Preliminary Timing Requirements for ILRS

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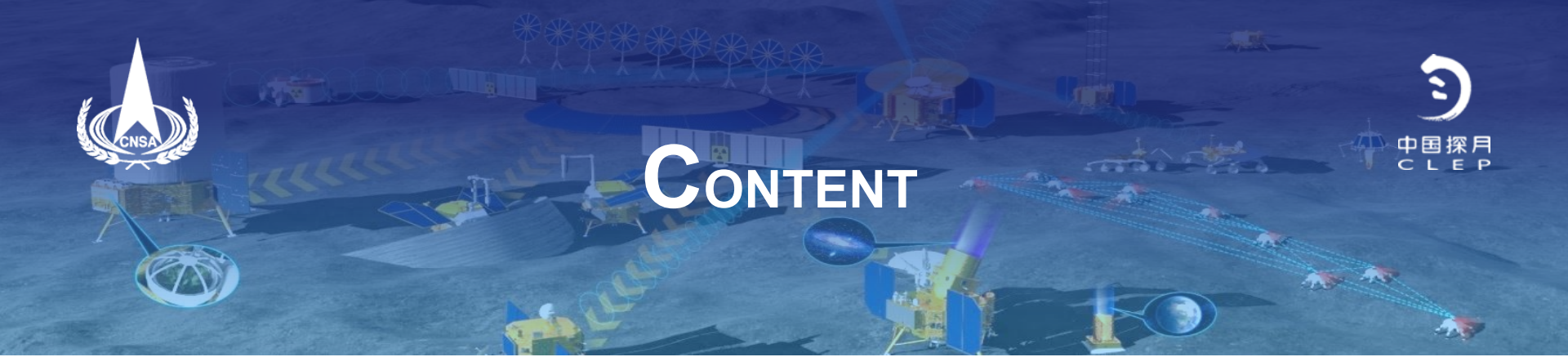
Nov 18th, 2025



CONTENT

International Lunar Research Station

Overview

Definition of ILRS

ILRS is a set of comprehensive scientific experimental facilities jointly constructed by multiple countries on the surface and in the orbit of the Moon

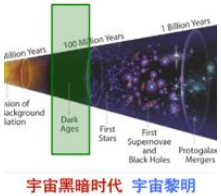
- with scalability and maintainability
- with the capability of long-term autonomous operation and short-term human participation.
- With the support capabilities including energy supply, central control, communication and navigation, Earth-Moon round trip, lunar scientific research, ground support and etc.
- Continuously carry out multidisciplinary, multi-objective, large-scale scientific and technological activities such as scientific exploration, resource utilization, and frontier technology verification.

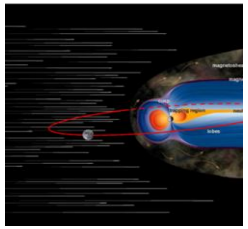
International Lunar Research Station Concept Diagram

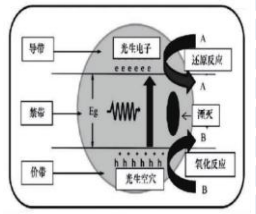
Mission Goals

Scientific Goals

- Geological survey of the Moon
- Astronomy observations
- Sun-Earth-Moon space environment observation
- Fundamental science experiment
- In situ resource utilization

