Lunar Navigation Satellite System (LNSS): Overview, Plan, and Demonstration Mission

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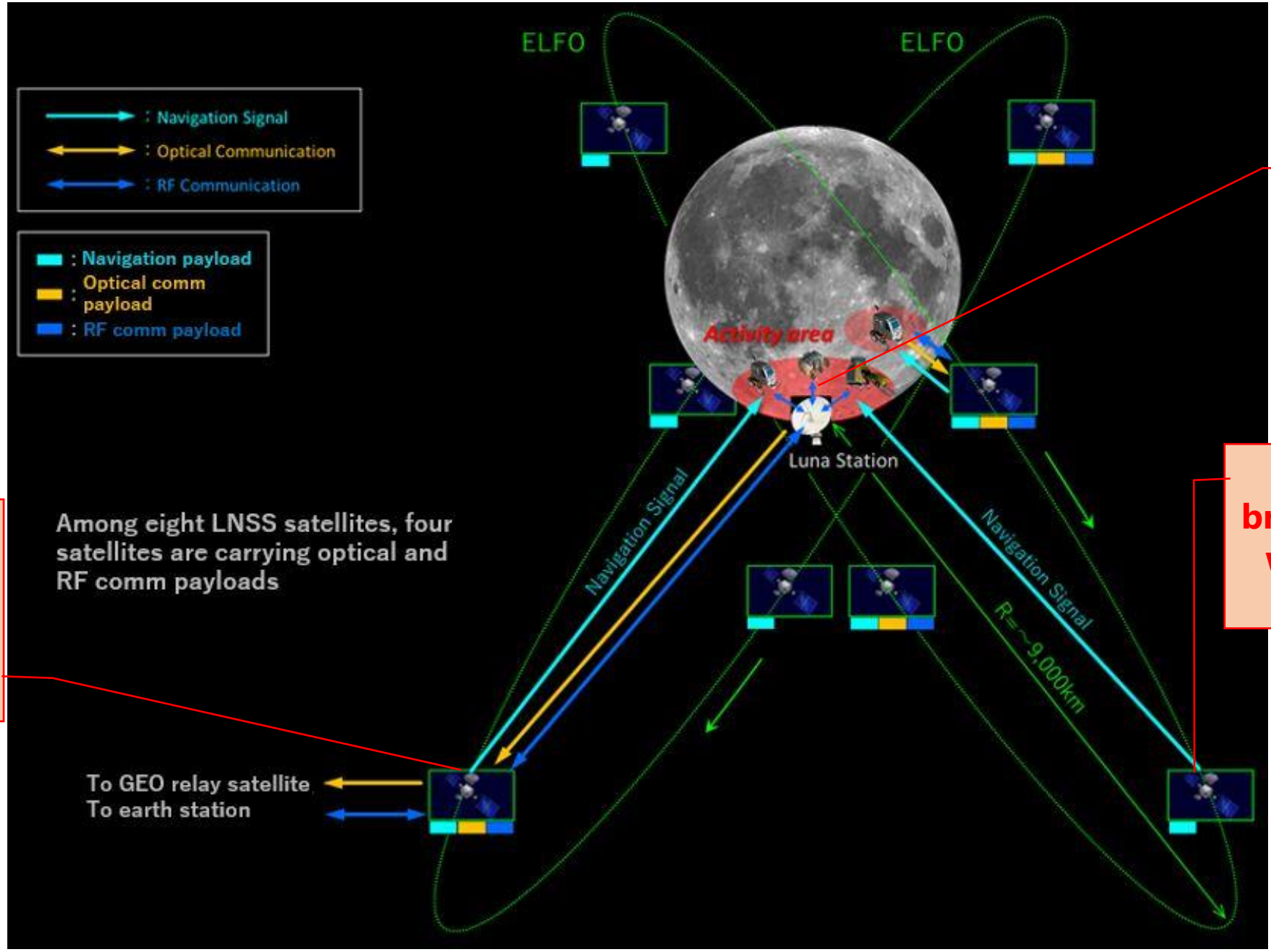
JAXA's plan

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



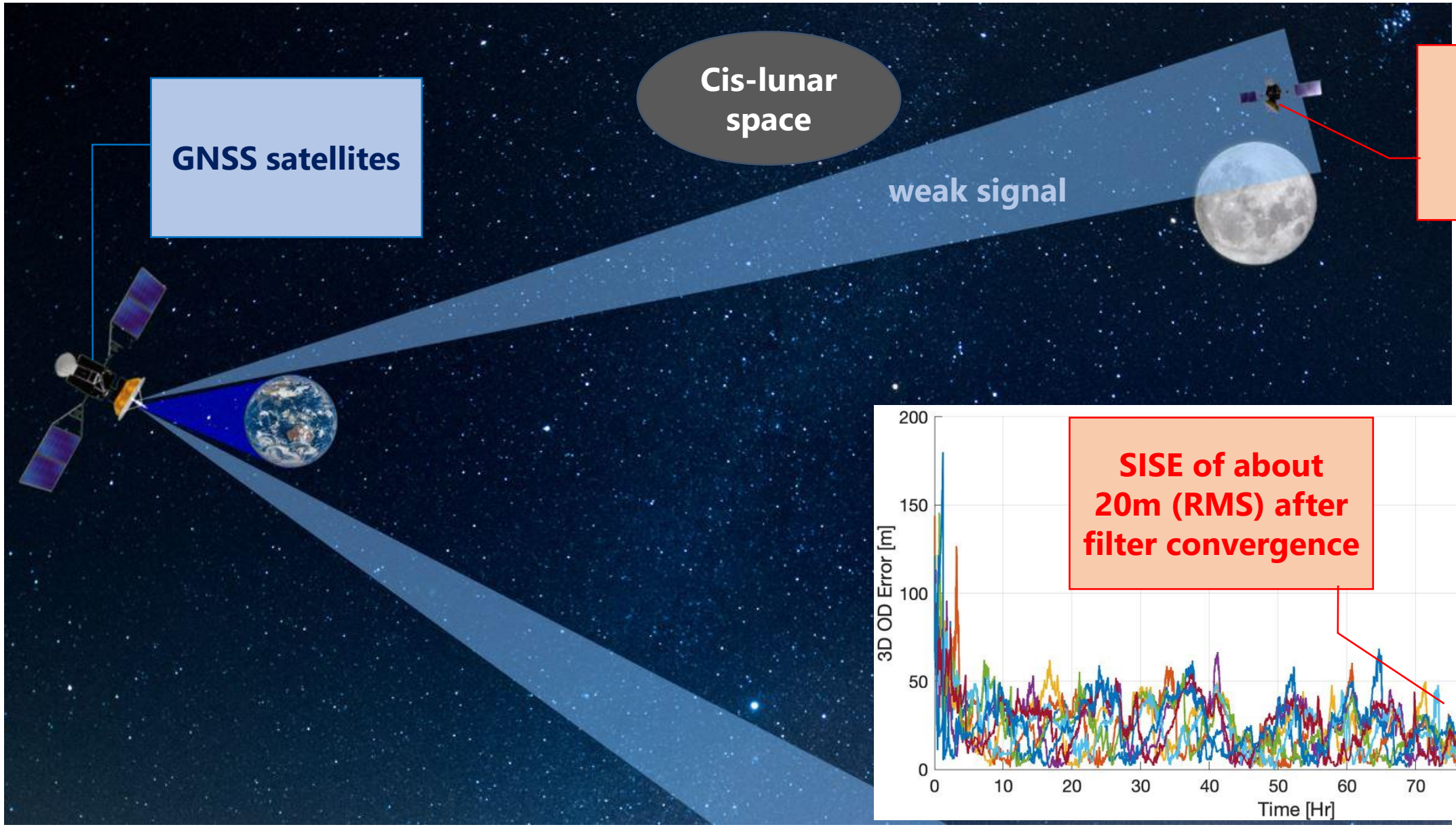
Target: South Pole region

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



LNSS single point positioning (SSP) accuracy for a fixed station at the South Pole

