LANS Interoperability Demonstration Mission Under Planning

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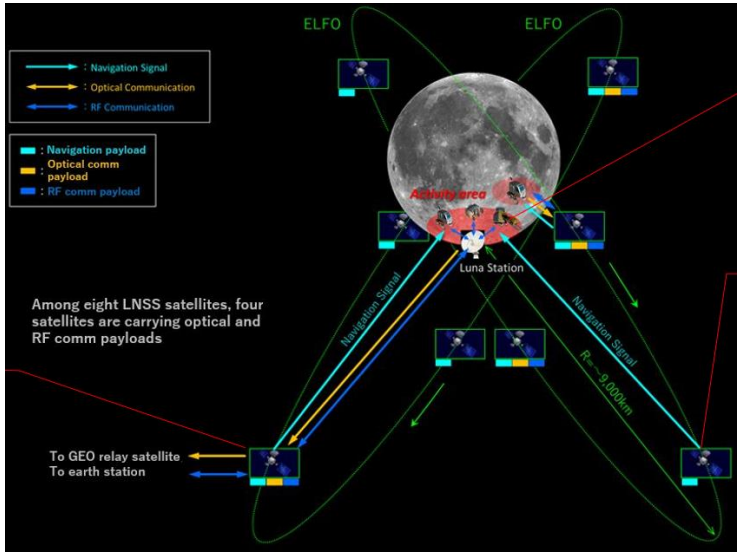
Lunar Comm&Nav (CPNT) systems by US, Europe, Japan

ESA Moonlight LCNS (2027～)

NASA LCRNS (2025～)

JAXA LNSS (2028～)



LCNS:
Lunar Communications Navigation Services

LCRNS:
Lunar Communications Relay and Navigation Systems

LNSS:
Lunar Navigation Satellite System

Towards the establishment of the Moon GNSS (LANS)

