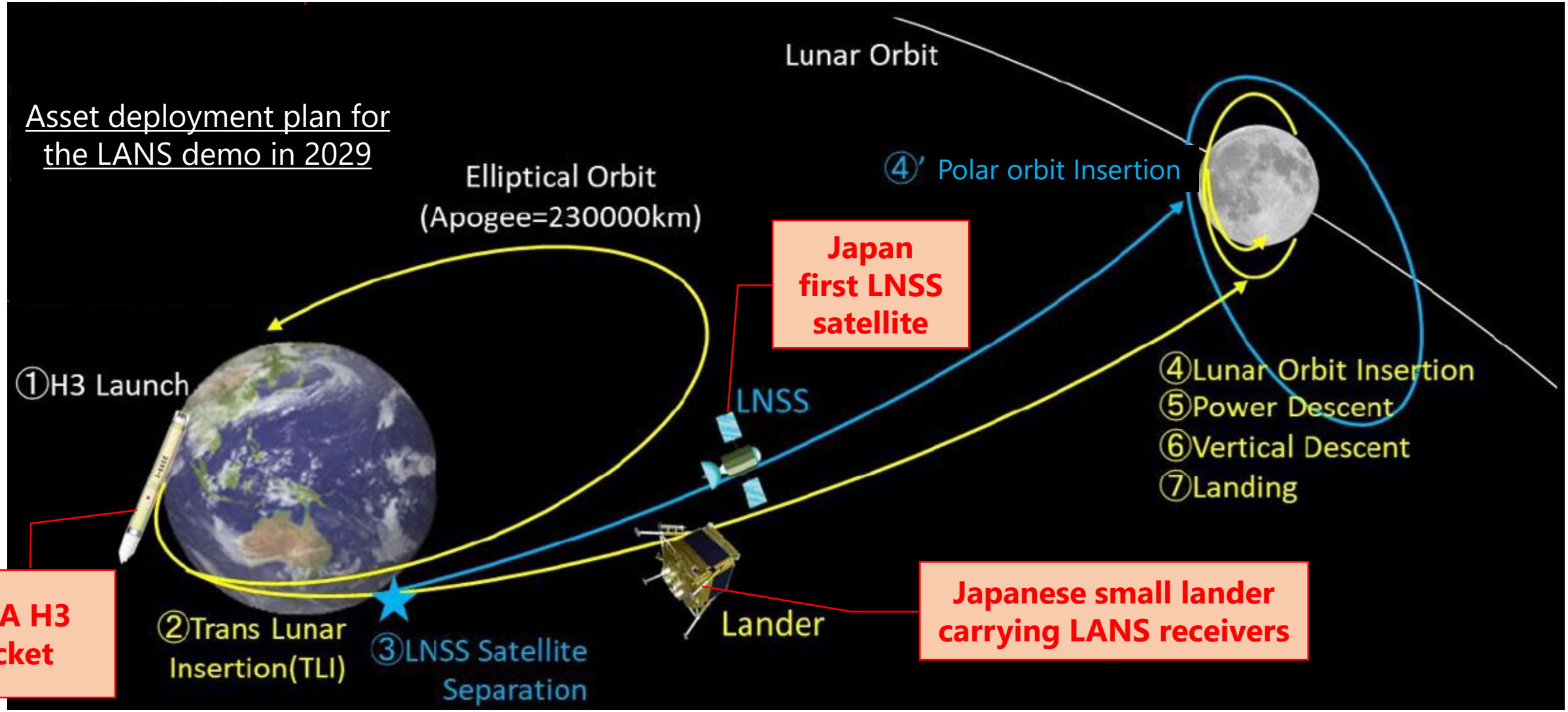
- **Concept of the LANS, message format of the Augmented Forward Signal (AFS), signal frequency, power, etc.**
- **Signal-In-Space-Error (SISE) requirement for LunaNet Service Providers (LNSPs)**
- **Lunar Reference System and Lunar Time System Standard**