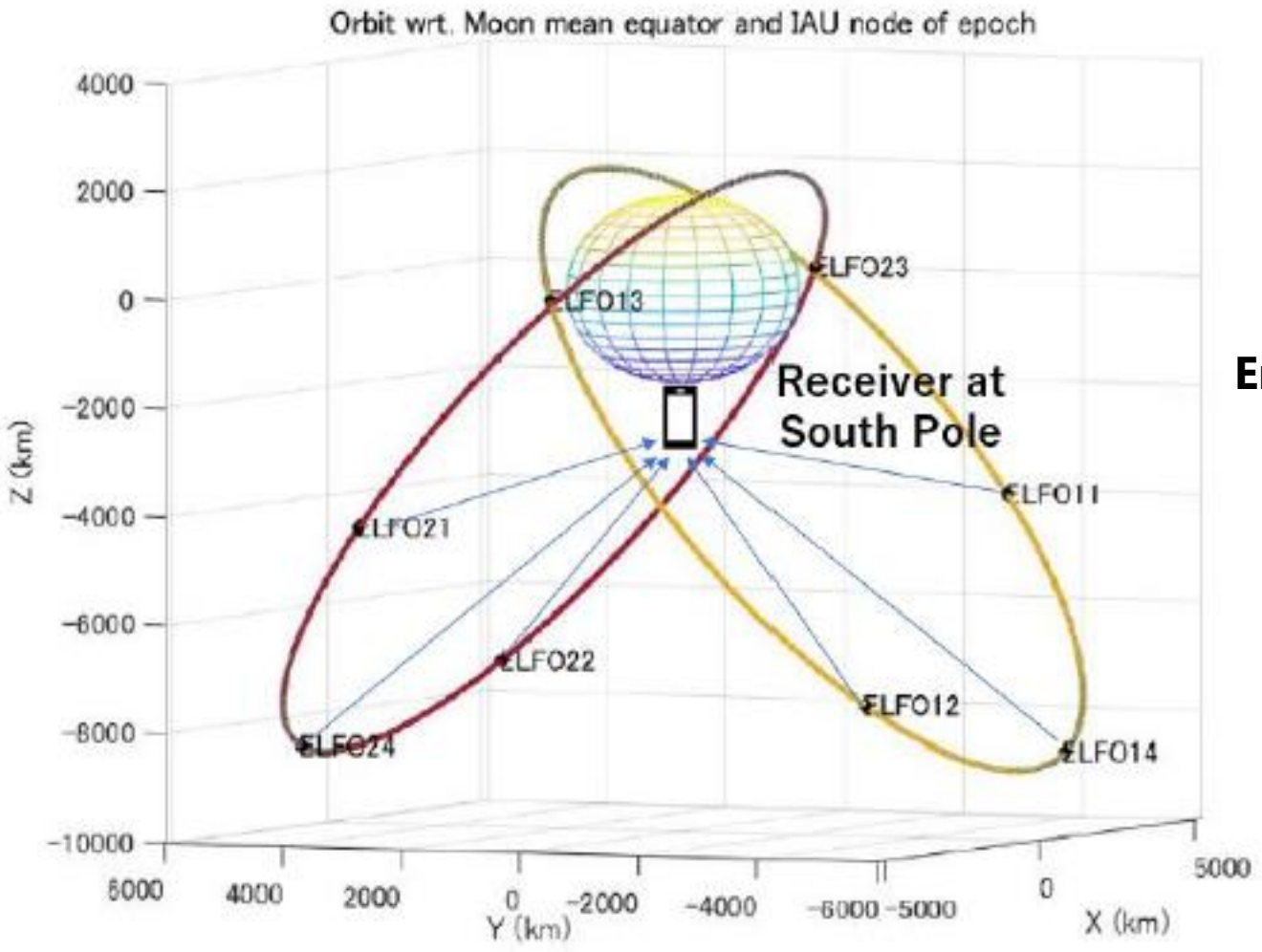
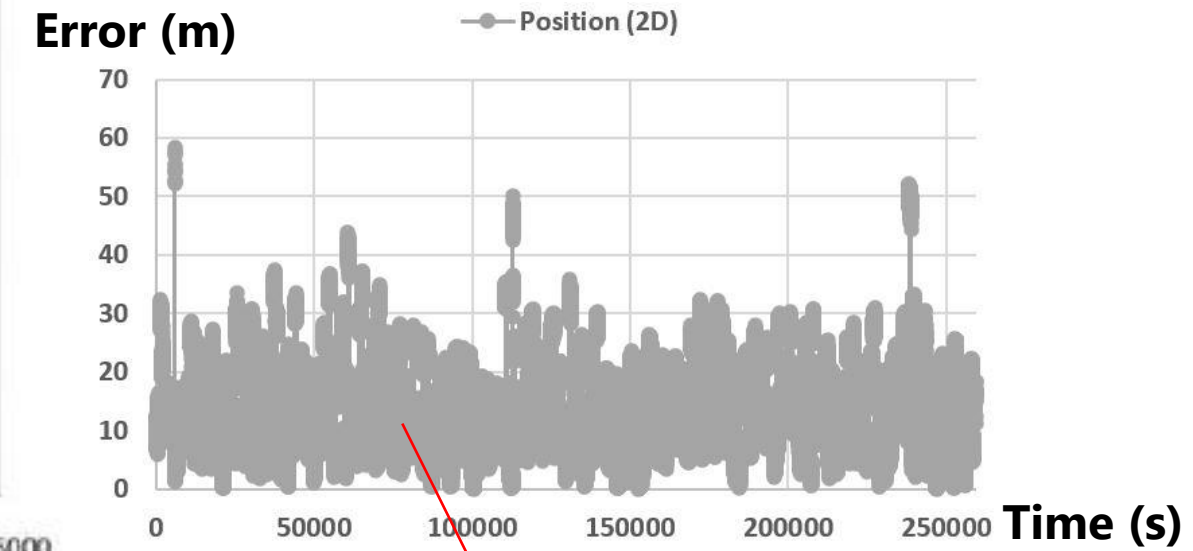


Figure 2: LNSS satellite constellation and receiver at South Pole.