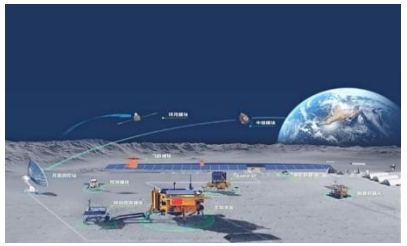




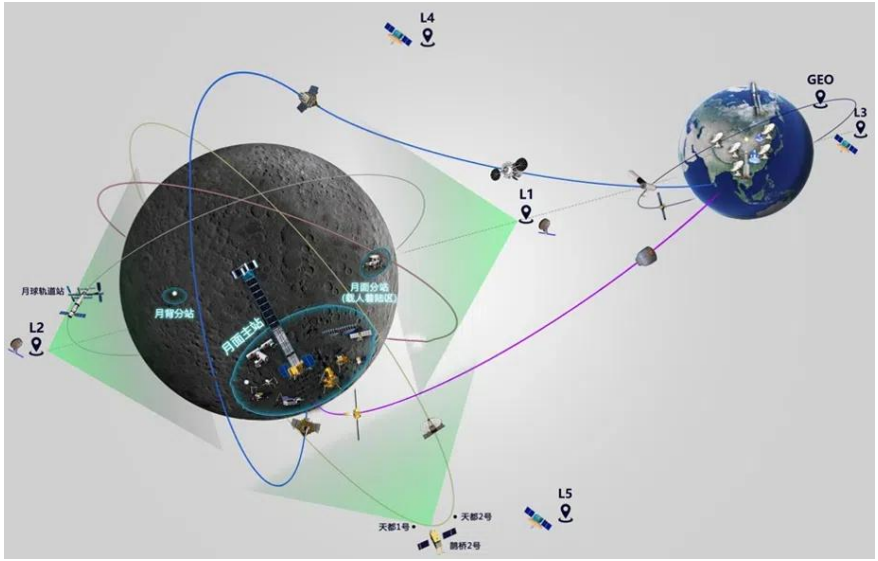


Engineering Goals

- Build comprehensive scientific research sharing platforms
- Promote technology to leap across generations in batches
- Lay the foundation for future large-scale application



Composition of the ILRS



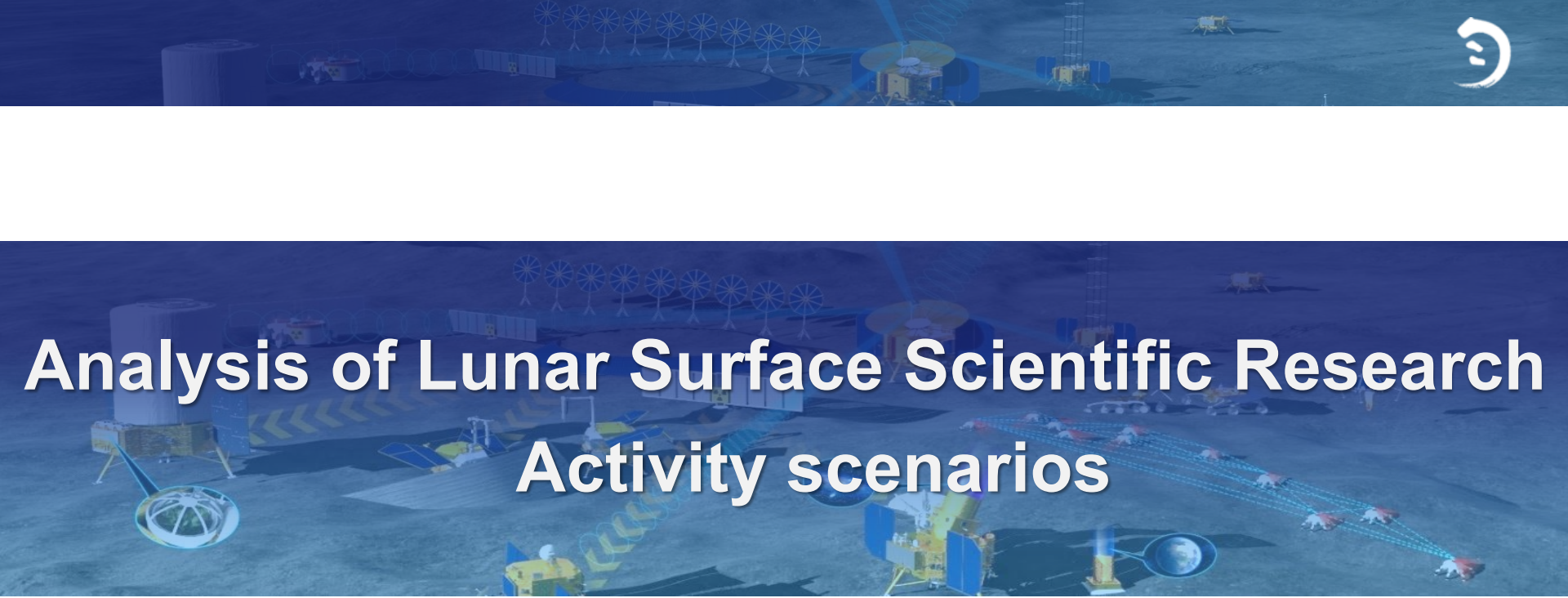
- The International Lunar Research Station consists of three parts:
  - Lunar Surface Segment
  - Lunar Orbital Segment
  - Ground Segment