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

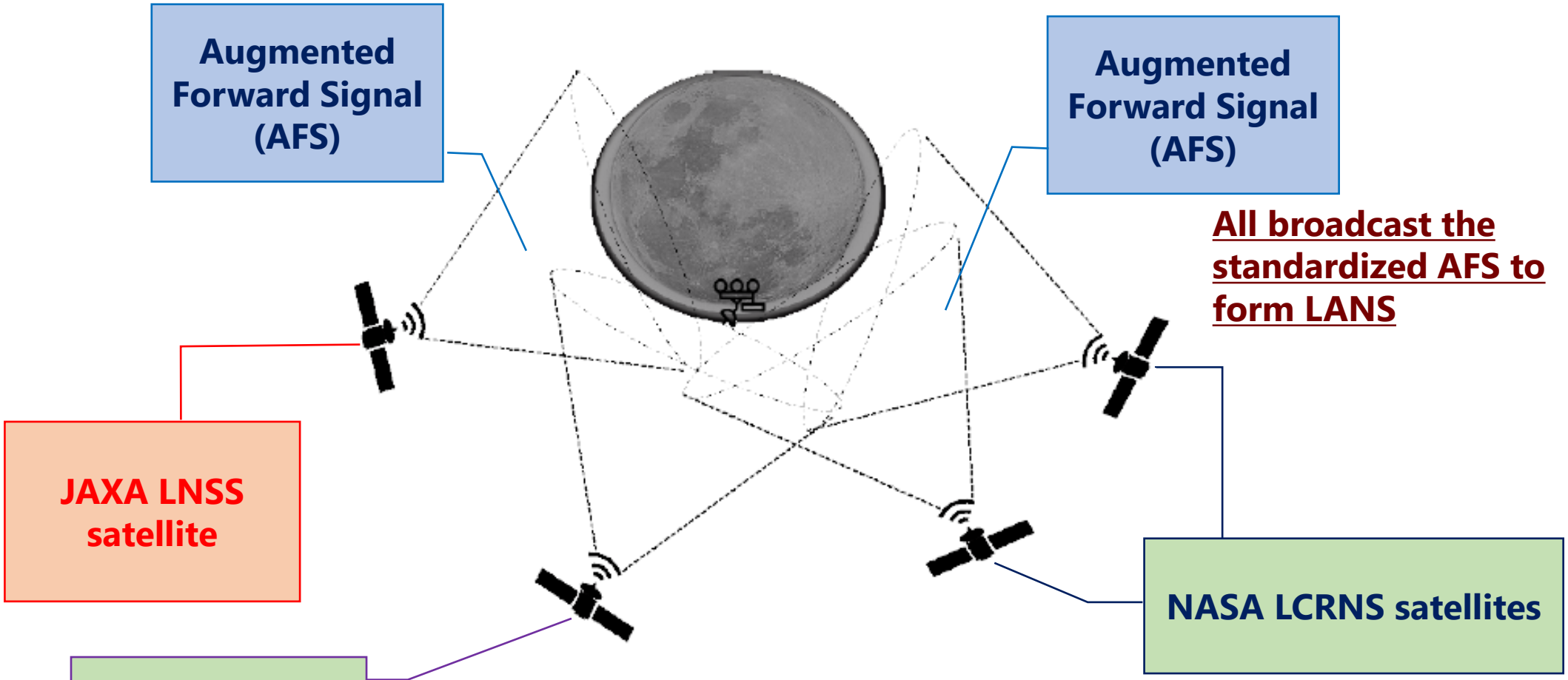


Figure 10 - LANS PNT Concept Provided by LunaNet Nodes

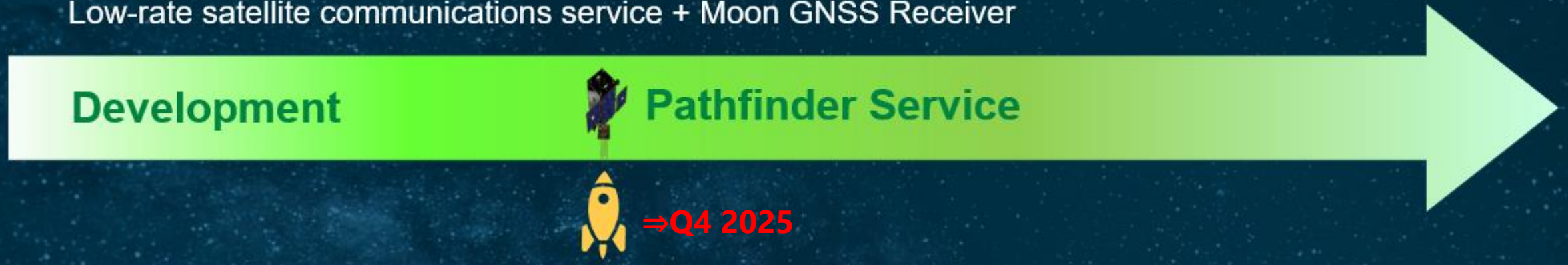
This figure was copied from the LunaNet Interoperability Specification (LNIS)
※LNIS is the standardization document for the LunaNet

Roadmap

ESA's plan

STEP 1: LUNAR PATHFINDER

Low-rate satellite communications service + Moon GNSS Receiver



STEP 2: MOONLIGHT CONSTELLATION

High-data rate satellite communications and navigation service

Mid term - Moonlight IOC

ESA's plan

- IOC phase will start by end of 2027 with at least one satellite transmitting the one-way (AFS) navigation signal
- Signal will be compliant with LunaNet requirements ensuring interoperability (same user terminal can work with multiple LNSP with minor SW modifications) **LNSP: LunaNet Service Provider**
- Orbits will be defined by the service provider, however ELFO orbits are expected (e.g.: 24h orbit period)

From LNIS:

*The **SISE** is defined as the instantaneous difference between the position, velocity and time of a LunaNet satellite as broadcast by the LunaNet node navigation message and the true satellite position, velocity and time, respectively expressed in the lunar reference frame [AD5] and the lunar system time reference [AD6].*

LCNS NAV service main targets (IOC)	
Requirement	Value
SISE	< 20m 95%
OWR availability	> 80%