- **Average SSP errors:**

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

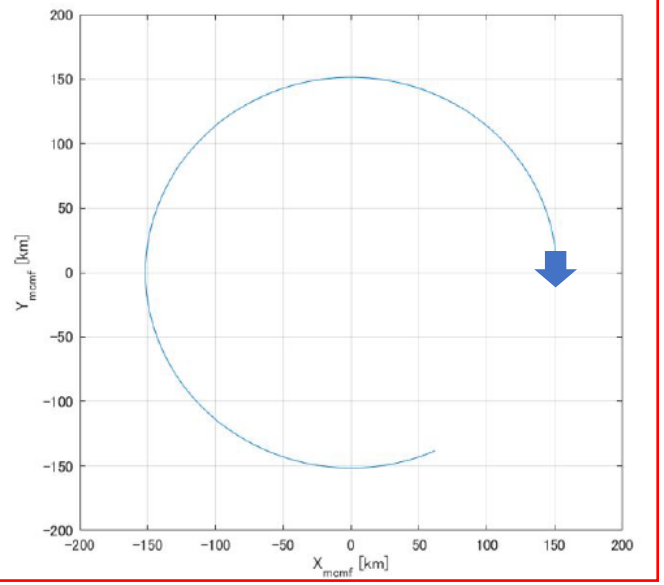
Our LNSS was designed to achieve the high 2D (horizontal) PNT accuracy

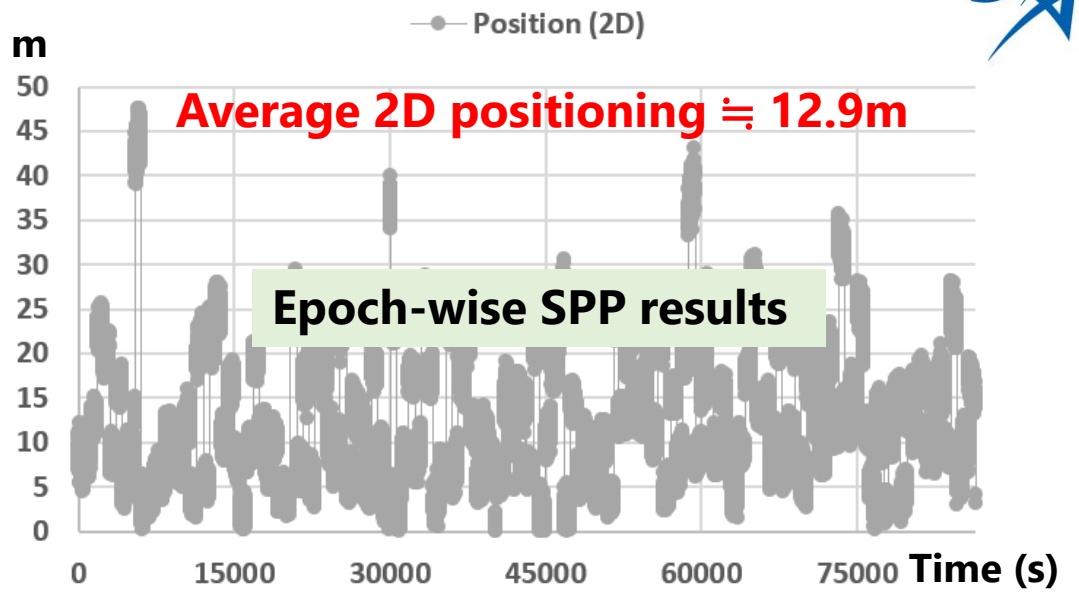


Less than 40m for most of the epochs

LNSS navigation accuracy for a moving object at the South Pole region

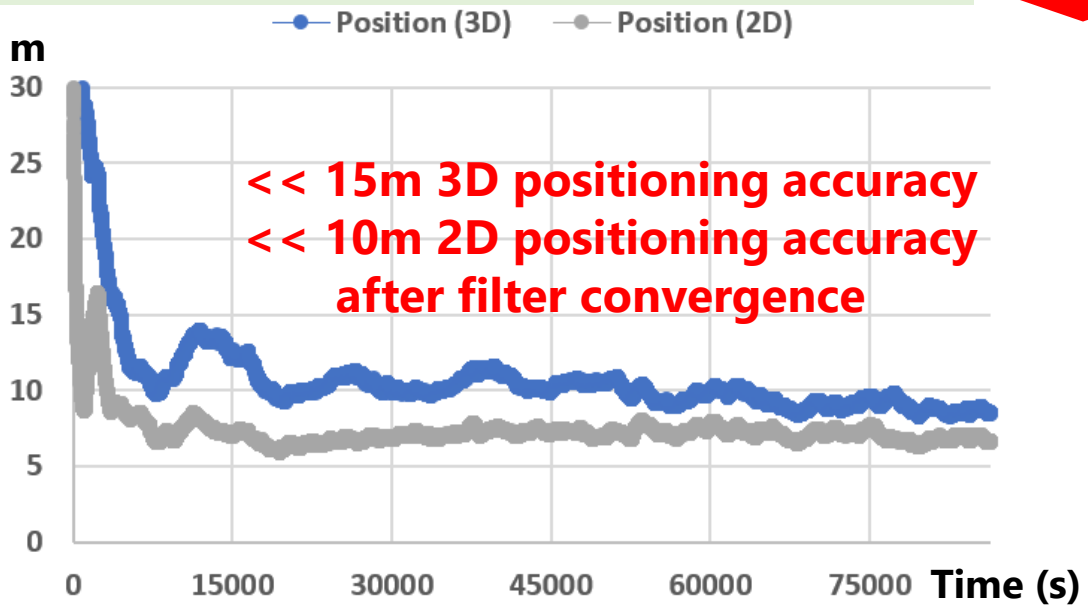
Assumed movement: circular movement with velocity of 3 m/s at south altitude of 85 degrees

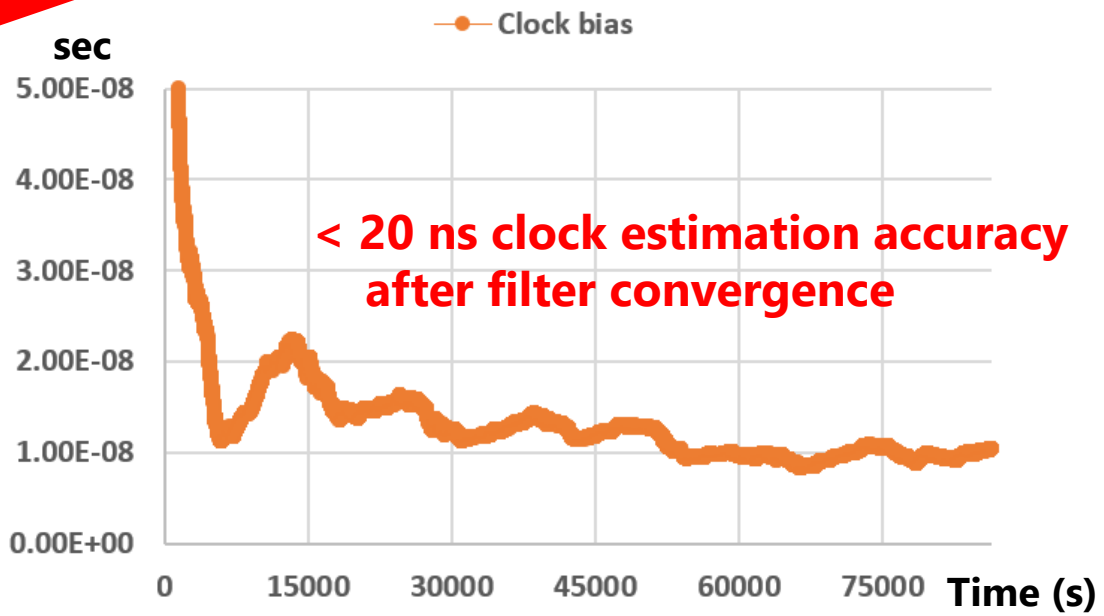




Navigation results (SISE vel of about 2cm/s)

Applying sequential measurement filtering (EKF)



