Lunar Navigation Satellite System (LNSS) and Its Demonstration Mission

Masaya Murata[1], Keidai Iiyama[2]

[1]Japan Aerospace Exploration Agency

[2]Stanford University

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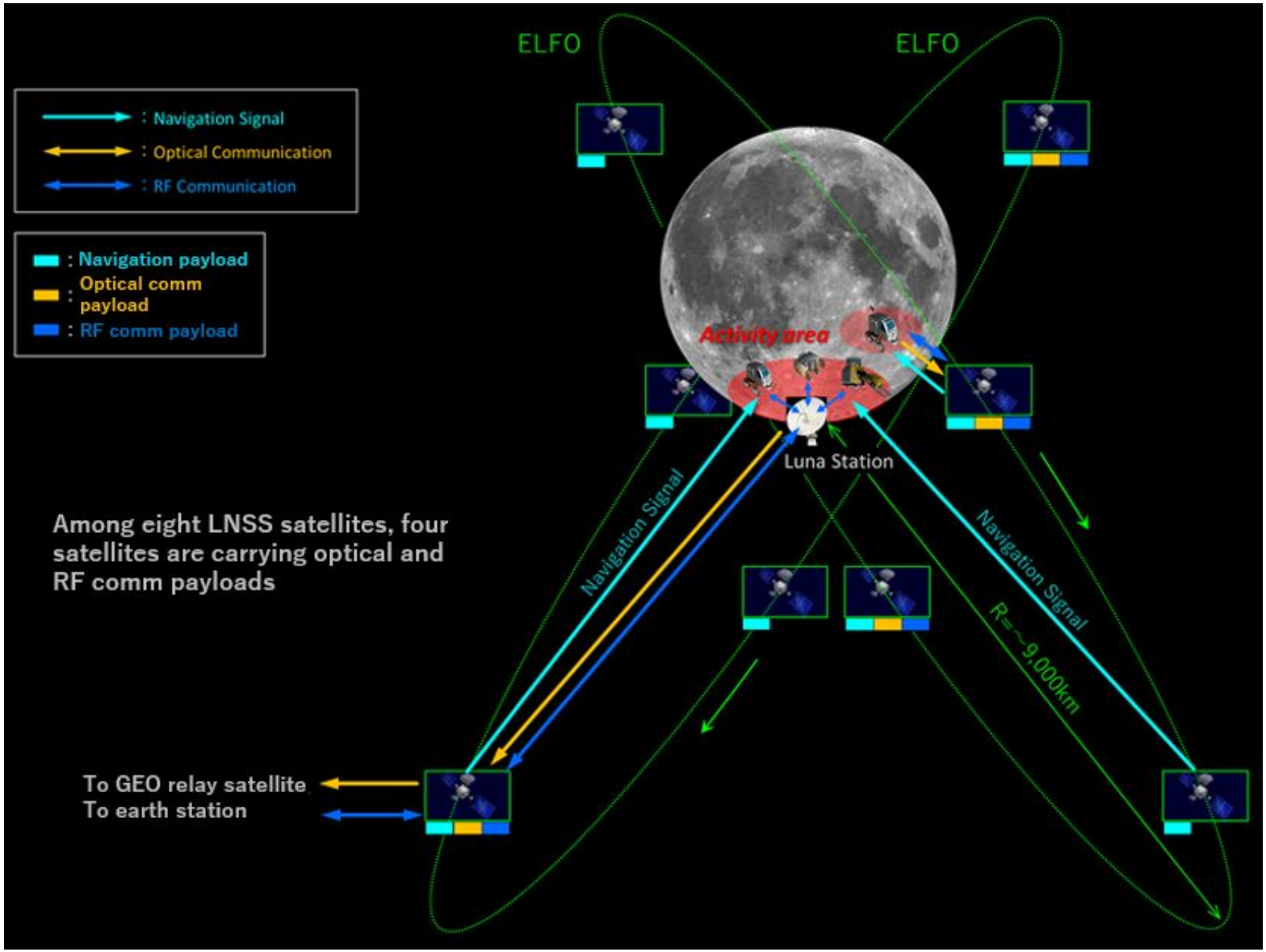
Outline

1. Lunar navigation satellite system (LNSS)
2. Mission and system overview of LNSS
3. Demonstration mission scheduled in 2028
4. Potential collaboration with ESA and NASA
5. Conclusions

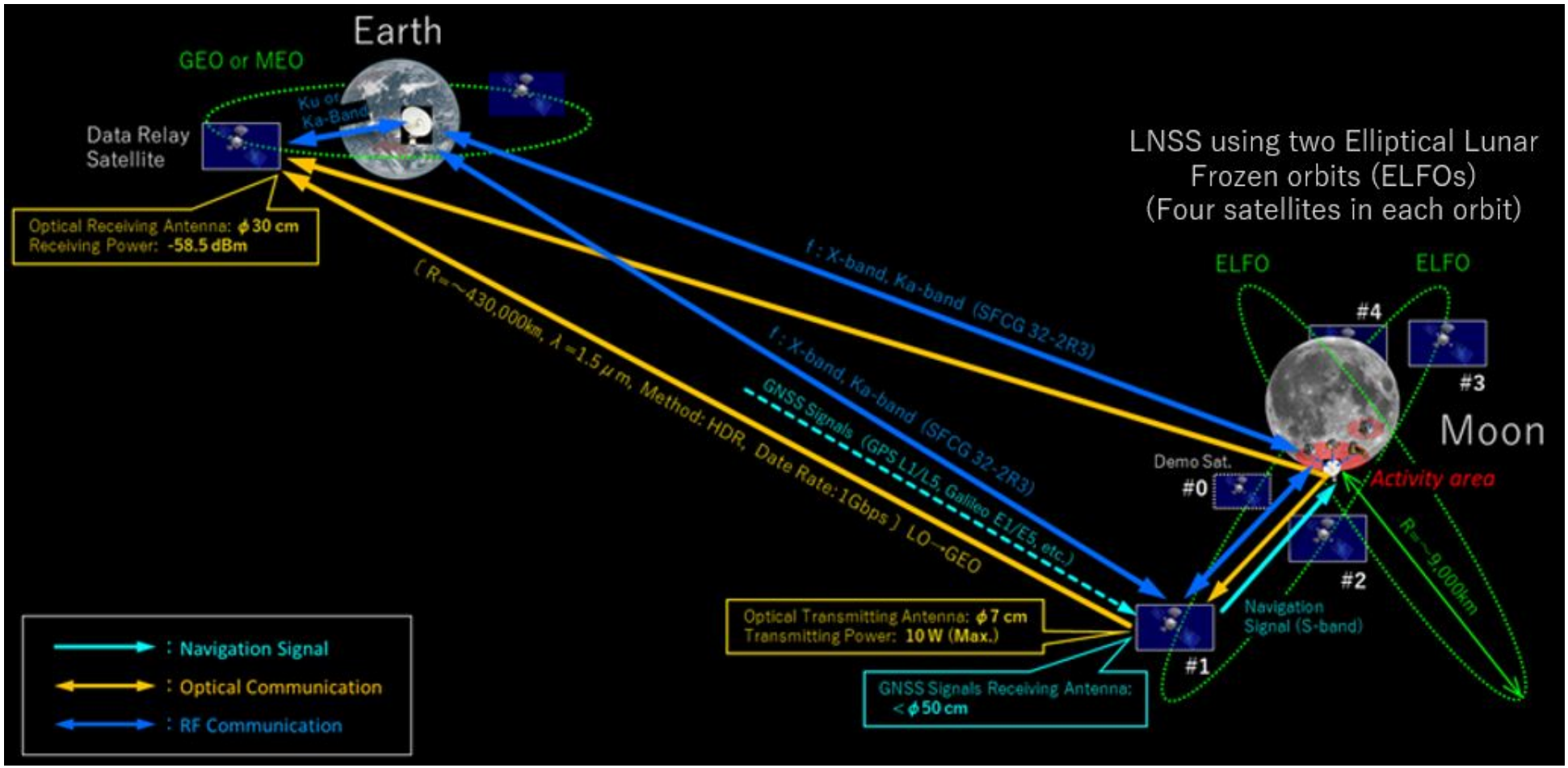
Lunar navigation satellite system (LNSS)