Initial Capability for **LCRNS**

NASA's plan

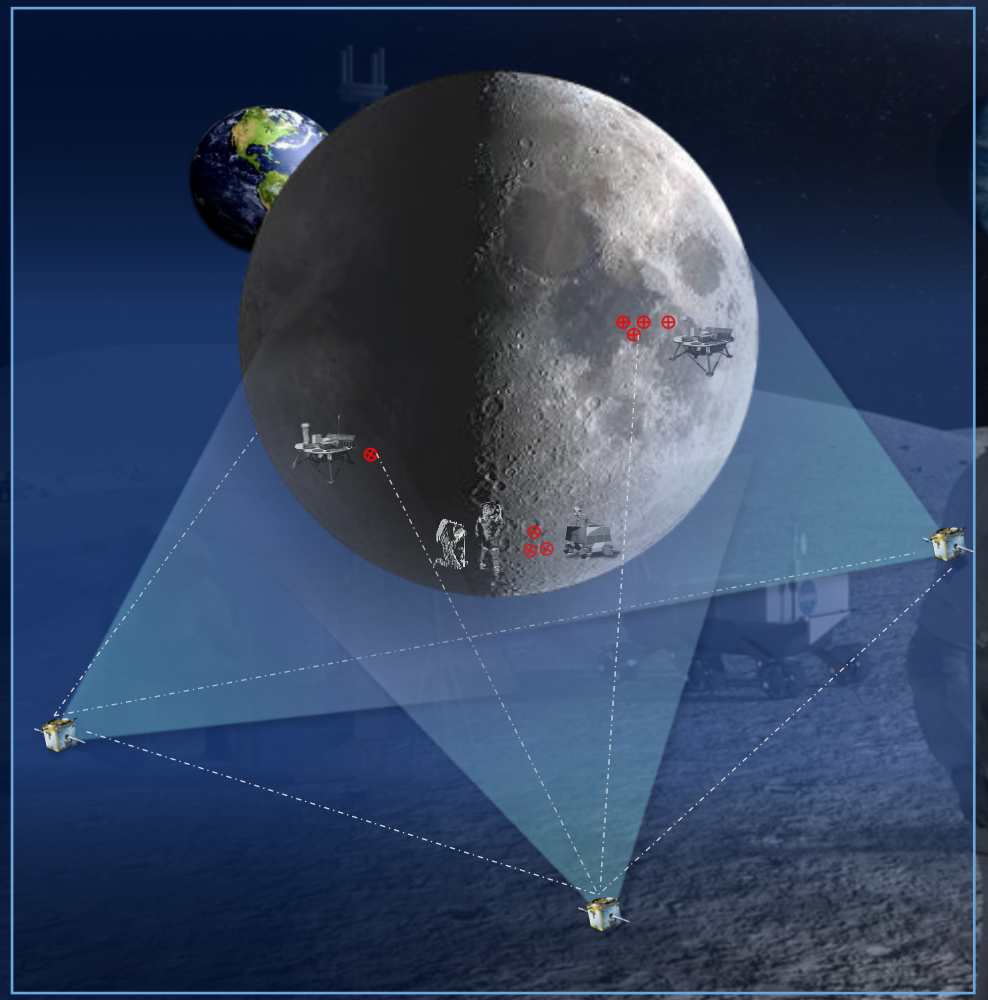
- IOC phase will begin late 2025 with IOC-Alpha with a minimum of one Augmented Forward Signal (AFS) broadcast over the South Pole region.
- IOC-Bravo is expected by 2027 with a minimum of two AFS over the same South Pole region.
- Service continues over an expanded South Pole volume with IOC-Charlie broadcasting a minimum of four AFS, also meeting a requirement for GDOP for a limited portion of an Earth day.

- The LCRNS AFS will comply with the LunaNet Interoperability Specification.

- LCRNS orbit(s) will be defined by the service provider and are expected to meet the Signal-in-Space-Error.

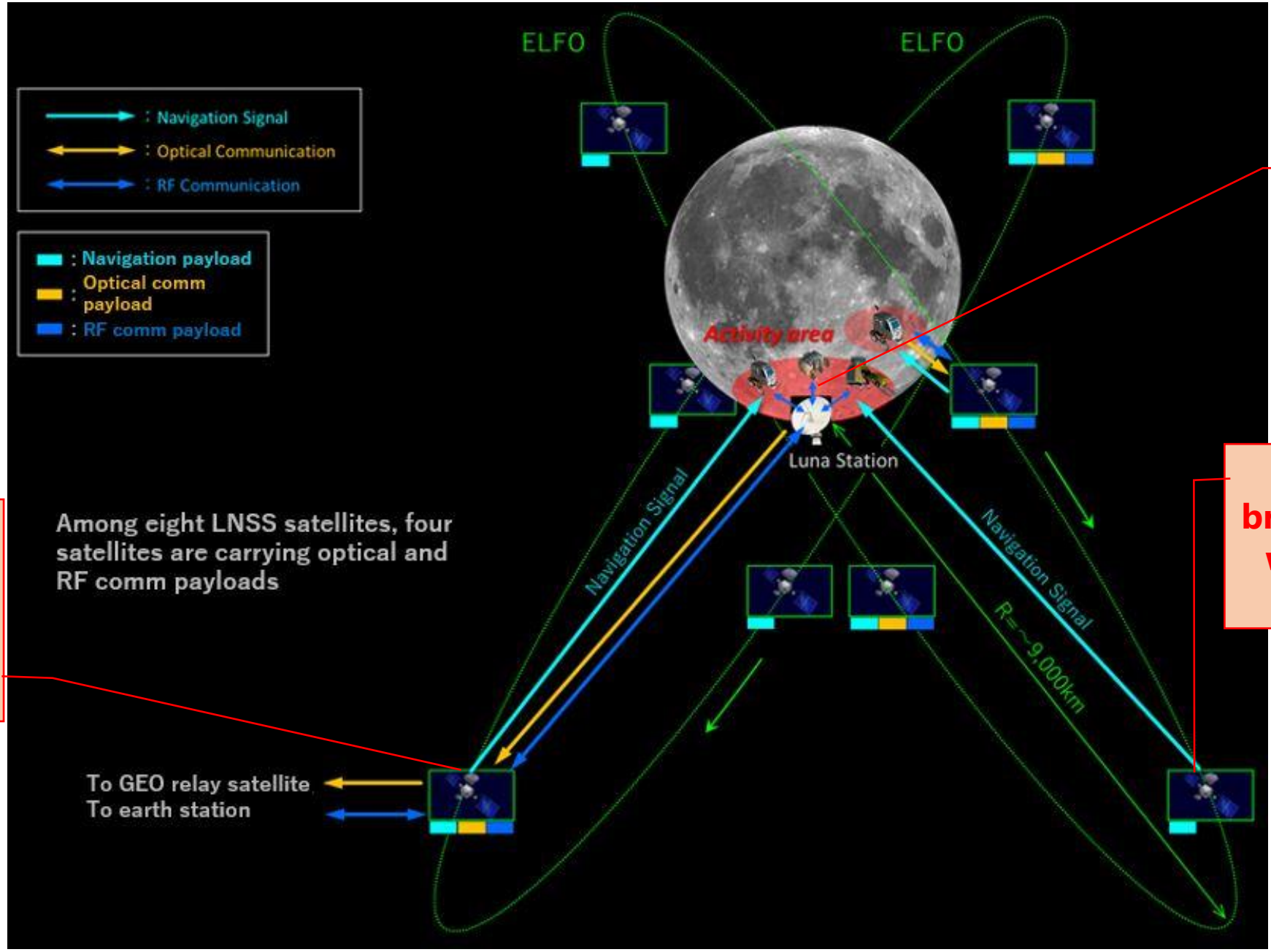
- It is expected that LCRNS will be capable of providing two-way measurements from Peer-to-Peer signals.