**The Japan LNSS complies with the LNIS to become interoperable and comparable with the other LNSPs**

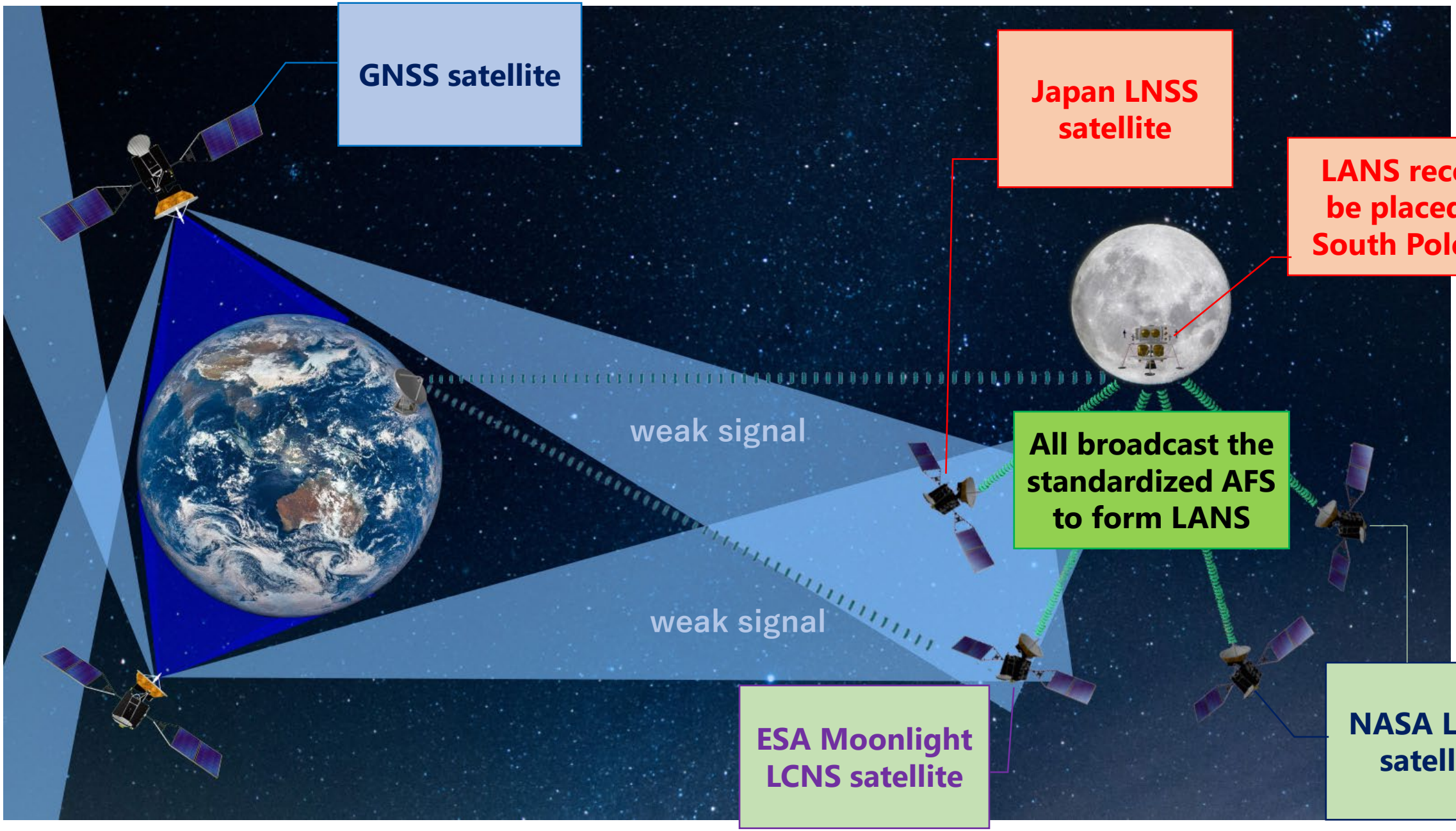
**Thanks to NASA and ESA, JAXA has joined the LNIS working groups and is now working with NASA and ESA for the publication of the LNIS Version 5 (publication effort ongoing)**