Cislunar Space & Lunar Surface

- Power Supply
- Command & Information
- Lunar Surface Transportation
- Scientific Operation
- Survival & Protection
- Cislunar Transportation

Ground

- Launch & Recovery
- TT & C
- Science & Application
- Operation Support



Analysis of Lunar Surface Scientific Research Activity scenarios

(1) Lunar Scientific Research Platforms

- **The Comprehensive Geology Research Platform**

  topography and geomorphology exploration, geological structure exploration, material composition exploration, sample collection, and sample selection

- **The Lunar Multi-physics Field Measurement Network Research Platform**

  gravity measurement, electromagnetic field measurement, lunar seismic measurement, and heat flow measurement

- **The Sky Survey Observation Research Platform**

  lunar ultraviolet-optical-infrared observation, ultra long wave observation, very long baseline interferometry (VLBI) observation, MeV gamma-ray observation and decihertz gravitational wave observation

- **The Sun-Earth-Moon Multi-sphere Observation Research Platform**

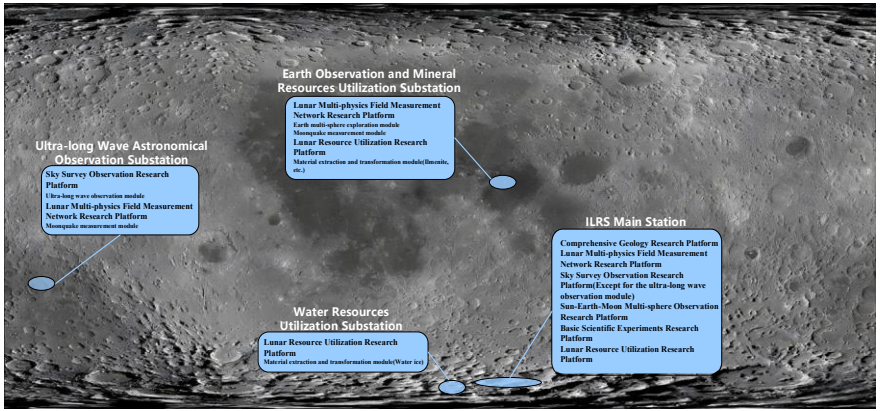
  solar exploration, Earth multi-sphere exploration, and near-moon space multi-source particle response exploration

- **The Basic Scientific Experiments Research Platform**

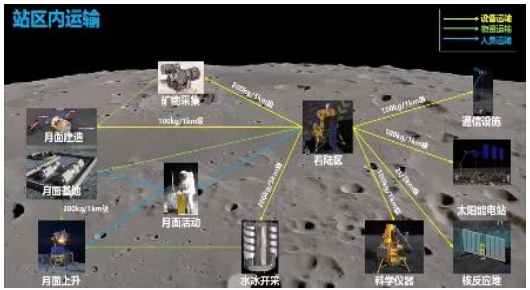
  life science, basic physical science and materials science

- **The Lunar Resource Utilization Research Platform**

  energy acquisition and utilization, material extraction and transformation, and lunar-based manufacturing and construction



(2) Main Lunar Surface Activities of ILRS



~10km ~100km

Within the main station area

- Deployment of support facilities
- Deployment of scientific facilities
- EVA and transportation of astronauts
- Deployment of in-situ resource development and utilization test facilities

Within the south pole area

- Long-distance scientific expeditions covering multiple permanent shadowing areas (PSRs)
- The construction and operation of water resources utilization sub-stations
- Long-distance transportation and deployment of scientific exploration instruments
- Long-distance transportation and deployment of in-situ resource development and utilization devices

Within the whole lunar surface

- The Far Side of the Moon Ultra-Long Wave Astronomical Observation Substation
- The direct-facing lunar observation substation
- Yuehai Mineral Resources Utilization Sub-Station
- The deployment of ultra-long-distance scientific facilities such as moonquakes