- Service delivery is reliant on defined lunar geodetic system and lunar time.



JAXA's plan

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



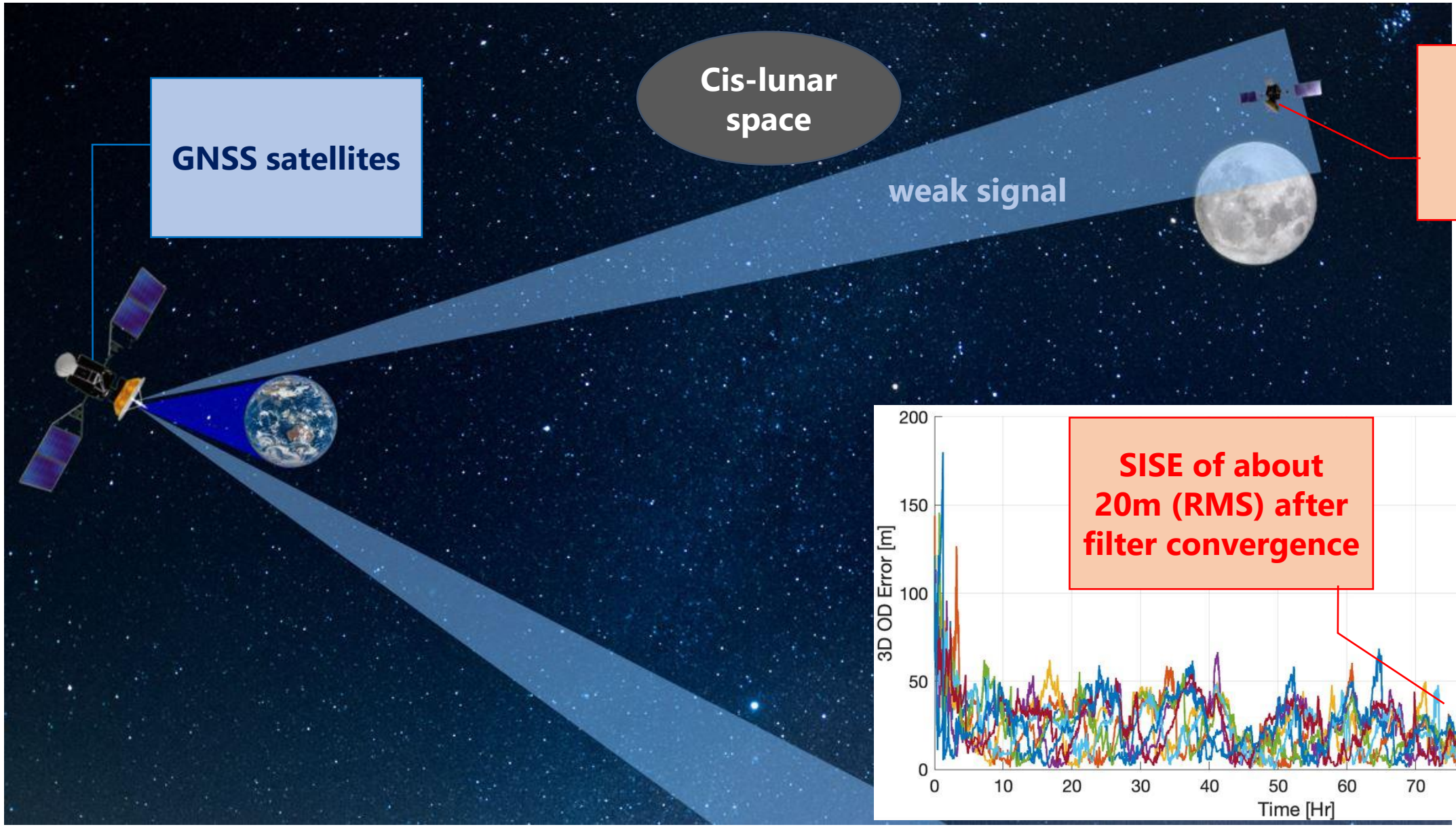
Target: South Pole region