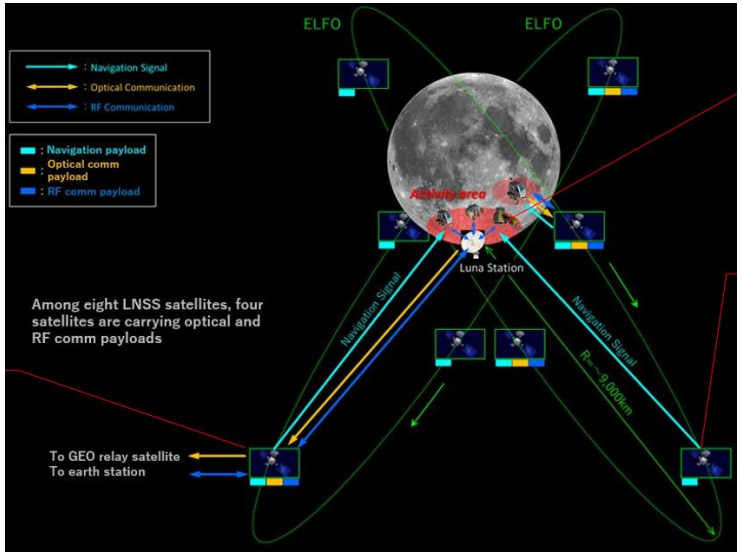


Lunar Comm&Nav (CPNT) systems by US, Europe, Japan

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)

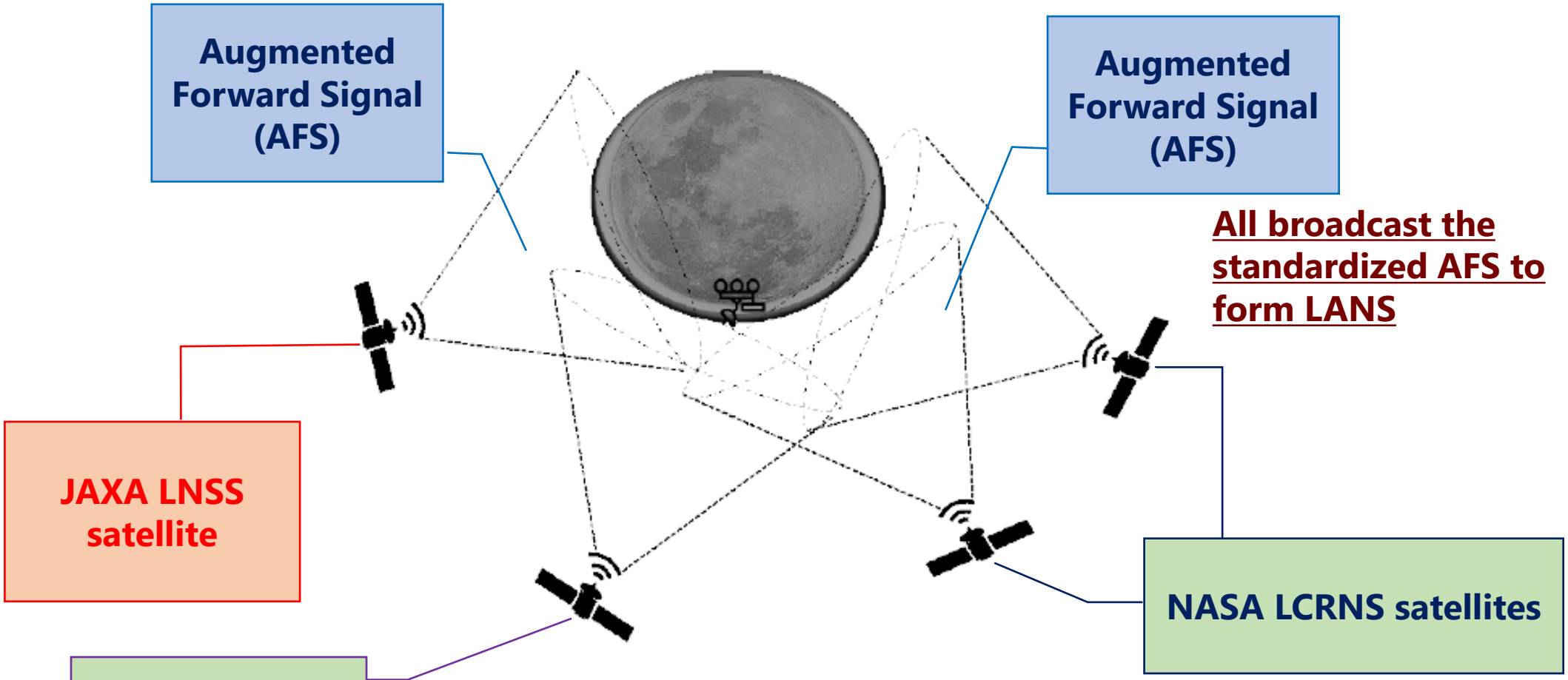
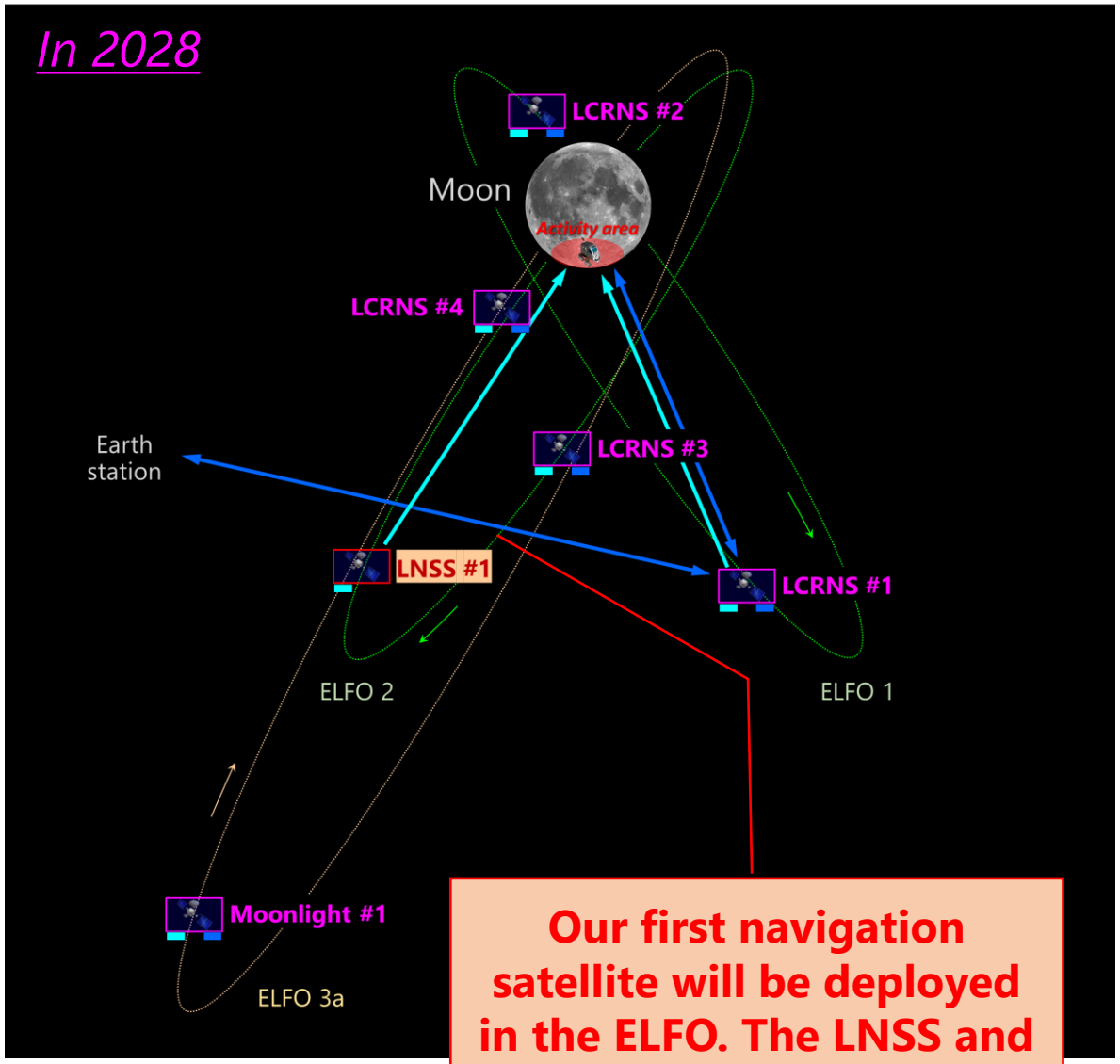