- GPS-like navigation system for moon designed by JAXA



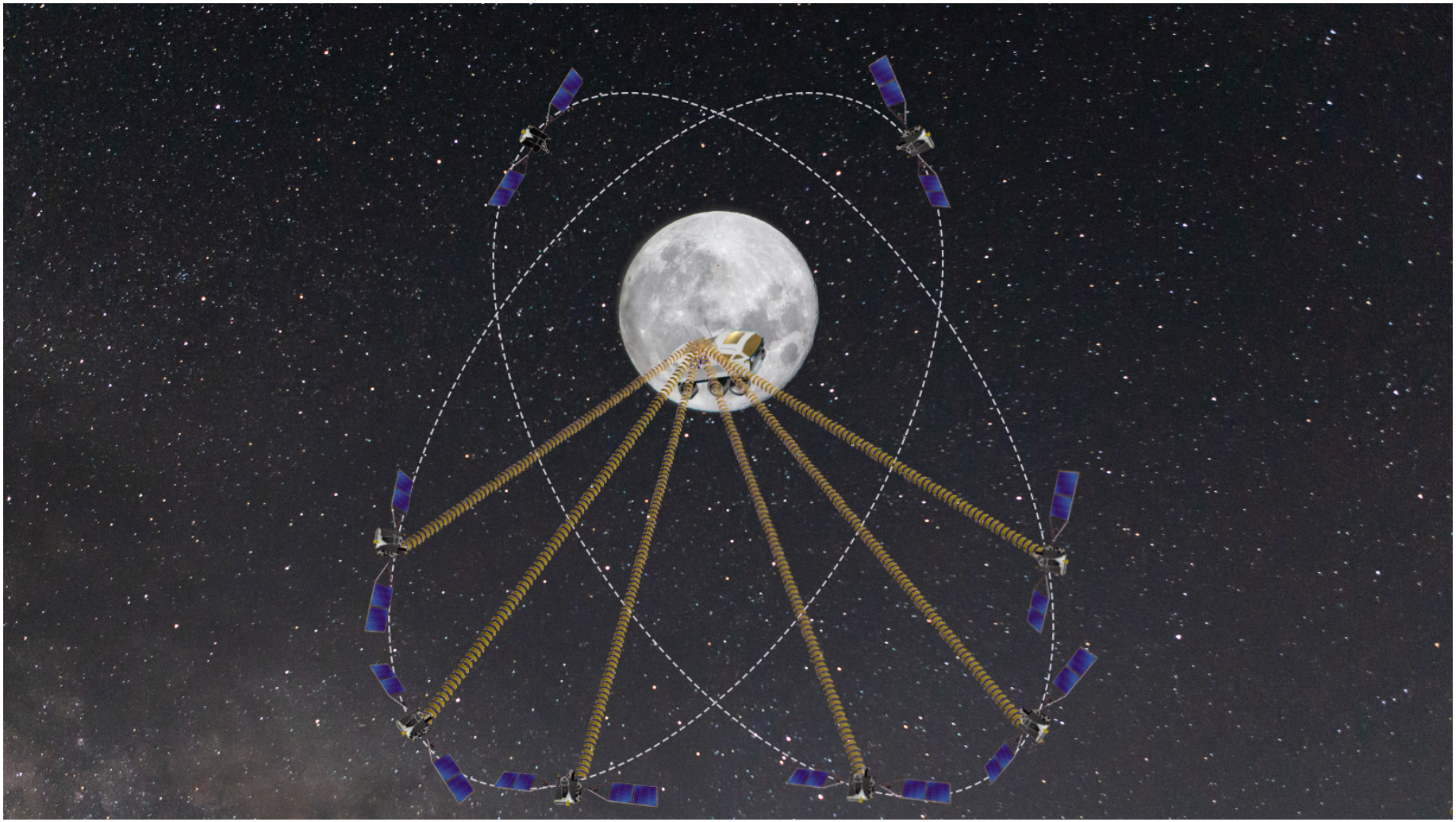
Lunar navigation satellite system (LNSS) (cont'd)

- Communication, positioning, navigation, and timing (CPNT)
  - Radio frequency and optical communication links between the moon surface user, the LNSS satellites, and the earth