LNSS satellite broadcasting one-way navigation signal

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

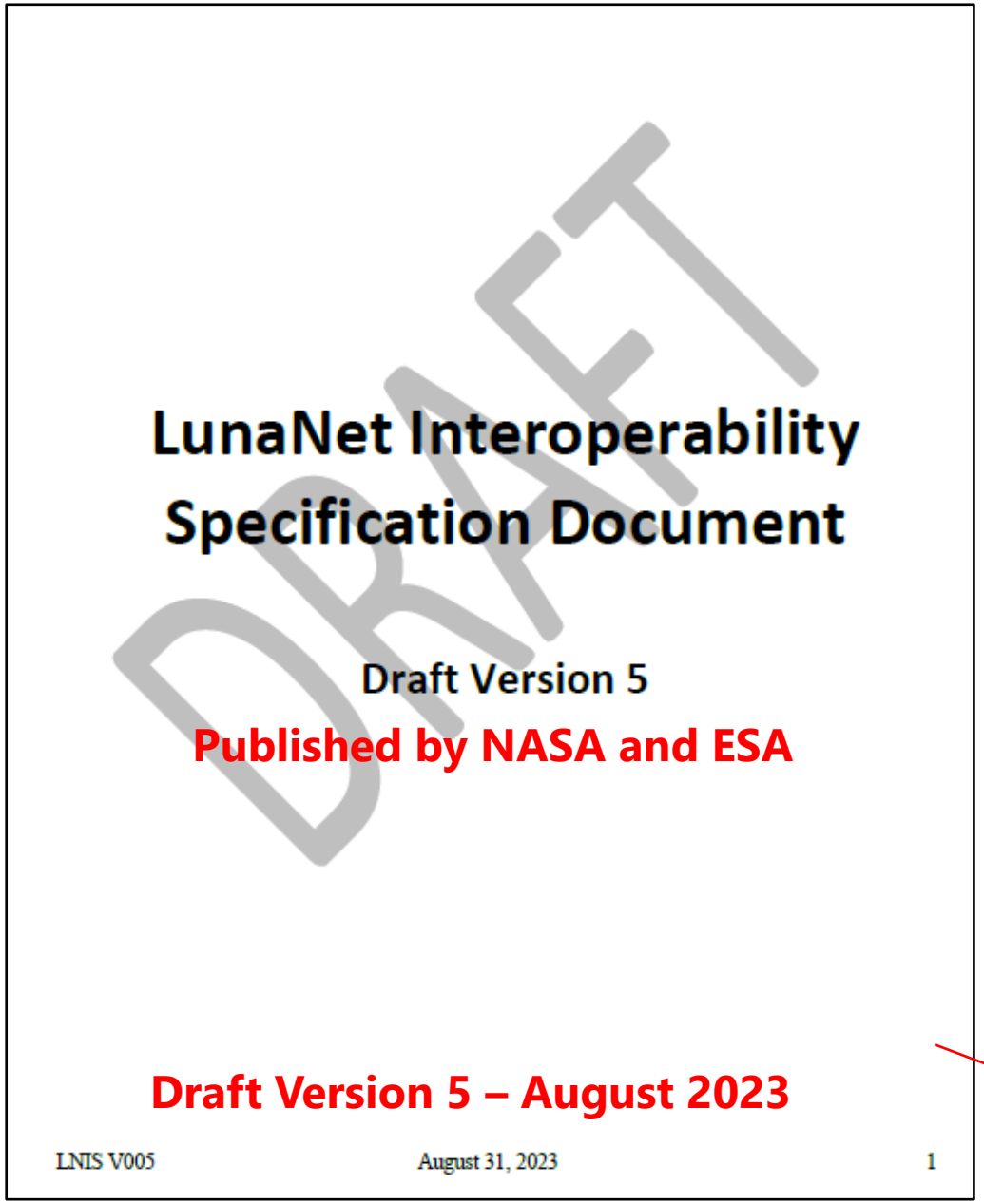
JAXA's plan

GNSS navigation (real-time OD) for LNSS satellites, making the lunar PNT autonomous