Preliminary Timing Needs for ILRS Lunar Surface Activities

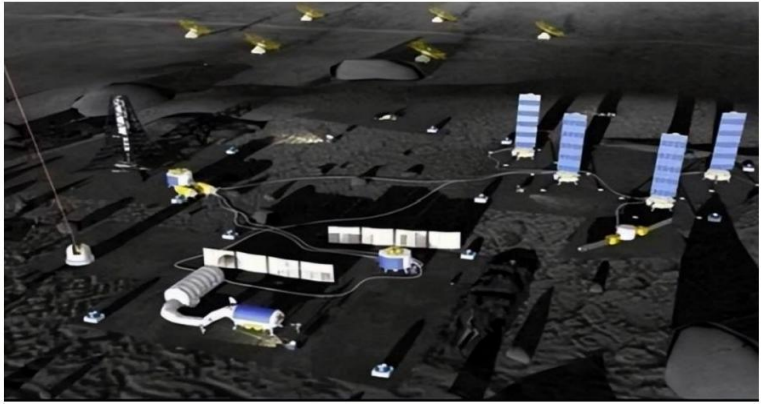
(1) Timing needs analysis for lunar activities in the main station area

Fixed-point landing

- The terrain in the South Pole region of the moon is generally rugged, which poses a high demand for landing capabilities. Especially in the later stages of the con-struction of the lunar research station, where facilities on the lunar surface are relatively concentrated, higher landing positioning accuracy is required.
- Timing: No special requirements

Deployment of general infrastructures and scientific instruments

- Time synchronization: When multiple scientific instruments and equipment carry out joint scientific exploration, energy, communication and other infrastructure services in coordination, time synchronization is required. The accuracy of time synchronization needs to reach the **millisecond** level to facilitate the precise matching of exploration data or services.



(1) Timing needs analysis for lunar activities in the main station area

Travel and operation of the independent mobile modules

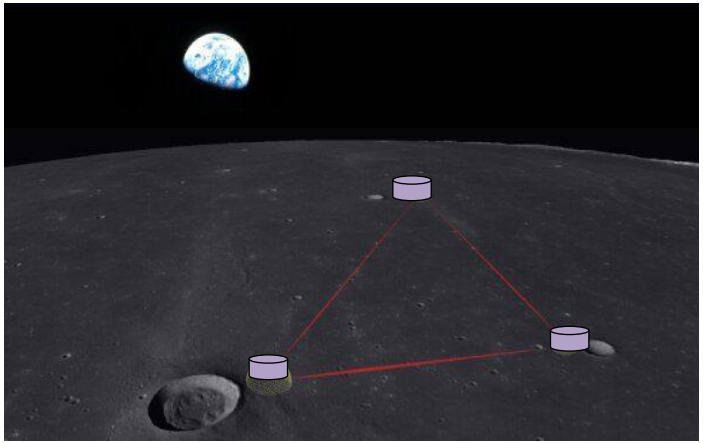
- Time synchronization: When multiple mobile devices on the lunar surface operate in coordination, precise time synchronization is required. The accuracy of time synchronization needs to reach the **millisecond** level to ensure reliable and stable collaborative operations among multiple devices on the Moon.

(1) Timing needs analysis for lunar activities in the main station area

Deployment of lunar-based ultraviolet-optical-infrared telescope

- Time synchronization: The accuracy needs to reach the **microsecond** level. On the one hand, it is used for real-time coordinate calculation to complete tele-scope pointing and tracking. On the other hand, it is used to record the accurate observation time of data, which facilitates high-precision and long-term baseline characteristic changes (such as luminosity) and periodic analysis of the target sources.

Deployment of the lunar gravitational wave observation array

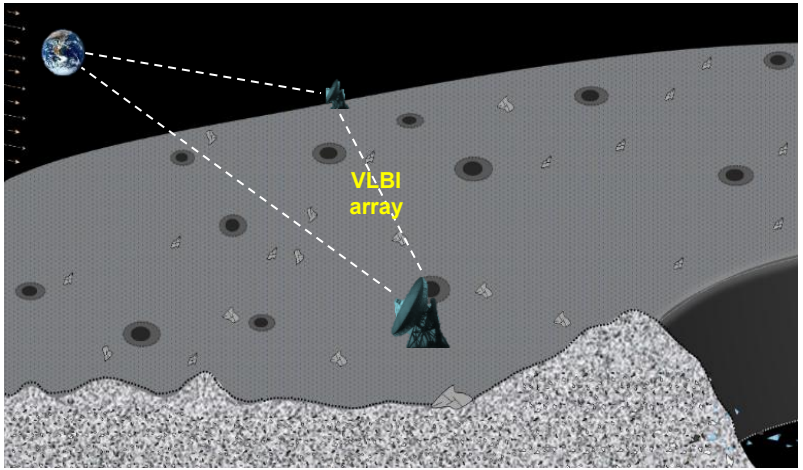


- Time synchronization: It is necessary to synchronize the time of multiple instruments several kilometers apart. The time synchronization accuracy should be better than **500 nanosecond** level to facilitate the precise matching of detection data and eliminate the influence of noise.