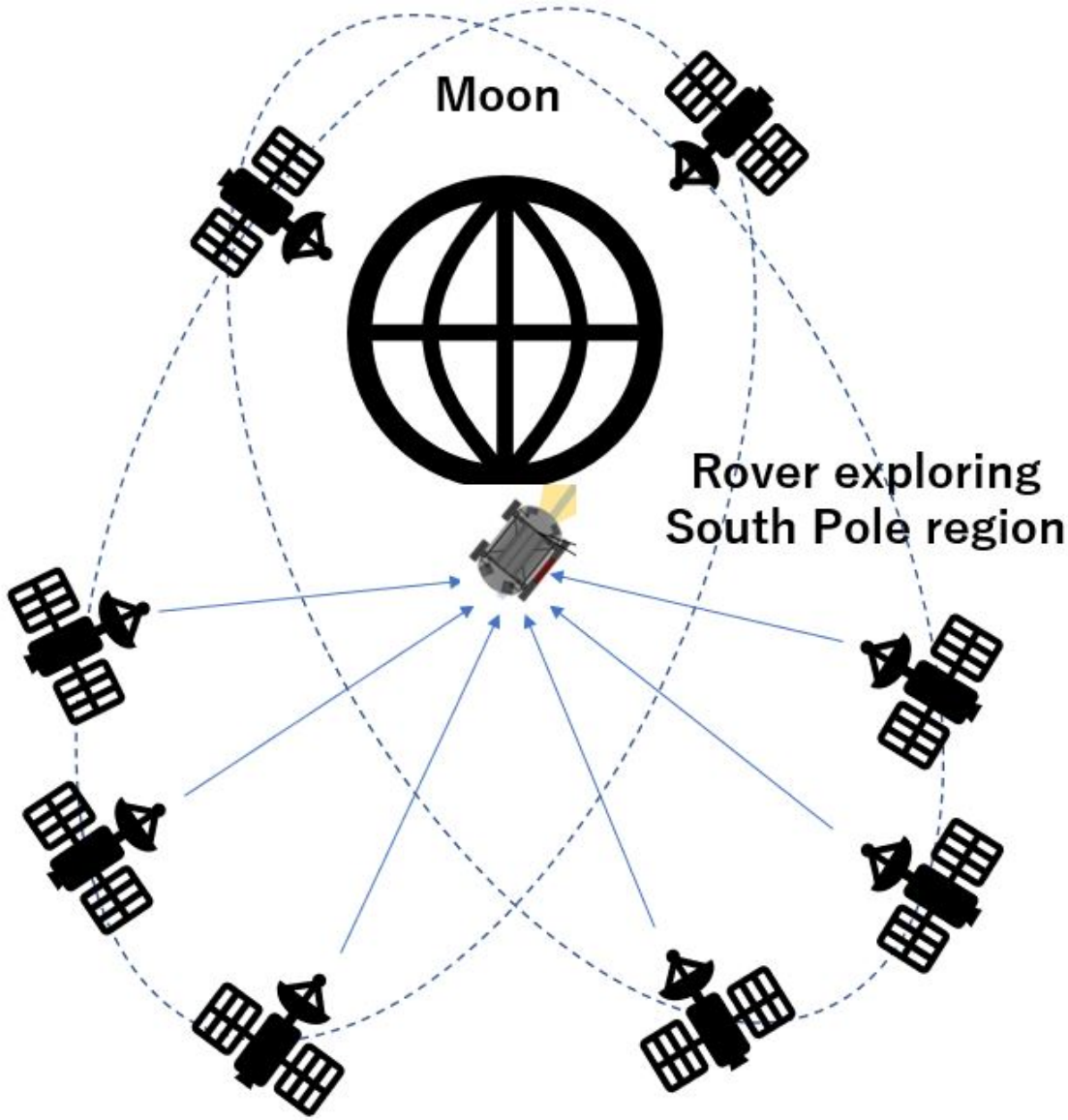
Mission and system overview of LNSS

- Helping our pressurized/exposed rover and EVA mission locate their own positions in real-time at the lunar South Pole region



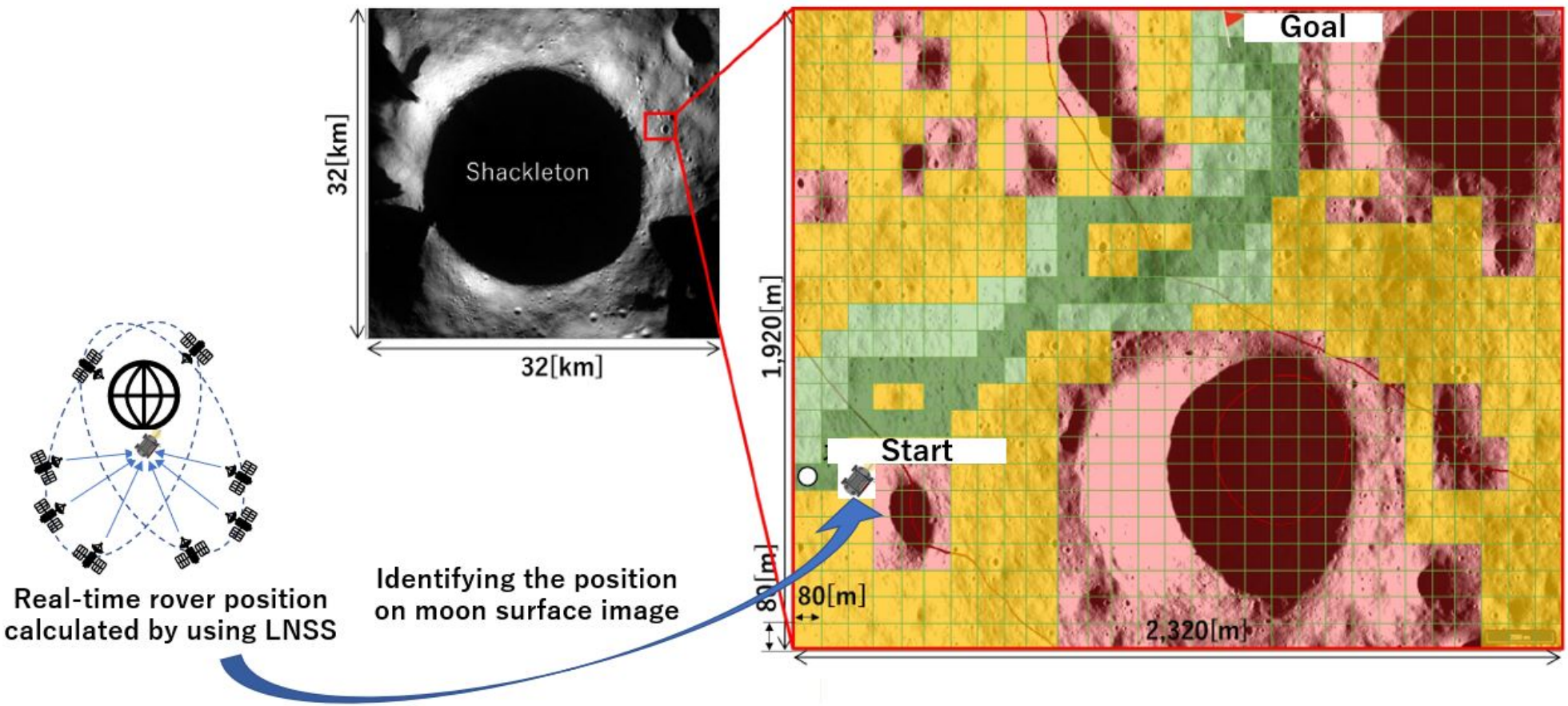
Mission and system overview of LNSS (cont'd)

- LNSS real-time positioning service for the rover



Mission and system overview of LNSS (cont'd)

- Localization of the rover on moon surface satellite images taken by, e.g., NASA lunar reconnaissance orbiter (LRO)