We constitute the Moon GNSS called Lunar Augmented Navigation Service (LANS)

LunaNet Interoperability Specification (LNIS) in which the LANS is defined



The LNIS includes:

- **Concept of the LANS, message format of the AFS, signal frequency, power, etc.**
- **LANS Initial Operations Capability (IOC) and Enhanced Operations Capability (EOC)**
- **Signal-In-Space-Error (SISE) definition for the LunaNet Service Providers (LNSPs)**
- **Lunar Reference System and Lunar Time System Standard**

The JAXA LNSS complies with the LNIS and will be designed to become interoperable and comparable with the other LNSPs such as ESA and NASA

LANS South Pole service coverage and performance volume

Signal-In-Space-Error (SISE) requirement

Table C-1: LNSP SISE

Error	Value
SISE pos	≤TBD m (95%) - Calculated as the 95th percentile of the time series of instantaneous SISE values over a TBD hours period.
SISE vel	≤TBD m/s (95%) - Calculated as the 95th percentile of the time series of instantaneous SISE values over a TBD hours period.

LANS South Pole service coverage

Figure 10: Notional LANS South Pole Service Coverage and Performance Volume

1. Signal-In-Space Error for positioning (SISE pos)

$$SISE_{pos} = \sqrt{(x-\tilde{x})^2 + (y-\tilde{y})^2 + (z-\tilde{z})^2 + (ct-c\tilde{t})^2}\,, \quad 1$$

Where x, y, z, t are the true position and time, while the corresponding tilde parameters represent the values broadcasted in the navigation message.

2. Signal-In-Space Error for velocity (SISE vel):

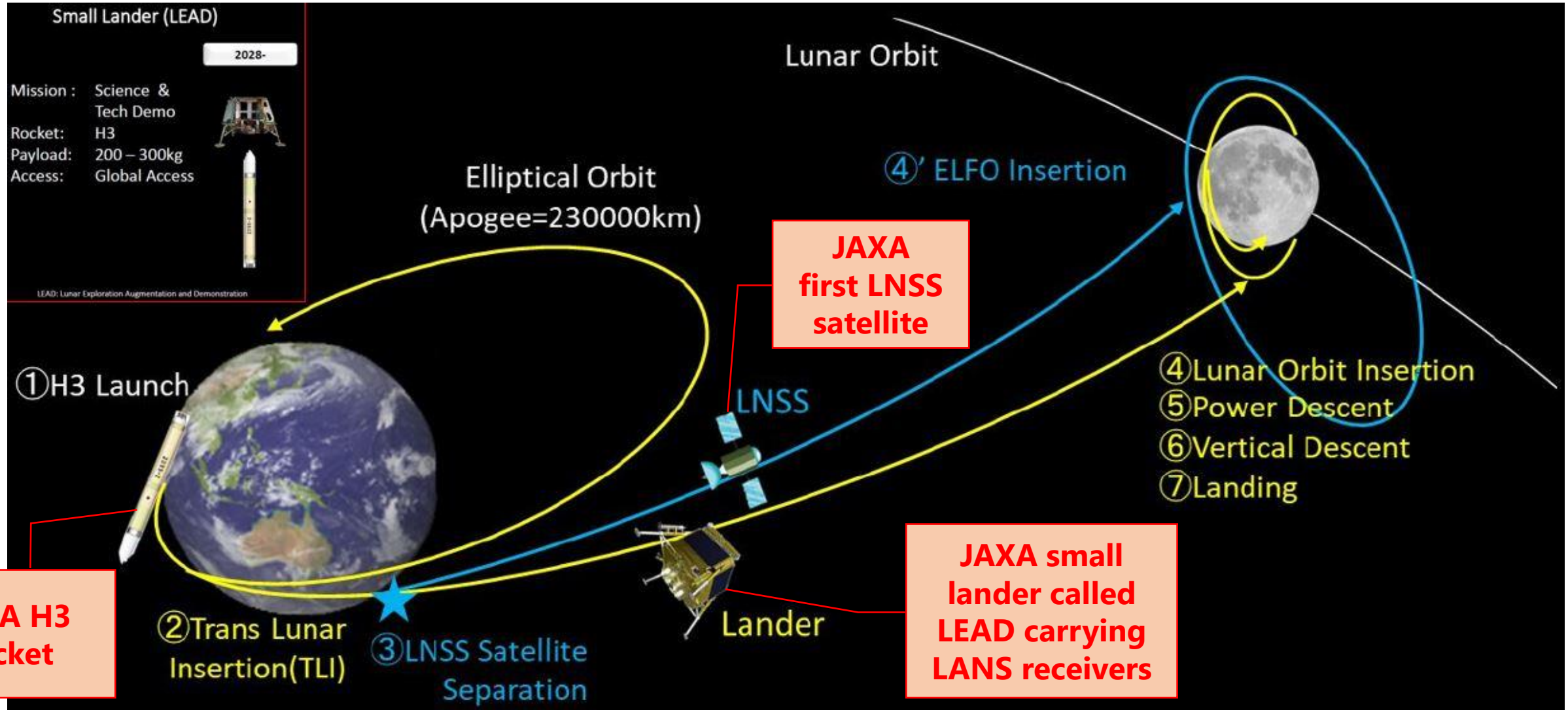
$$SISE_{vel} = \sqrt{(\dot{x}-\tilde{\dot{x}})^2 + (\dot{y}-\tilde{\dot{y}})^2 + (\dot{z}-\tilde{\dot{z}})^2 + (c\dot{t}-c\tilde{\dot{t}})^2}\,, \quad 2$$