(1) Timing needs analysis for lunar activities in the main station area

Deployment of the lunar-based VLBI observation array

- Time synchronization: Very Long Baseline Interferometry (VLBI) array achieves sub-milliarcsecond resolution through multi- antenna signal phase difference calculations, and its detec-tion performance also depends on the absolute accuracy of baseline length and the nanosecond consistency of time synchronization. In order to achieve a larger equivalent aperture and reduce the difficulty of construction, a single site can be built in antenna array mode.Each VLBI site requires time synchronization service with an accuracy of **100 nanoseconds**.

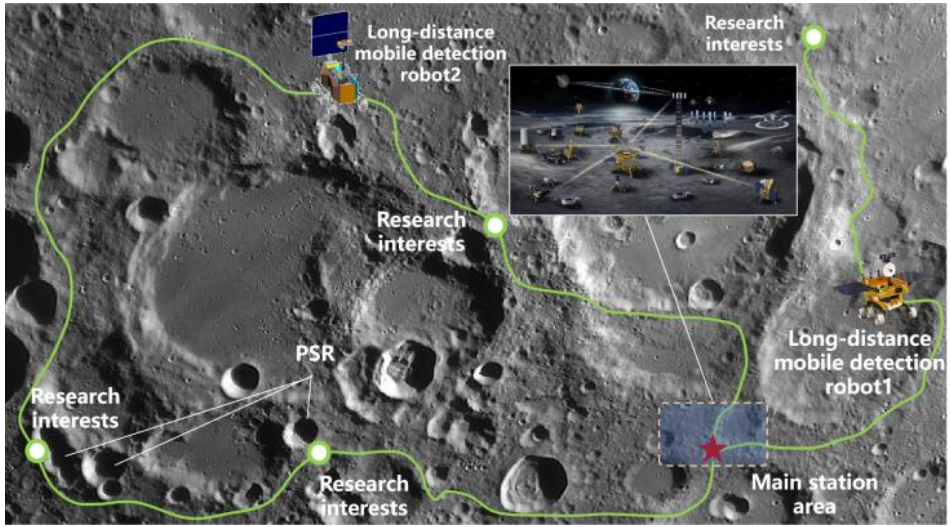


(2) PNT needs analysis for lunar activities in the South Pole region of the Moon

Long-distance scientific expeditions and instrument deployment

- When conducting long-distance scientific expeditions and instrument deployment, the independent mobile modules will leave the support of the lunar communica-tion network in the main station area, relying on direct ground links or lunar orbit constellations for TT&C, and relying on Ground TT&C (if visible), autonomous navigation by on-board sensors, lunar orbit satellite navigation, and other means to provide positioning and navigation information. The PNT needs are slightly lower than those of the independent mobile modules operating within the main station area.

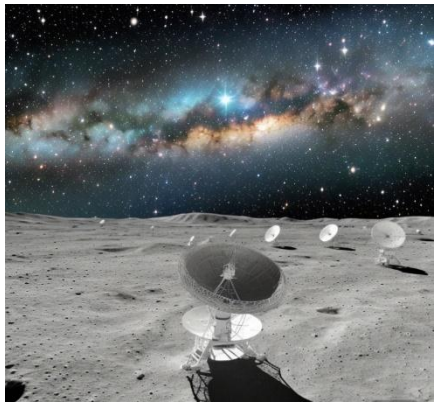
- Time synchronization: When multiple scientific instruments and equipment conduct joint scientific exploration, time synchronization is required. The accuracy of time synchronization needs to reach the **millisecond level** to facilitate the precise matching of exploration data.