Figure 10 - LANS PNT Concept Provided by LunaNet Nodes

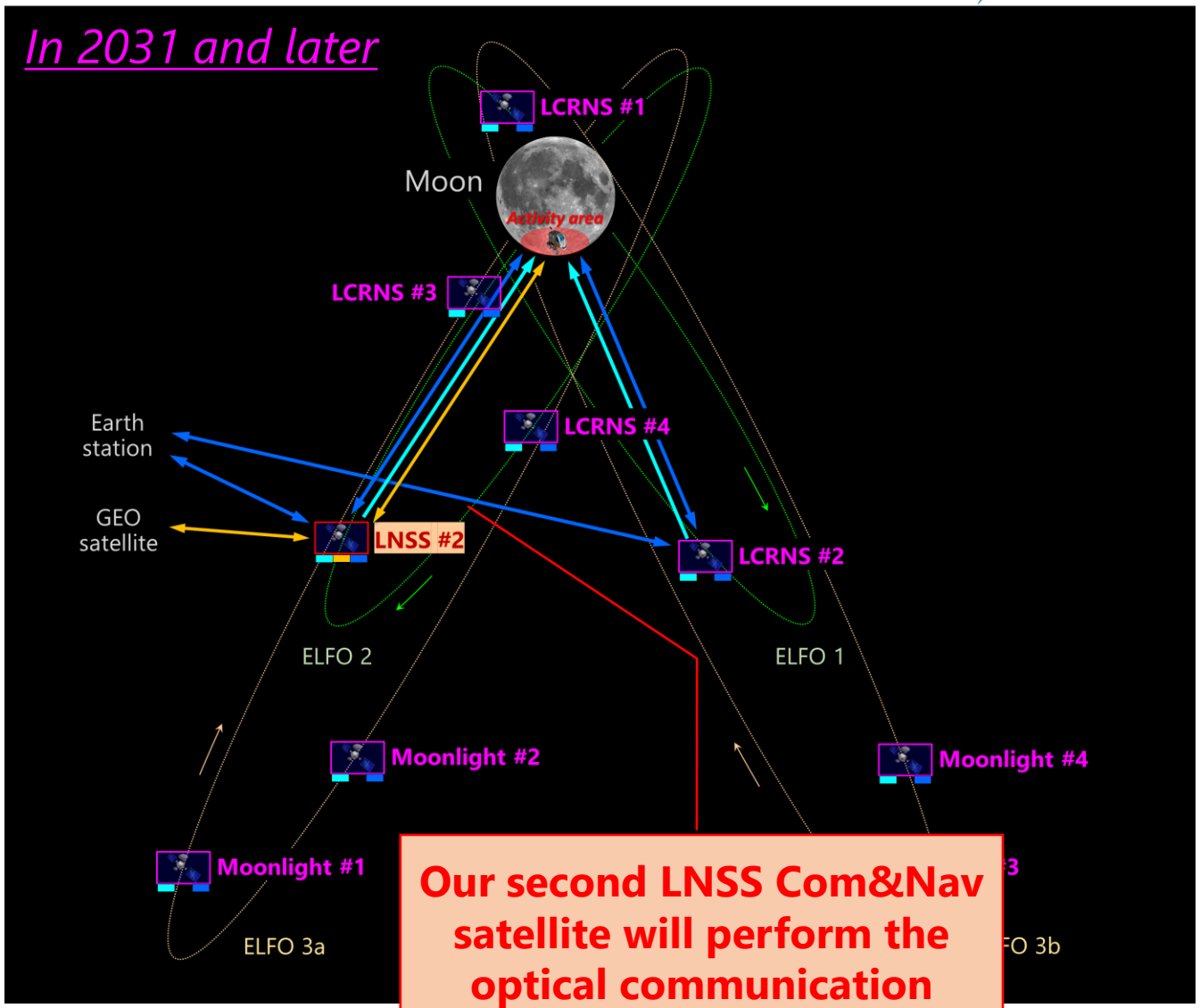
This figure was copied from the LunaNet Interoperability Specification (LNIS)
※LNIS is the standardization document for the LunaNet

JAXA's plan

LNSS contribution towards the establishment of Moon GNSS (LANS)
※ ESA Moonlight and NASA LCRNS orbits are notional in figures below



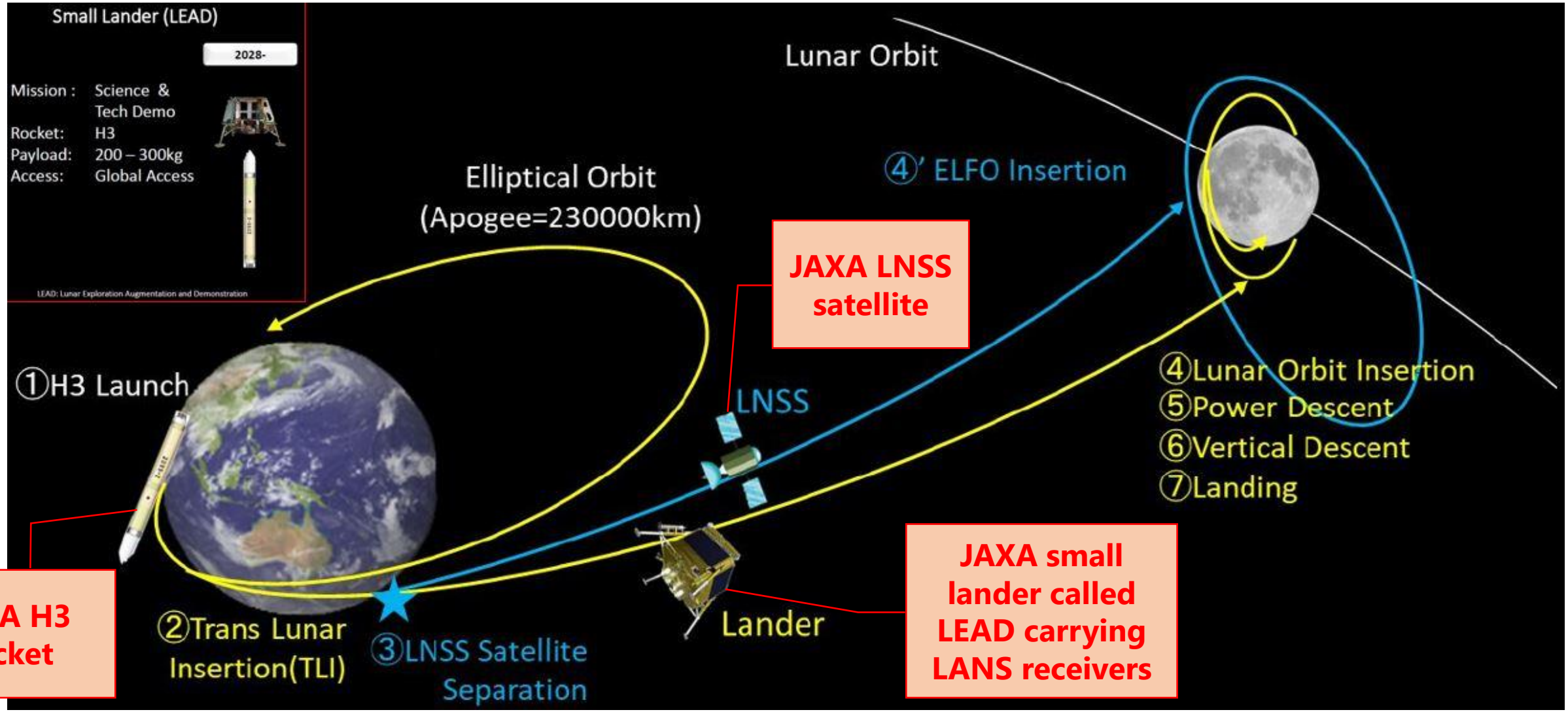
Our first navigation satellite will be deployed in the ELFO. The LNSS and LANS IOC accuracy will be both evaluated