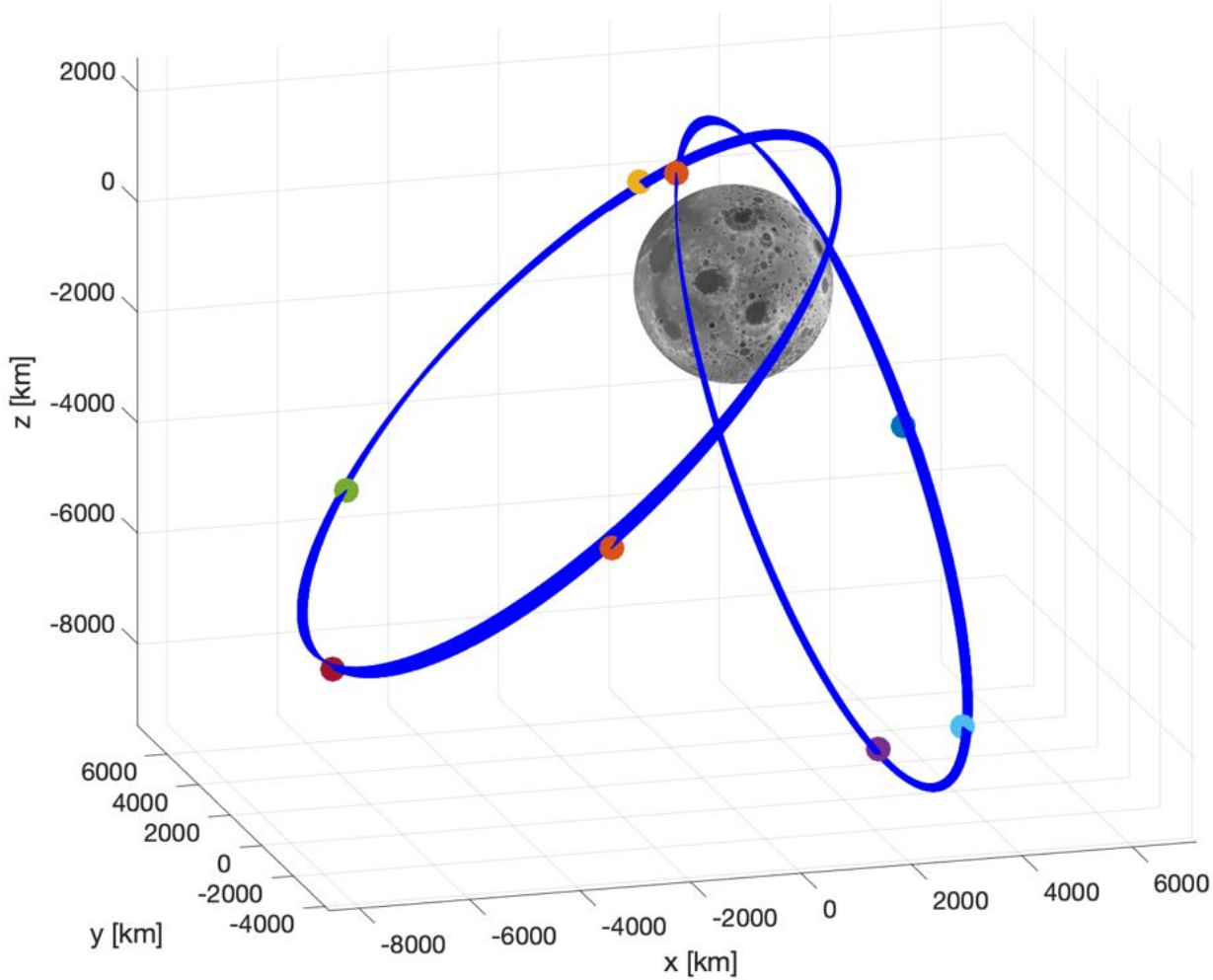


Requirements of LNSS

- Real-time horizontal positioning accuracy less than 40 meters at the lunar South Pole region at any time
  - We need the specific satellite constellation and accurate orbit and clock determination for the LNSS satellites
  - Although the nominal operation duration for our pressurized rover is eight-hour per day, one-day continuous PNT service becomes necessary to support the astronauts' EVA
- 10 Mbps and more, and hopefully 1 Gbps transmission rate between the moon and the earth
  - We use the LNSS satellites as communication relay satellites using X-band and Ka-band. Optical communication links are also possible choices

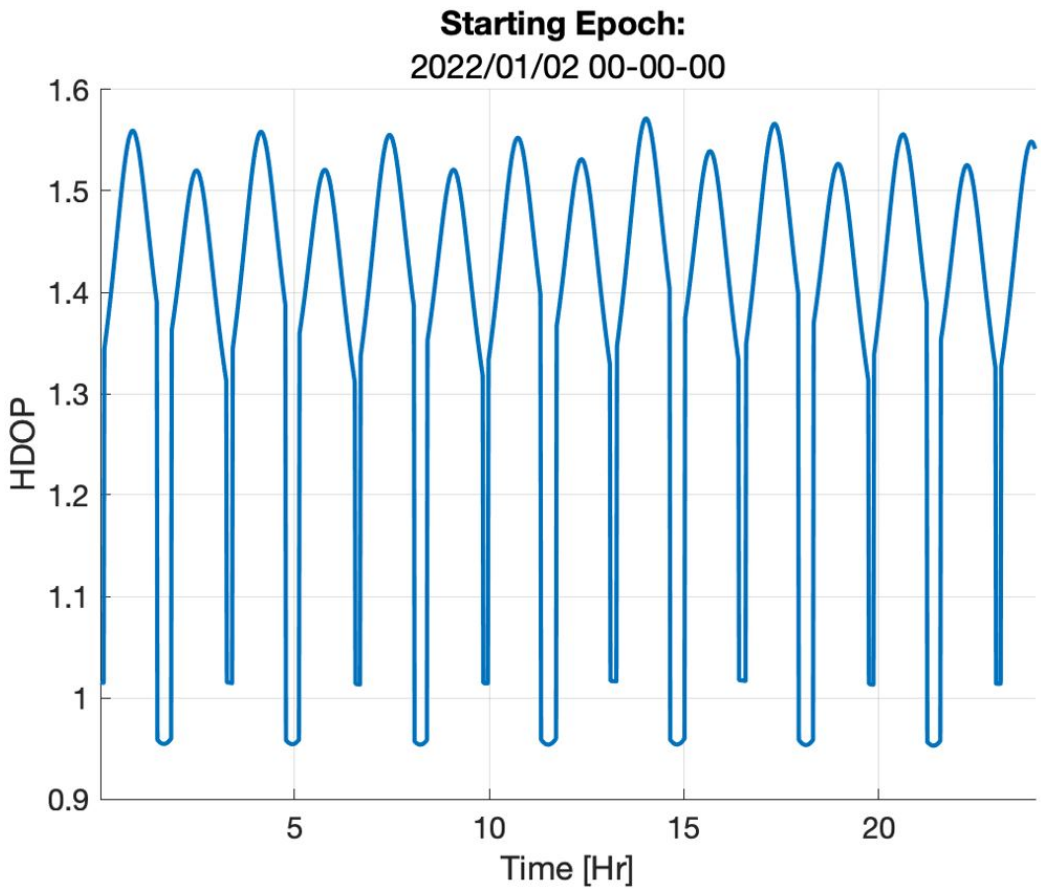
LNSS satellite constellation

- Eight-satellite constellation with two elliptical lunar frozen orbits (ELFOs) whose orbital periods are about twelve hours
- This constellation enables high horizontal positioning accuracy at the South Pole region, as shown in the next few slides