(3) PNT needs analysis for other activities on the lunar surface at greater distances

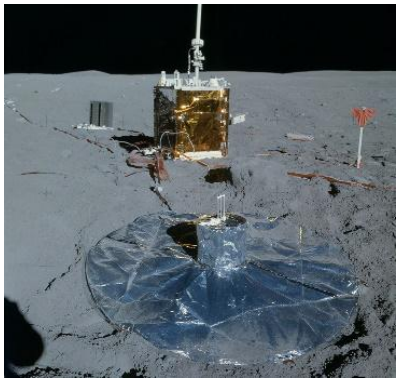
Deployment of the ultra-long wave radio observation array

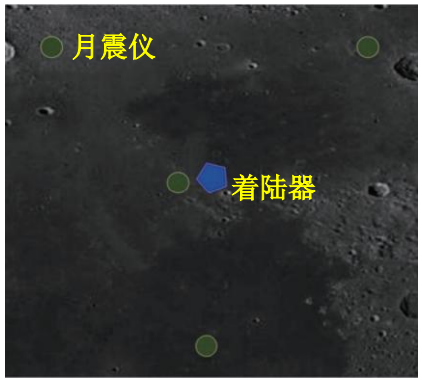
- Time synchronization: All sub-stations share the same clock. The clock itself requires good frequency stability and can be synchronized with external time synchronization according to the preset cycle or as needed. The time synchronization accuracy should be better than **1 microsecond**.



Deployment of the lunar seismograph

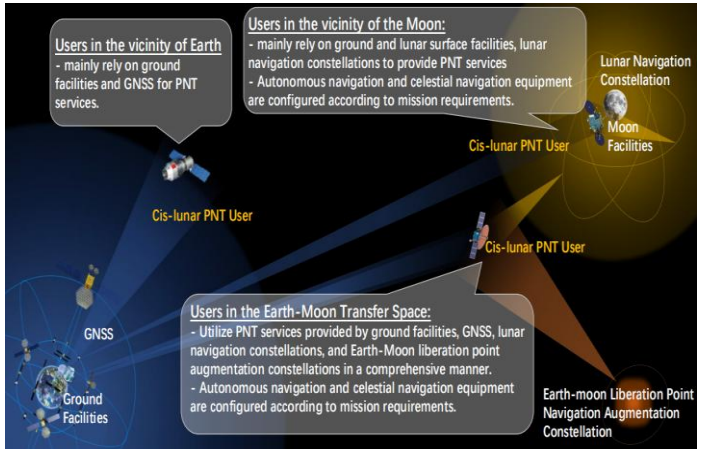
- Time synchronization: It is necessary to synchronize the time of multiple instruments, and the time synchronization accuracy should be better than the **500 nanosecond** level to facilitate the precise matching of detection data.