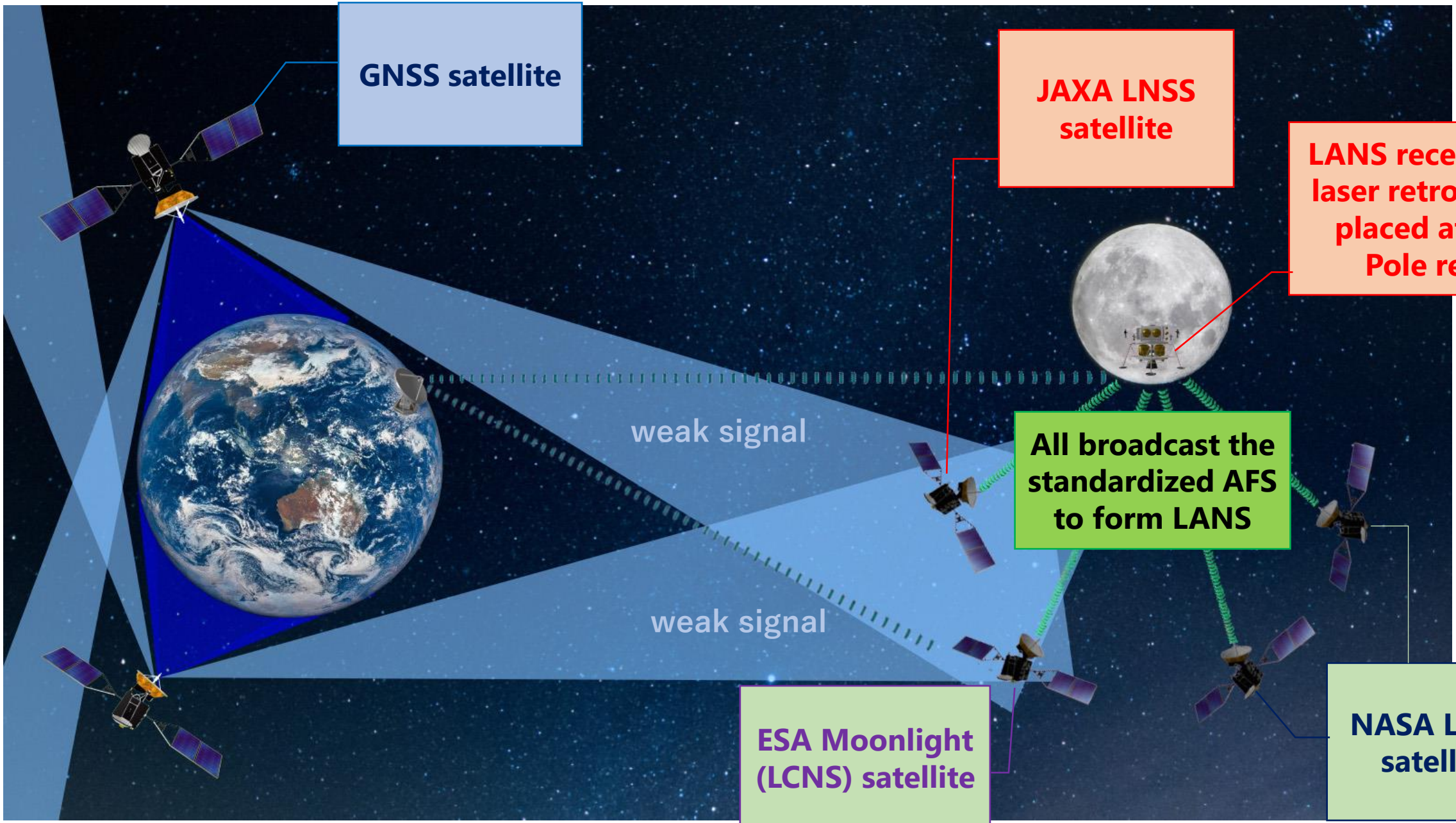
Our second LNSS Com&Nav satellite will perform the optical communication experiment between Moon and Earth