# Plan of LANS interoperability and PNT demonstration mission targeting in 2029

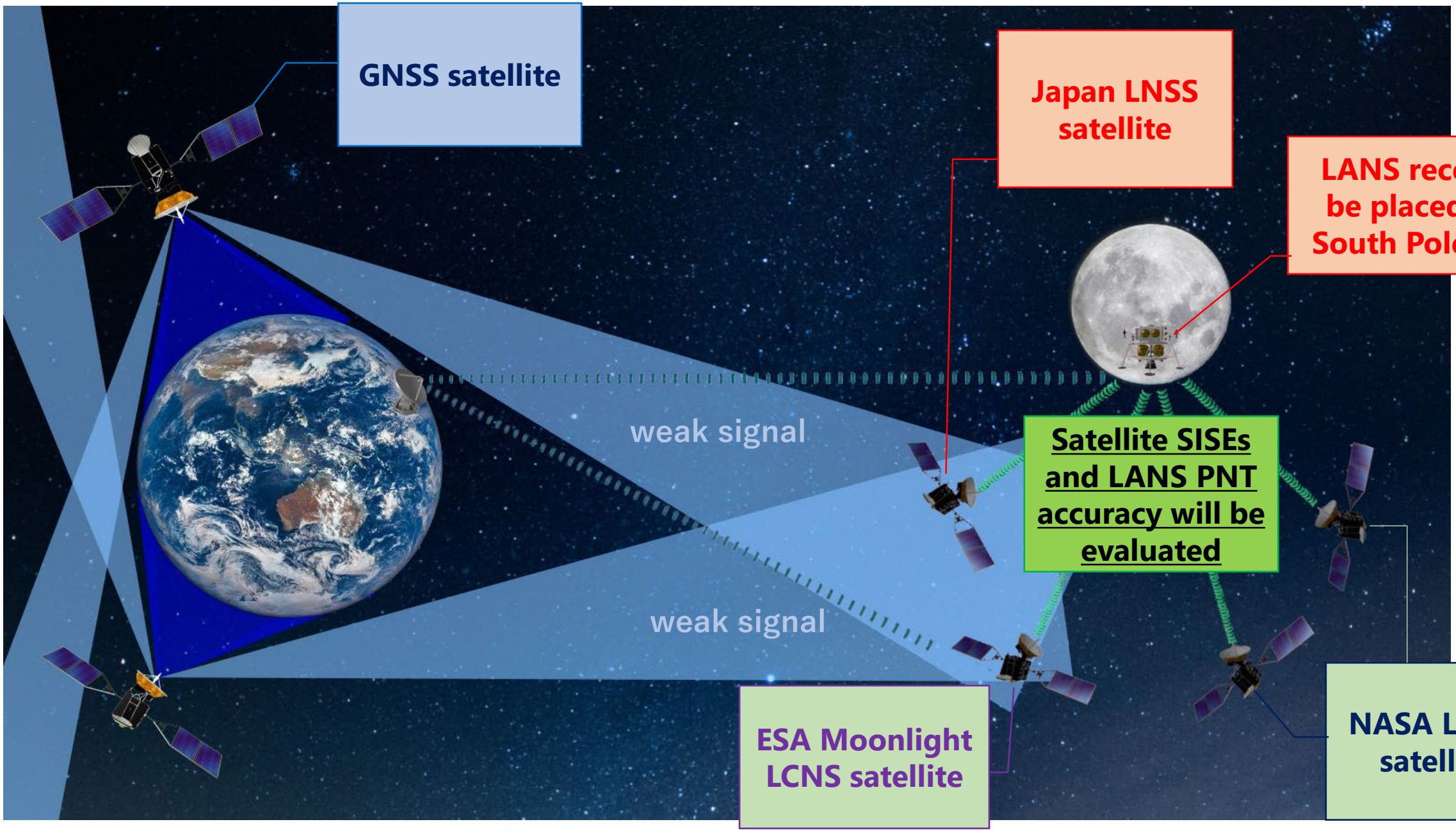
# JAXA is proposing the first-ever ESA-NASA-JAXA LANS interoperability demonstration