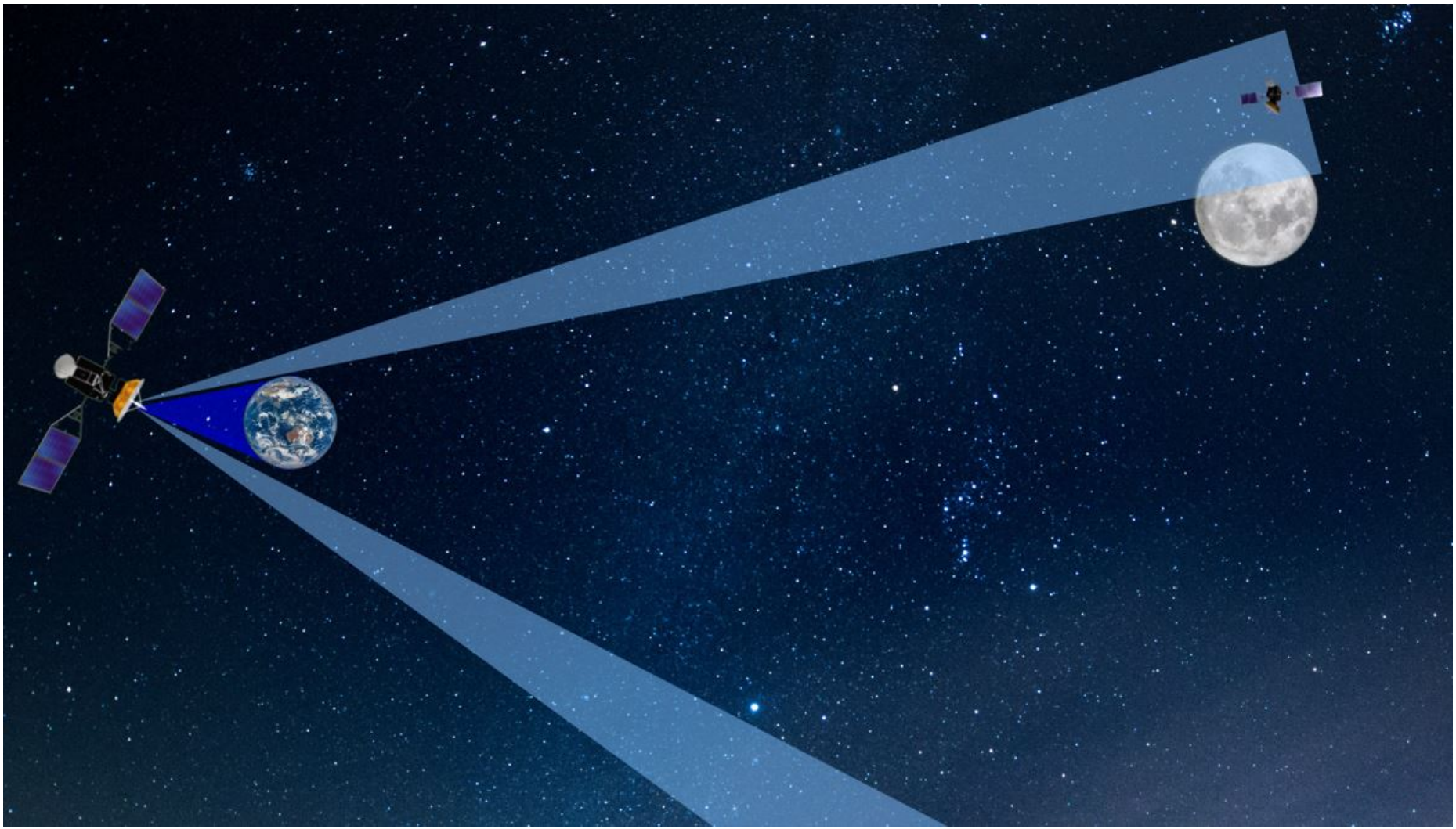
LNSS satellite constellation (cont'd)

- Our constellation achieves the low horizontal dilution of precision (HDOP) at the lunar South Pole at any time
  - For reference, the HDOP of the GPS at the Tsukuba space center in Japan was about 1.2
- We aim for the HDOP of 1.3 and the SISRE of less than 30 meters to meet our positioning accuracy requirement



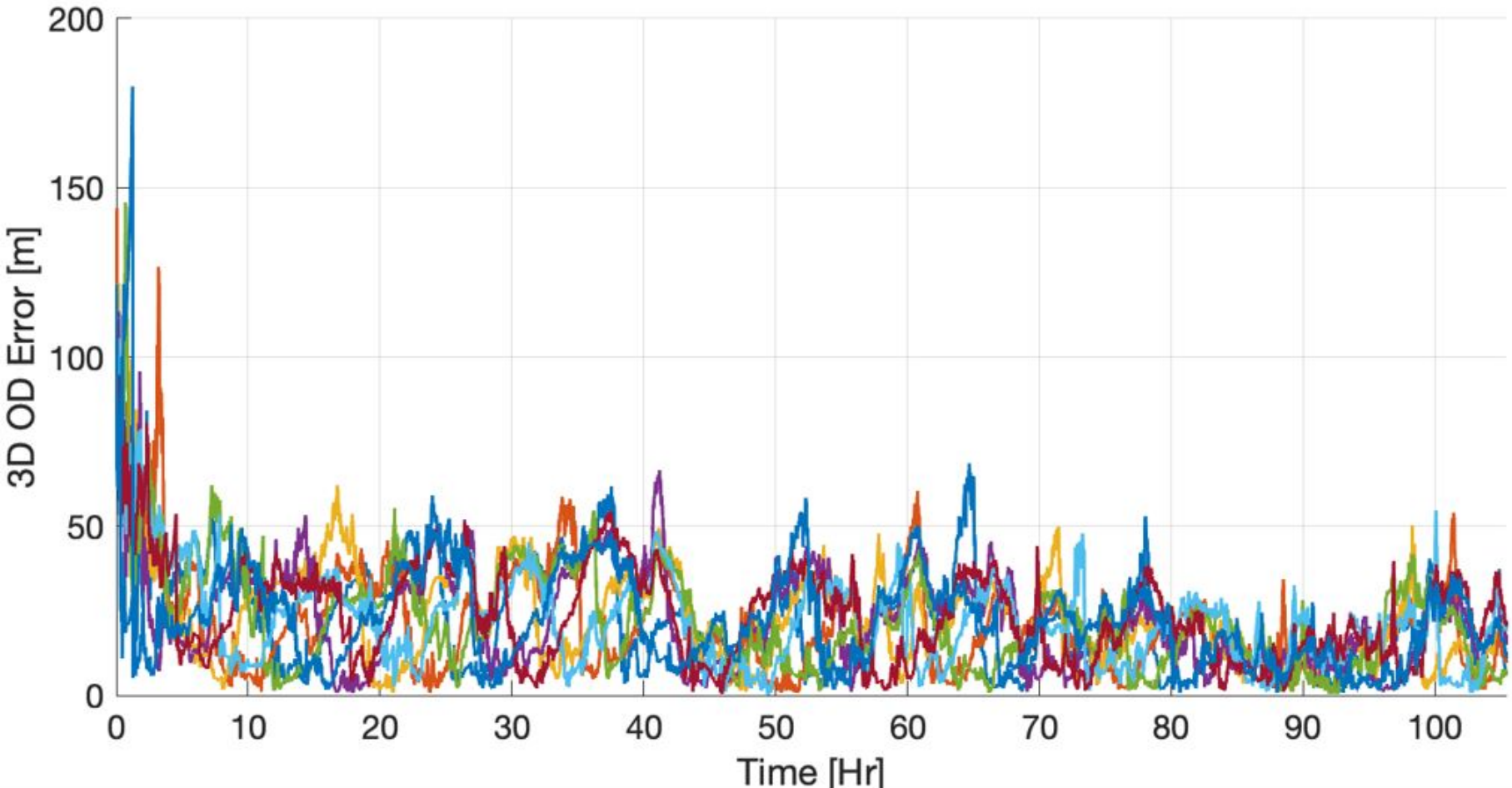
Orbit and clock estimation of LNSS satellites