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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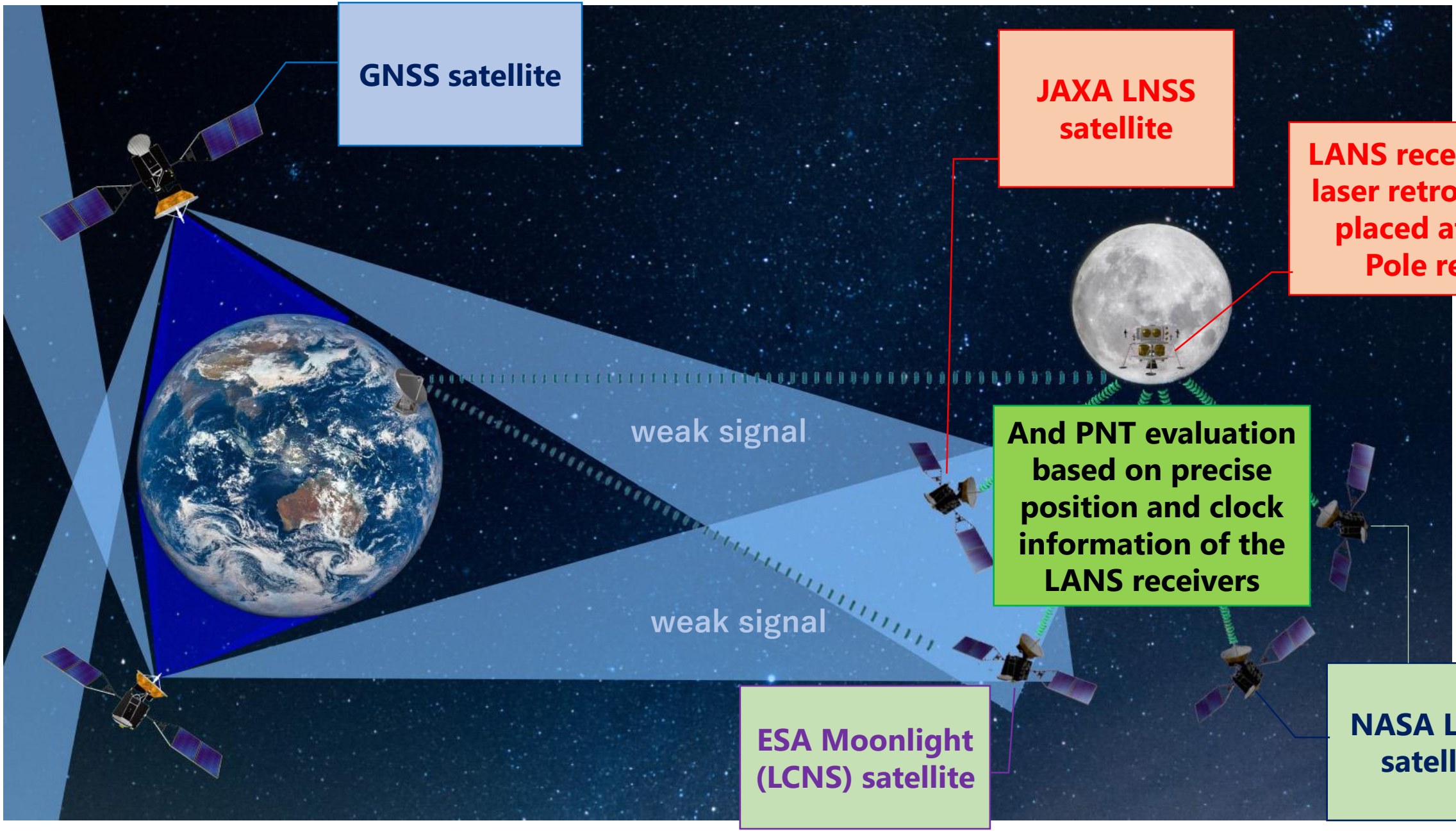
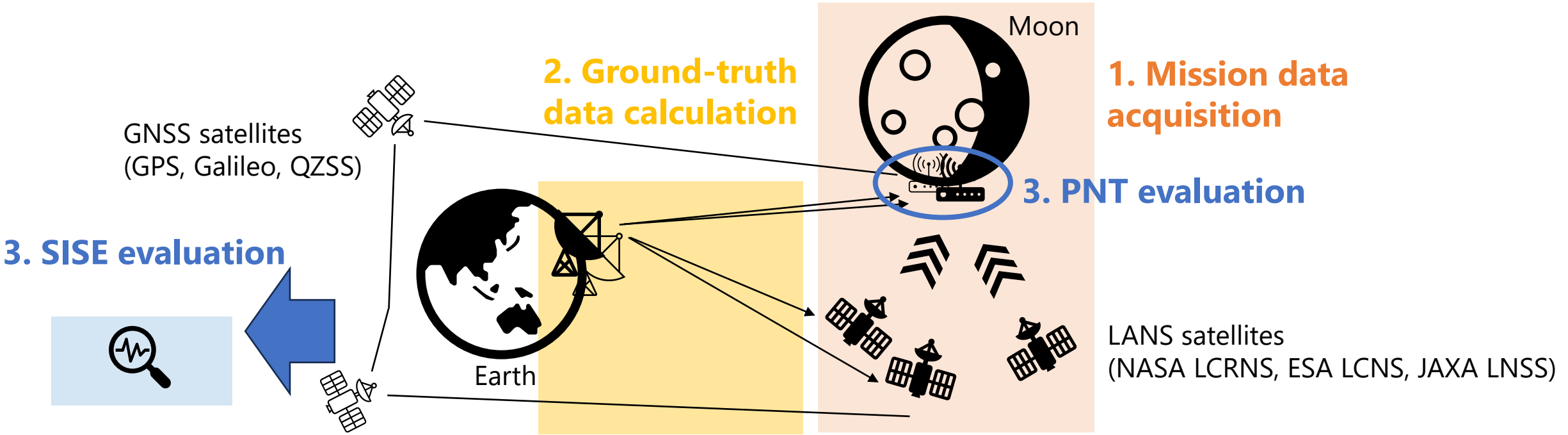


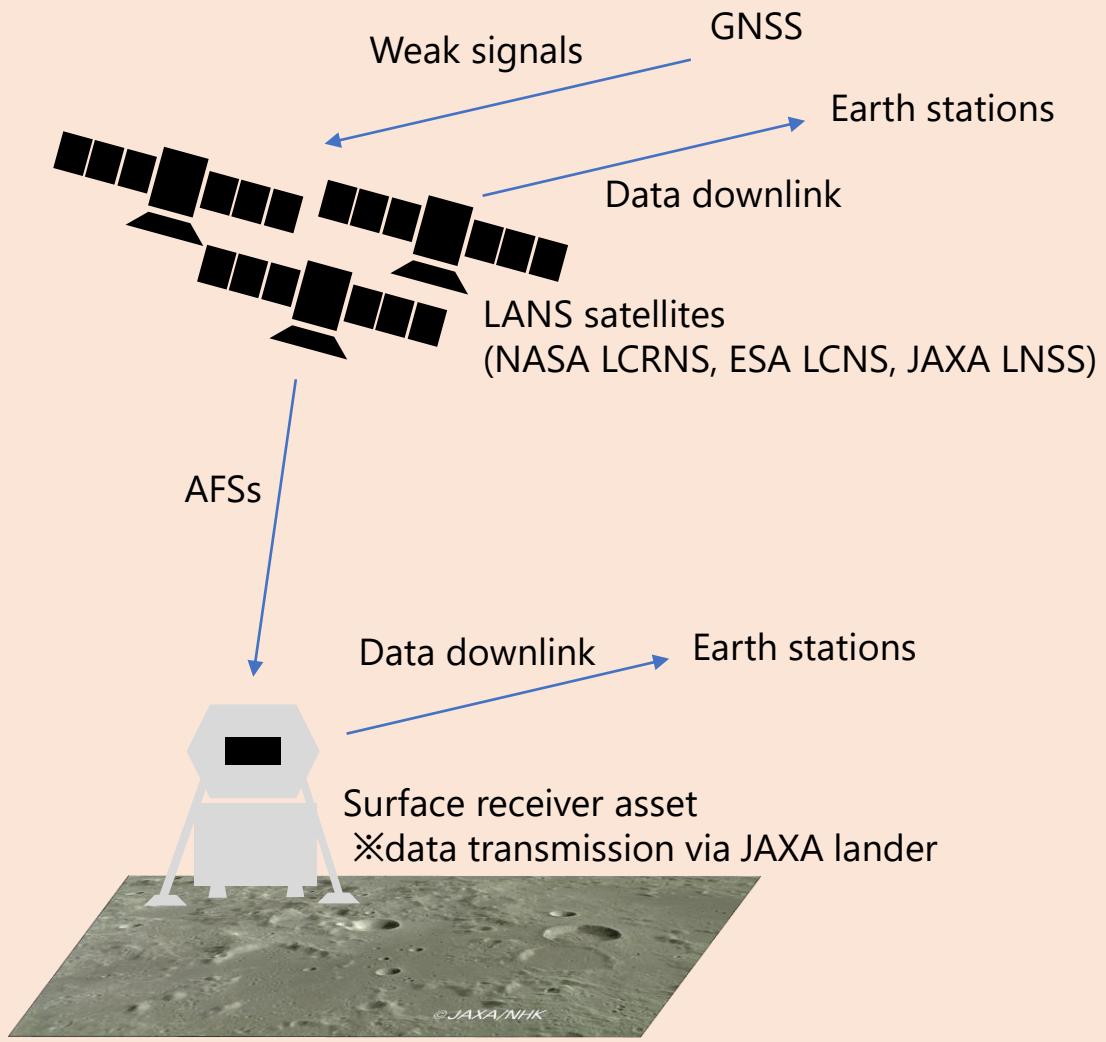
LANS interoperability and PNT demonstration – concept of operation