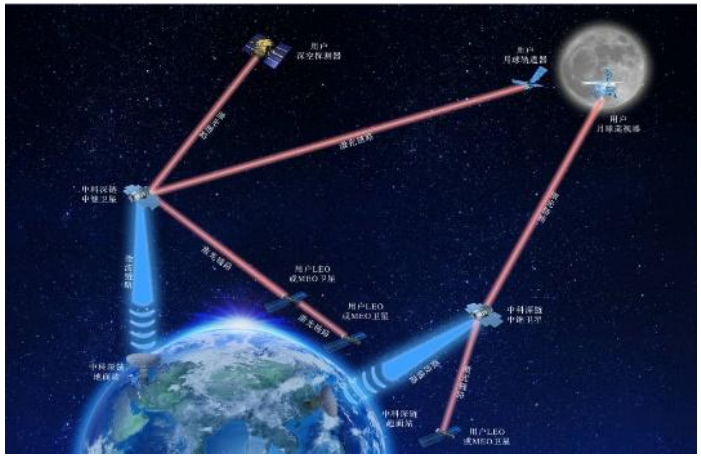


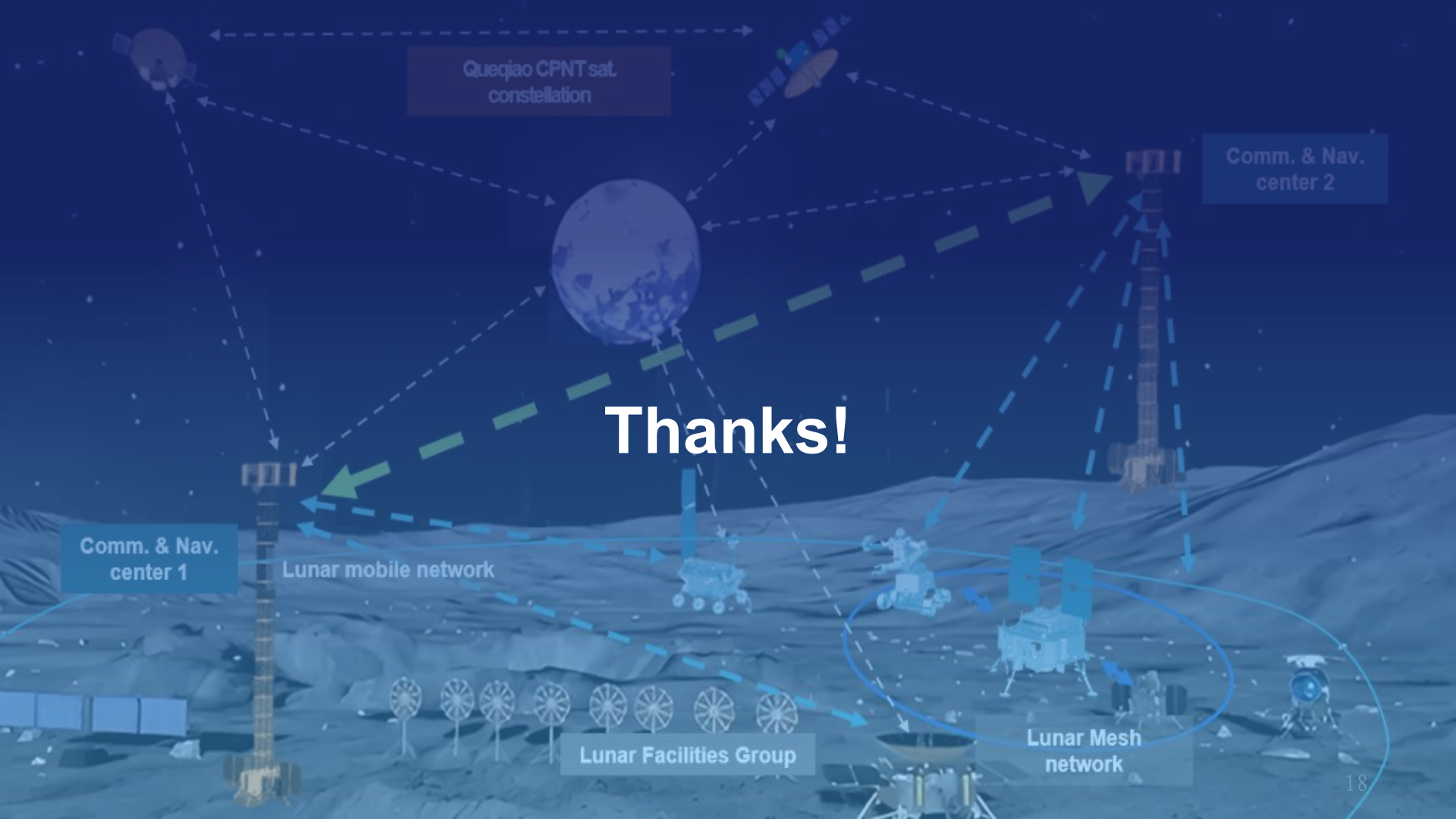


(4) Summary of PNT capability requirements

Scope of activities	Scientific research activities	Timing needs
Lunar surface activities within the main station area (~10 km)	Fixed-point landing	No particular requirements
	Deployment of general infrastructure and scientific instruments	Joint exploration devices require millisecond-level timing accuracy
	Travel and operation of independently moving modules	Millisecond-level timing accuracy
	Deployment of lunar-based UV-optical-infrared telescope	Microsecond-level timing accuracy Time
	Deployment of the Lunar gravitational wave observation array	Synchronization accuracy of 500 nanoseconds
	Deployment of the lunar VLBI observation array	100 nanoseconds timing accuracy
Lunar surface activities in the South Pole region (10 km to 100 km)	Long-distance scientific expeditions and instrument deployments	Millisecond-level timing accuracy
Scientific research activities on the entire lunar surface (over 100 kilometers)	Deployment of the seismograph	500 nanoseconds timing accuracy
	Deployment of ultra-long wave radio observation array	Microsecond-level timing accuracy






Queqiao CPNT sat. constellation
Comm. & Nav. center 2
Comm. & Nav. center 1
Lunar mobile network
Lunar Facilities Group
Lunar Mesh network

Thanks!