- GNSS navigation using the weak navigation signals



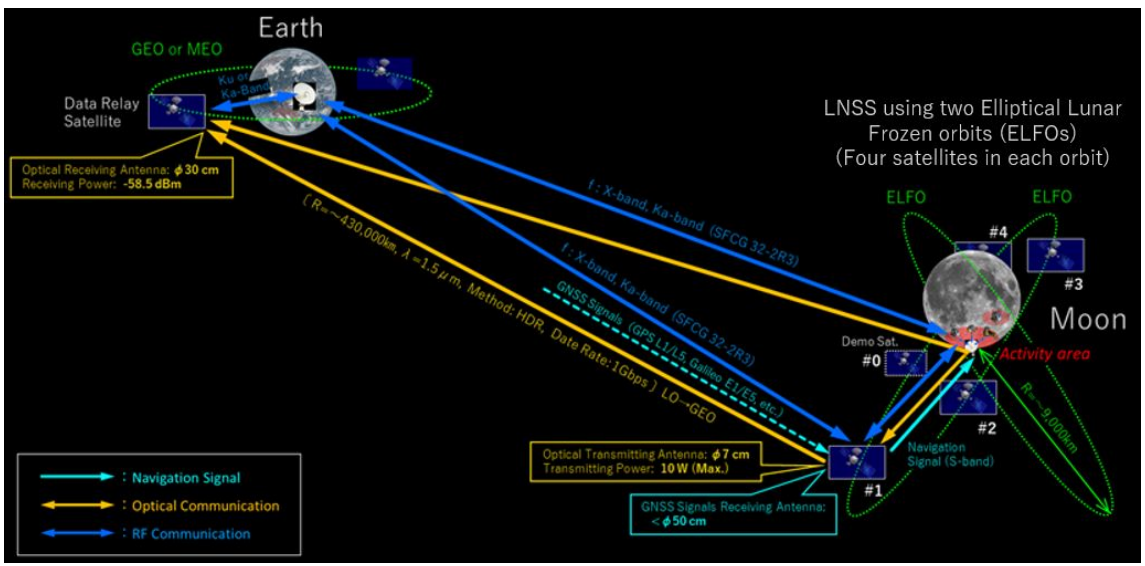
Orbit and clock estimation of LNSS satellites

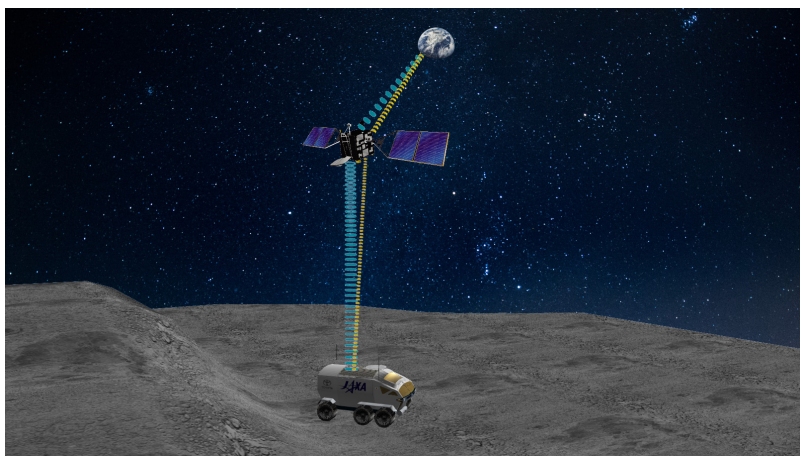
- The following graph shows the expected GPS navigation accuracy for the eight LNSS satellites with space-borne rubidium atomic clock frequency standard (RAFS) clocks
  - Each color represents each satellite. The RMSEs after the filter convergences were 16.5 (orbit) and 1.4 (clock bias) meters



Communications of LNSS

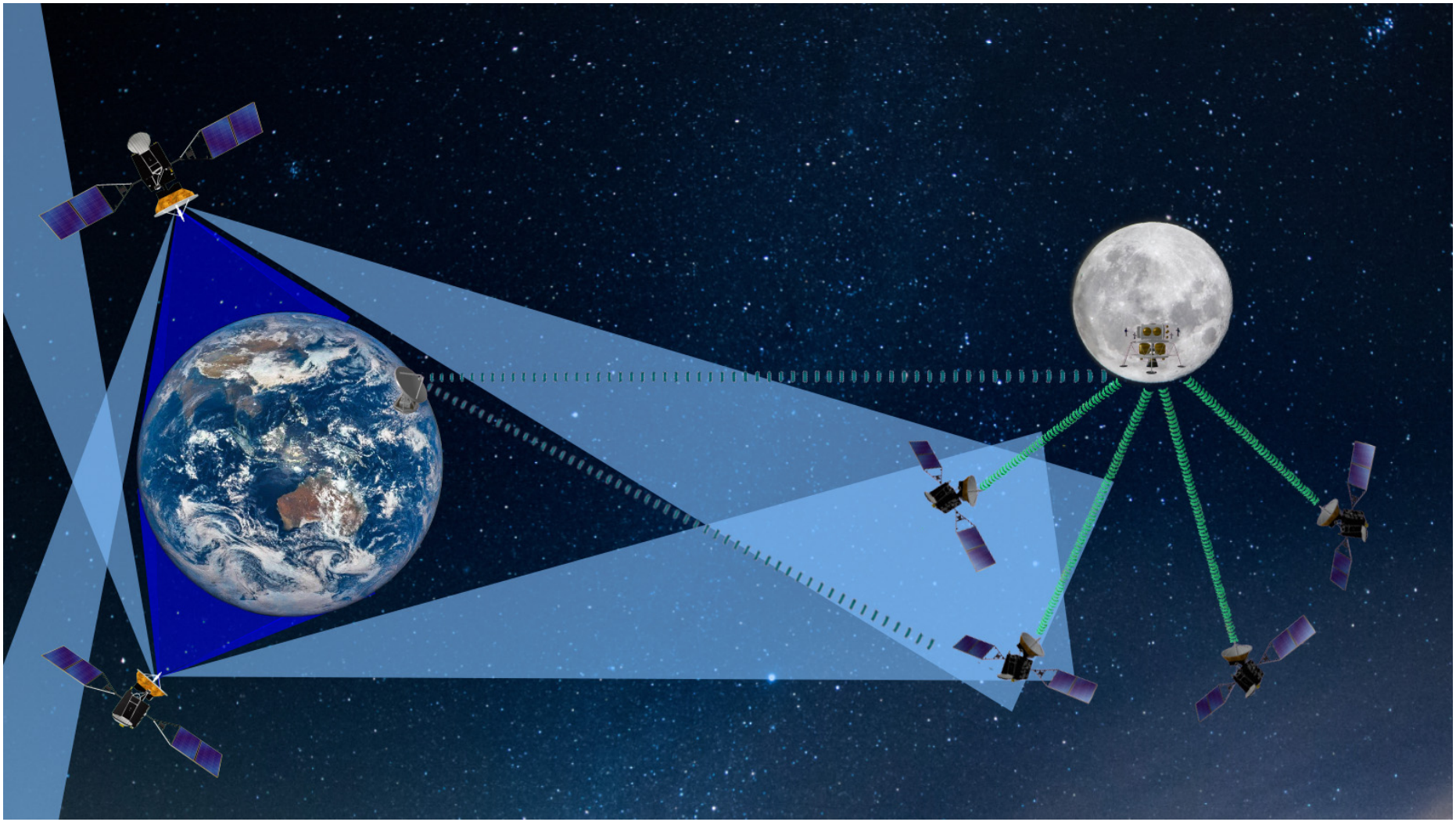
- Requirement: 10 Mbps and more, and hopefully 1 Gbps transmission rate between the moon and the earth
  - 10 Mbps to 1 Gbps from the moon surface to the earth for mission data transmission
  - We use the LNSS satellites as communication relay satellites using X-band, Ka-band, and possibly optical links too