Where $\dot{x}, \dot{y}, \dot{z}$ represents the velocity and $c\dot{t}$ the clock drift.

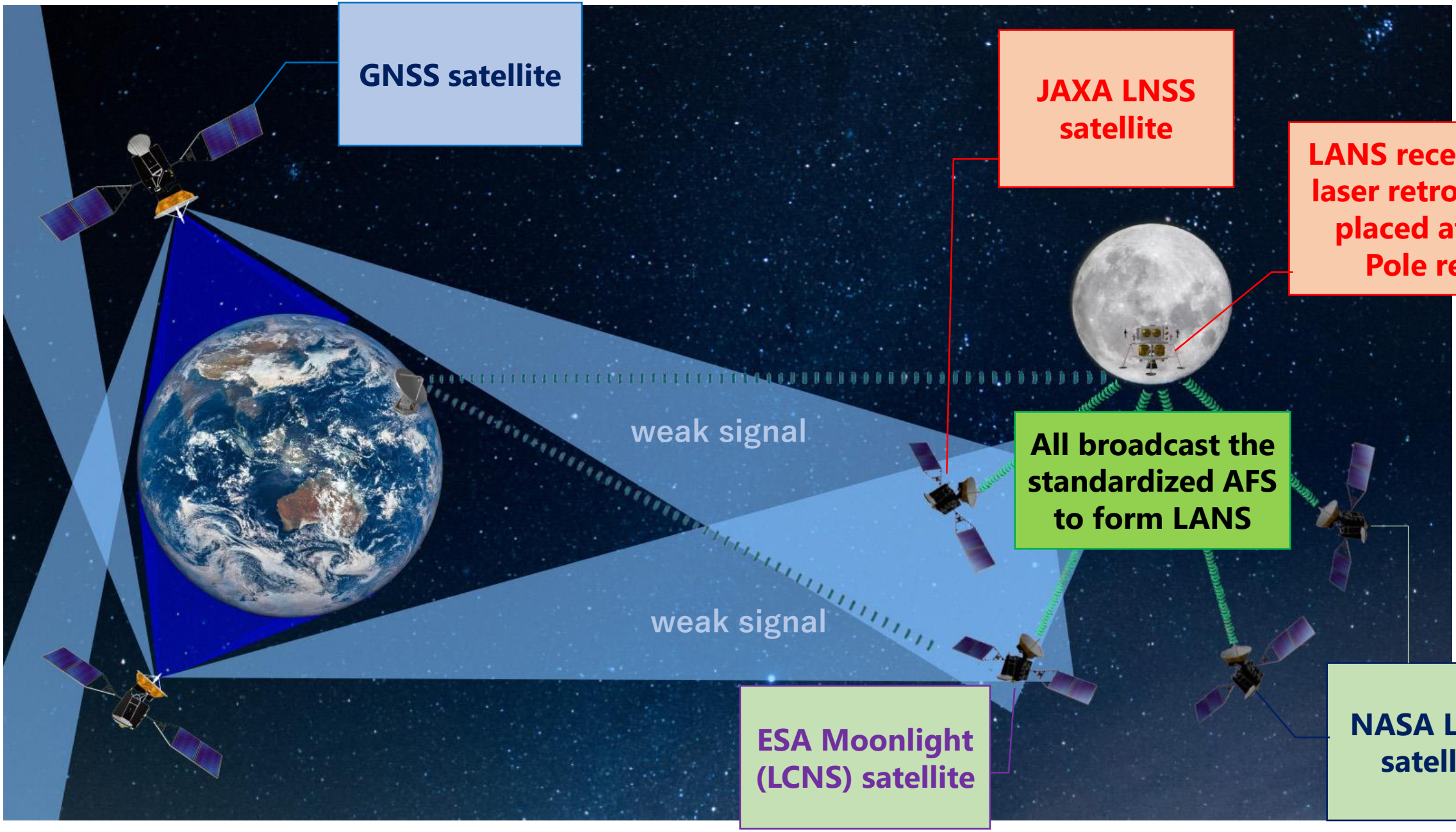
Both SISEs are based on lunar reference frame and time, which will be defined in the LNIS applicable documents called Lunar Reference System and Lunar Time System Standard