# LANS receiver to be placed at the South Pole region will receive all broadcasted AFSs

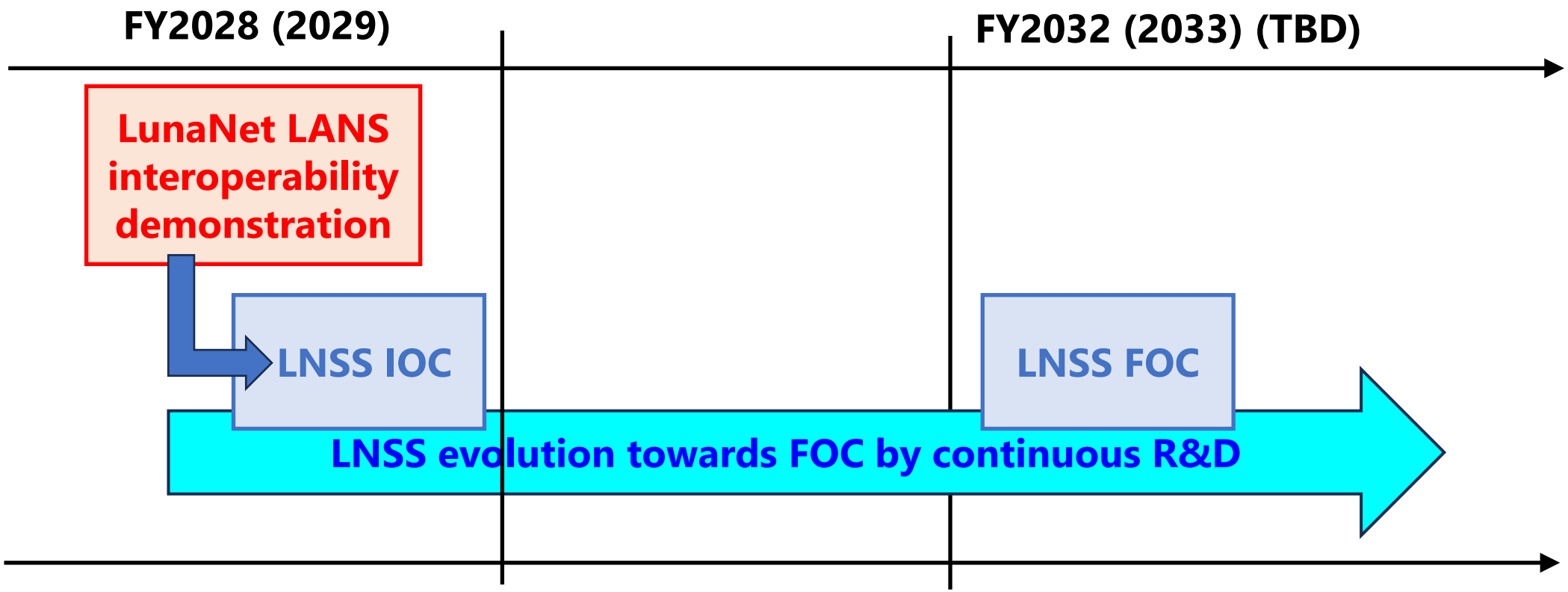


# The SISEs for satellites forming the LANS and LANS PNT accuracy will be evaluated



JAXA's plan

# Towards the LNSS Full Operating Capability (FOC) in 2032-2033 timeframe




- **Our feasibility study (FS) towards FOC starts from this year**
  - **LNSS SISE enhancement by using GNSS precise measurements and etc.**
  - **LNSS augmentation by using moon surface assets such as surface beacons**
  - **Development of LANS receiver PNT algorithm (combined navigation algorithm)**
  - **Service region expansion (satellite constellation design for entire moon surface)**

# Takeaways

- LNSS first satellite launch expected in 2028/2029 to do the proposing LANS interoperability and PNT accuracy demonstration with ESA and NASA

- Our FS towards the LNSS FOC is ongoing, aiming for continuous accuracy enhancement and service region expansion

- <u>We continue working with our international partners to realize lunar PNT system of systems</u>



New working group on lunar PNT (WG-L) established at ICG this year!

# Joint ICG-IOAG Multilateral Cislunar PNT Workshop

11-13 February 2025, Vienna, Austria and broadcast

**Registration now open**

**(until 8th December)**

https://www.unoosa.org/oosa/en/ourwork/icg/working-groups/b/CislunarPNT2025.html