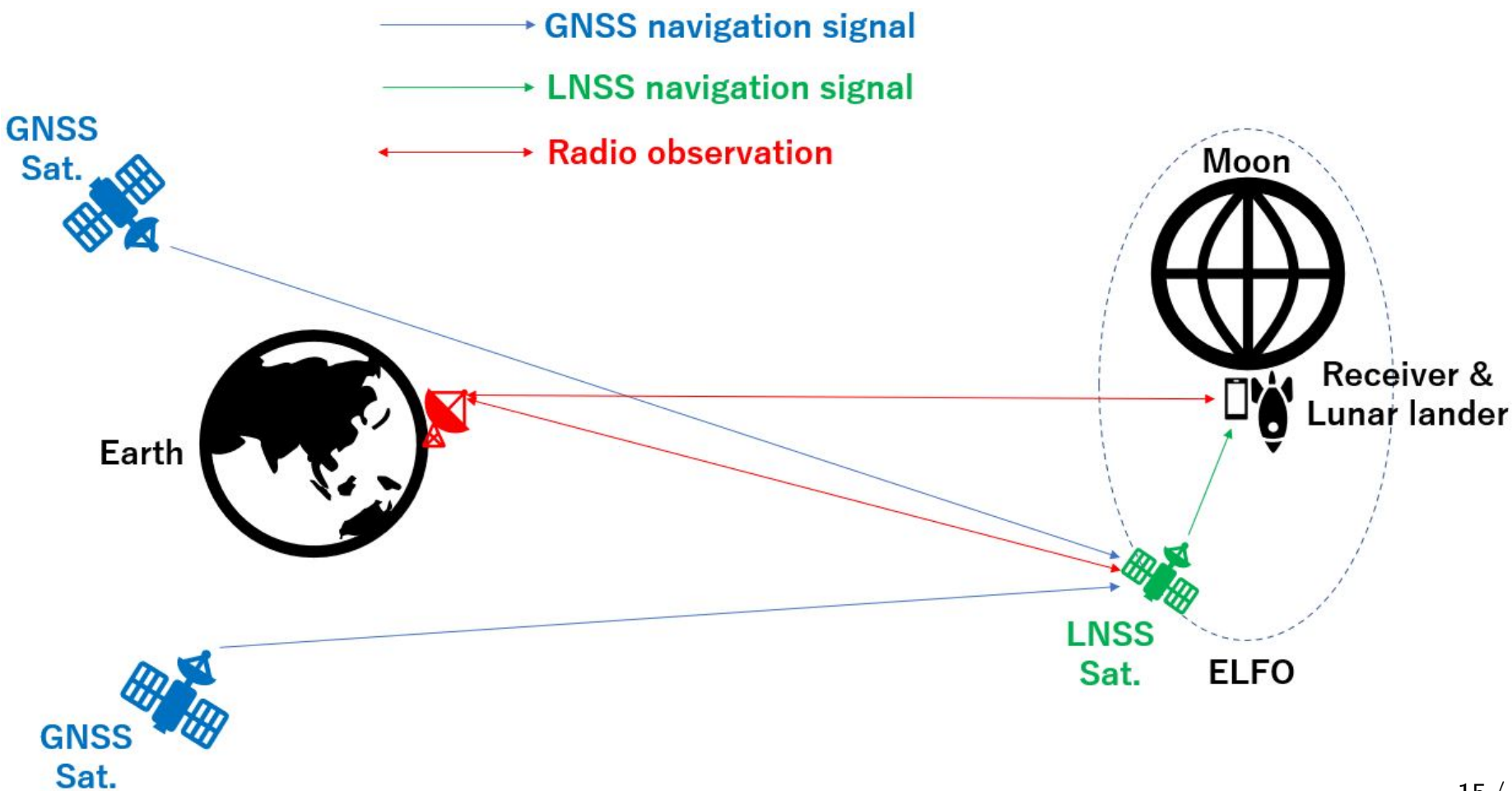
Demonstration mission scheduled in 2028

- How accurate PNT do we actually achieve on the lunar surface? Demonstration mission in real moon environment