Plan of LANS interoperability demonstration mission targeting in 2028

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



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



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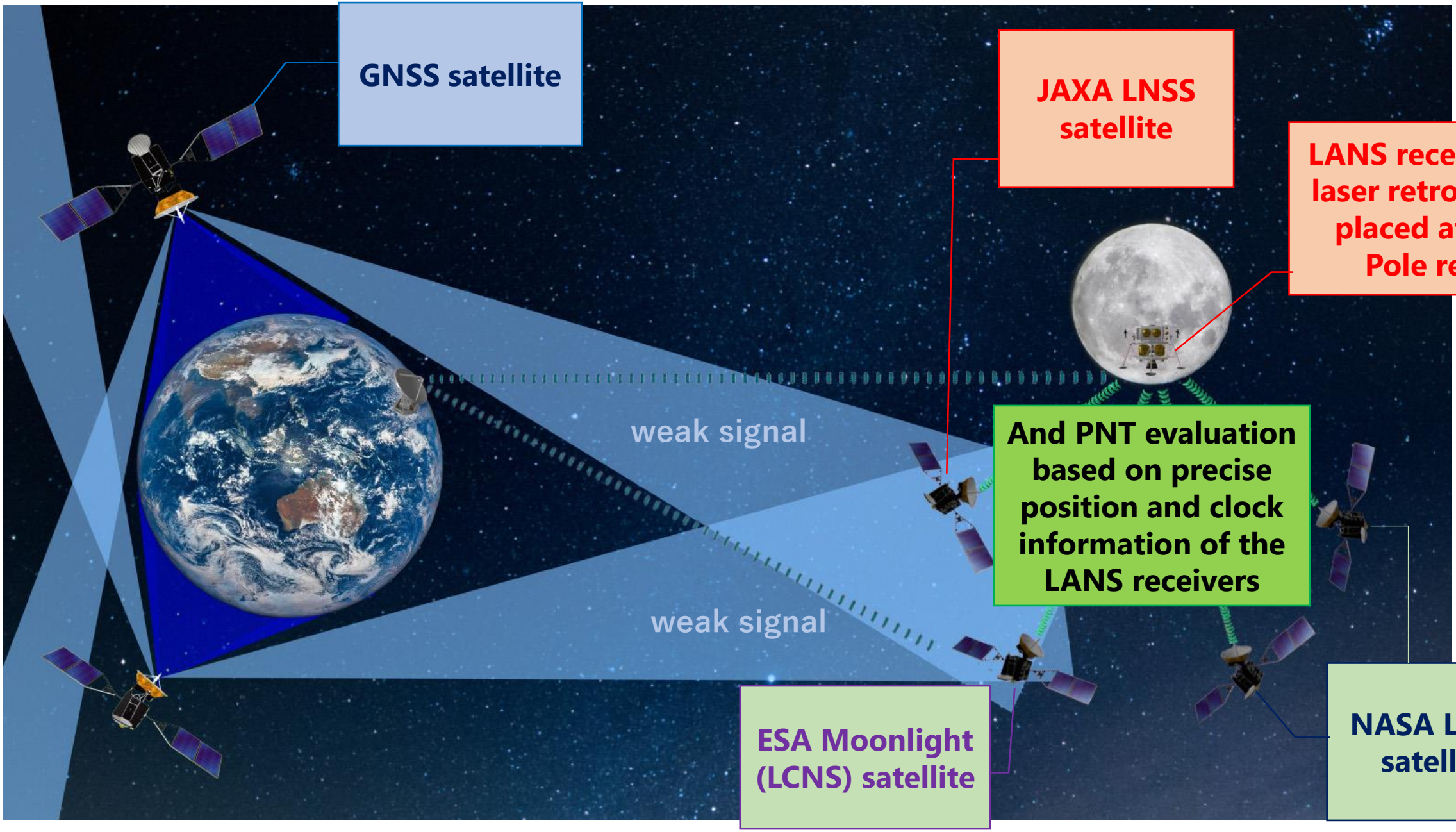

Takeaways

・The JAXA LNSS, ESA Moonlight LCNS, NASA LCRNS will comply with the LNIS and join the LANS that becomes the Moon GNSS

・ESA, JAXA, and NASA encourage the LANS interoperability demonstration mission in 2028 and are currently assessing their respective participation. The receivers to be located at the South Pole region will receive all LNSPs AFSs and send them back to the Earth for the in-depth analysis

・In this demonstration mission, a laser retroreflector will be placed on the Moon surface for the precise position estimation of the LANS receiver. The laser ranging data will be also utilized for the refinement of the Lunar Reference System (LRS)