☐ Three major steps for the demonstration

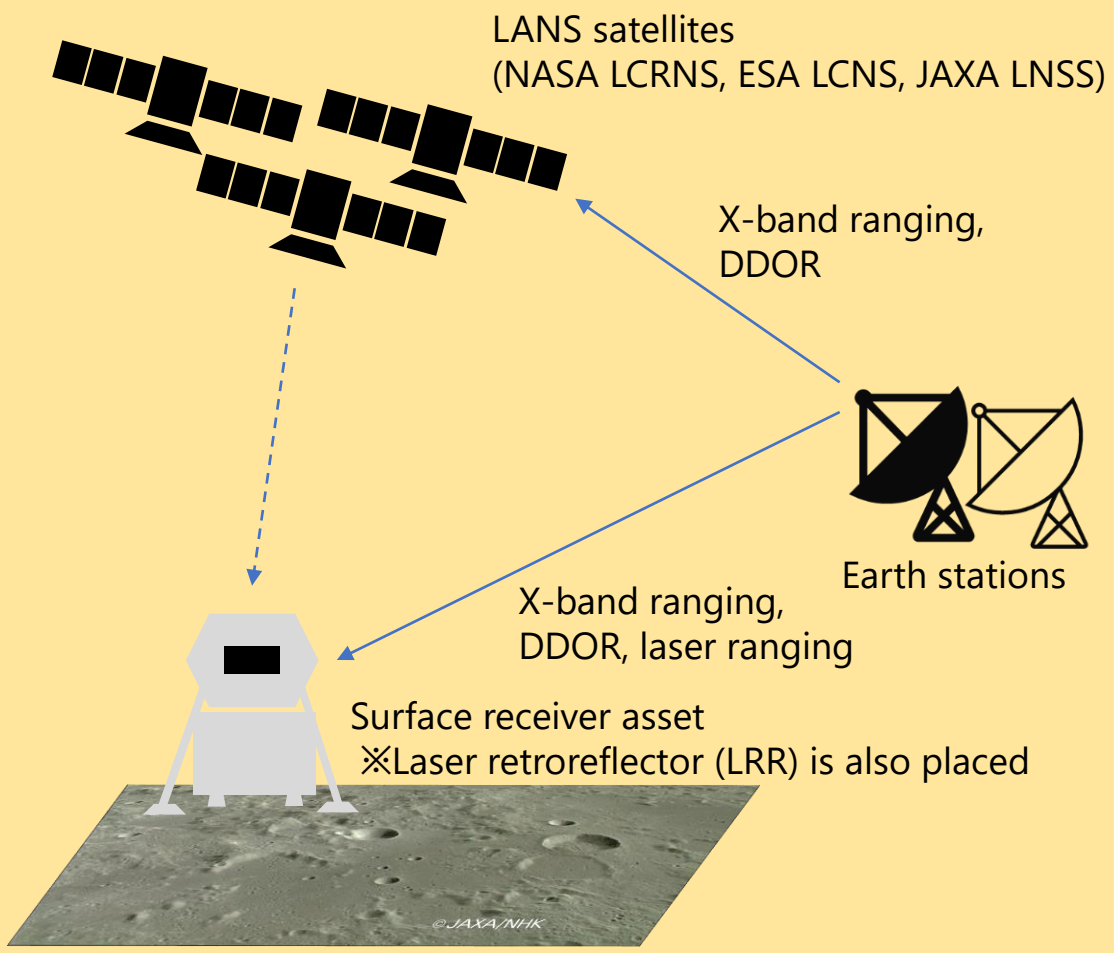
1. Mission data acquisition in Moon environment
2. Ground-truth data calculation by Earth stations
3. SISE and PNT evaluation by comparing the mission data with the ground-truth data



Mission data acquisition and ground-truth data calculation



GNSS weak signal and LANS AFS acquisition in actual moon environment



Precise satellite orbit, receiver position, and clock determination using earth stations

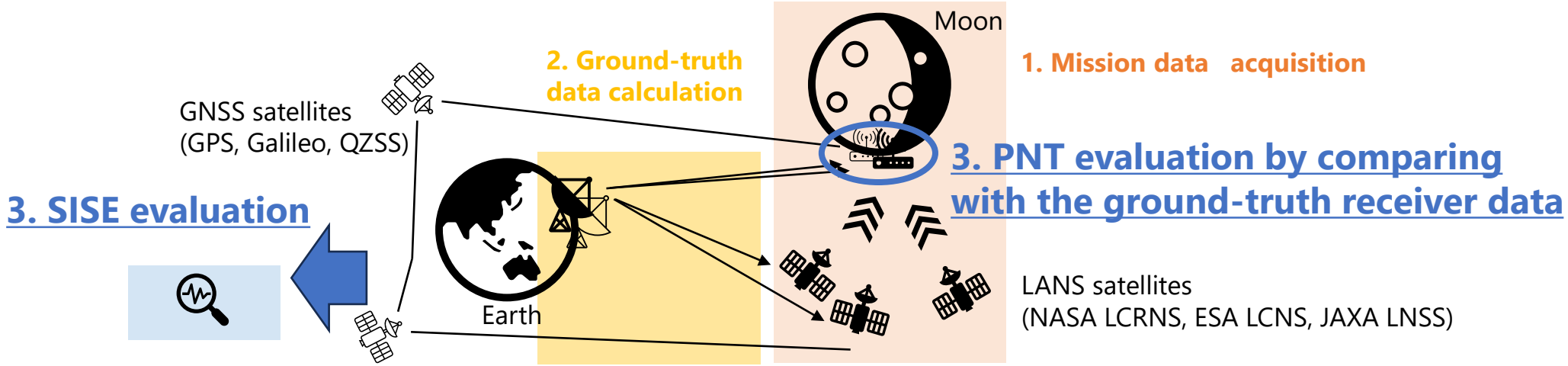
SISE and PNT evaluation

☐ The SISE evaluation procedure

① Calculate true pseudo ranges based on the ground-truth data and compare them with the actual pseudo ranges to evaluate unknown error caused by hardware and moon environmental delays

② Evaluate errors in the satellite ephemerides (orbit and clock prediction errors) by comparing the ephemerides with the ground-truth data

③ The SISE is assessed by adding the ephemeris error and the identified unknown error, based on which the moon surface positioning accuracy is evaluated by multiplying with the LANS DOPs



Takeaways

・The JAXA will comply with the LNIS and our lunar PNT system called the LNSS will join the LANS, together with NASA LCRNS and ESA LCNS

・JAXA is proposing the LANS interoperability demonstration mission in 2028 and ESA and NASA 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 Earth stations for the in-depth analysis

- ✓ The SISE of each LNSP and the LANS PNT accuracy are evaluated

・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)