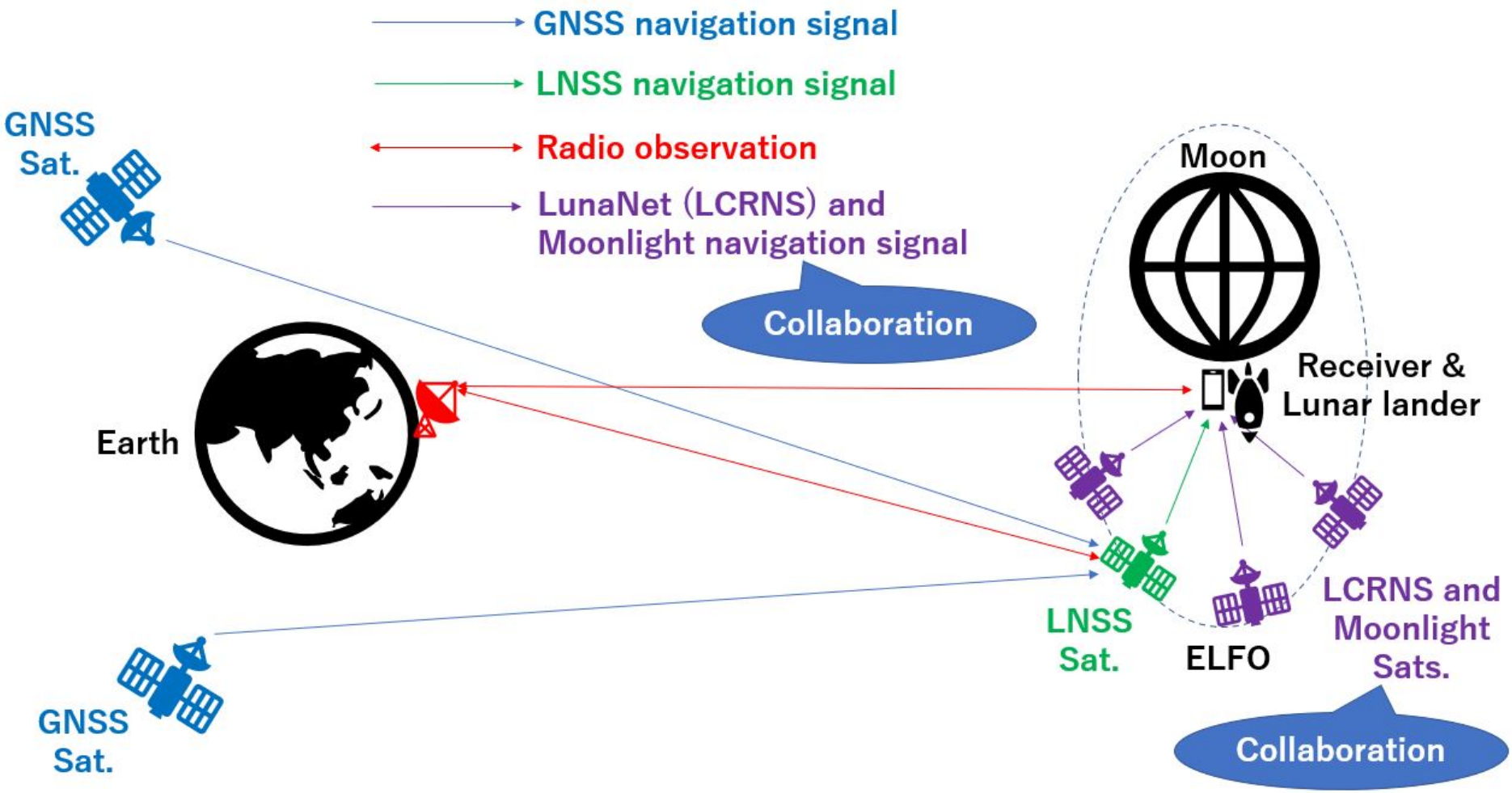
Overview of demonstration mission

- One LNSS satellite and a receiver will be deployed in the ELFO and at the South Pole region, respectively
- These satellite and receiver will be launched and delivered to the moon environment by our rocket and lander



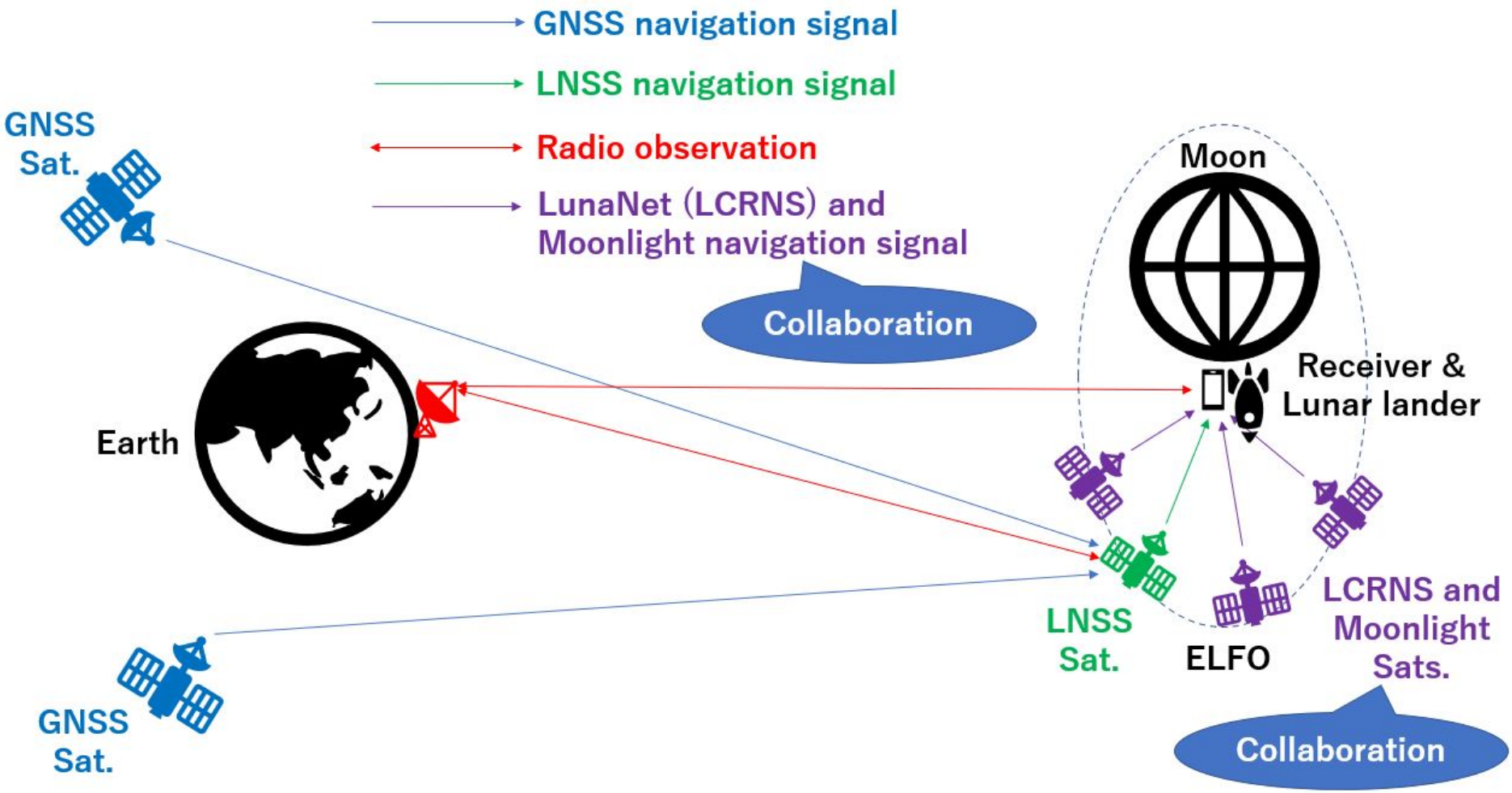
JAXA proposal for enhancing outcome

- Collaboration with the NASA's lunar communications relay and navigation systems (LCRNS) and the ESA's Moonlight to prove our PNT capability on the lunar surface



JAXA proposal for enhancing outcome (cont'd)

- LNSS and Moonlight comply with the US's LunaNet interoperability specification so that the receiver at the South Pole region can receive both LNSS and Moonlight signals



Lunar PNT interoperability

- The interoperability has been one of the key issues in the GNSS community, which has been successful by the international efforts
- The interoperability is also the case for the lunar PNT systems under planning such as the NASA's LCRNS, ESA's Moonlight, and our LNSS
- Thanks to the US's LunaNet activity, we all comply with the LunaNet interoperability specification so that the signals of the LCRNS, Moonlight, and LNSS all become the same
- Interoperability recommendation to the ICG-16 "Coordination of GNSS and lunar PNT systems for lunar operations" prepared by the WG-B Space Use Subgroup (SUSG)

Conclusions

- Mission and system overview of our LNSS are presented
- The demonstration mission is currently under planning and scheduled in 2028, which will become the first-ever lunar PNT experiment in the actual moon environment
  - We intend to perform this mission together with ESA and NASA to prove our PNT capability on the lunar surface