16th Meeting of the International Committee on
Global Navigation Satellite Systems

# The Envision of Earth-Moon Communication-Navigation System

XiongWen He, Hui Yang , Xinuo Chang,
Xianqiang Li, Jionghui Li, Qinyuan Zhao, Yuchen Jia
China Academy of Space Technology(CAST)

October 2022

# CONTENTS





# Current Situation and Envision of Deep Space Exploration in China

# 01

# Current Situation and Envision of Deep Space Exploration in China

**The peaceful exploration，development and use of outer space are equal rights for all countries in the world. China calls on all countries working together to build a community with a shared future for mankind, and deepen international exchanges and cooperation in space on the basis of equality, mutual benefit, peaceful utilization and inclusive development.**

**——2021 China Space White Paper**

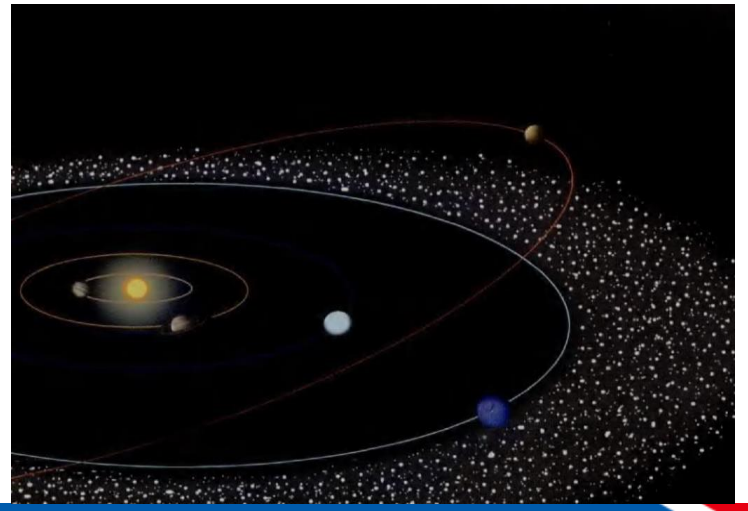
# Current Situation and Envision of Deep Space Exploration in China

**In deep space exploration, “CE-4”has landed on the far side of the moon, “CE-5” returned to the earth with soil of the moon. Three steps of China’s Lunar exploration project “surrounding, landing and returning ”have been successfully added. “TW-1” visited Mars, accomplished “surrounding, landing and touring ”with one mission. Space Exploration of China has been accomplished from Earth-Moon scope to interplanetary scope.**

# Current Situation and Envision of Deep Space Exploration in China

**In the coming year, China will continue to carry out Lunar exploration project, such as exploring and taking samples from polar region, high-precision Lunar polar region landing ,shadow crater flying, and carry out cooperation in the construction of international Lunar Research Stations.**

**China will continue to carry out planetary exploration project, complete missions like sampling and returning from Mars, exploring the Jupiter scope, sampling from near-Earth asteroids, exploring the comets belt, and demonstrate plans for exploring the margin of solar system.**





# Communication-Navigation Requirement of Deep Space Exploration

# 02

# Communication-Navigation Requirement of Deep Space Exploration

## 1. Requirements for Lunar Exploration Engineering

### （1） Unmanned lunar exploration

| ~2030 | 2031-2035 |
| --- | --- |
| CE-7 prepares to accomplish surrounding, landing ,touring and jumping on the south pole of the Moon<br>CE-6 prepares to sample and return from the far side of the Moon.<br>CE-8 prepares to accomplish technical identification for key technology of International Lunar Research Station. | Implementing a series of tasks of ILRS, building International Lunar Research Station, including command center, facilities of energy, communication and Lunar research. |

the Fourth Phase of Lunar Exploration

International Lunar Research Station

## 1. Requirements for Lunar Exploration Engineering

### （1）Unmanned lunar exploration : communication and positioning requirements

**For unmanned lunar exploration，due to the current limited ground-based communication and positioning support for special locations such as lunar polar region, it is necessary to increase the coverage and the number of users served simultaneously.**

- **Communication：**

**The fourth phase of Lunar Exploration and the International Lunar Research Station all target the polar region of the Moon. It is necessary to increase the coverage capability of the Moon South Pole ,and support frequency bands including X, Ka, UHF, etc.**

- **Positioning：**

**In the construction of the International Lunar Research Station, the lander will land on the same area densely.**

# Communication-Navigation Requirement of Deep Space Exploration

## 1. Requirements for Lunar Exploration Engineering

### （2）Manned lunar exploration： communication and navigation requirements

- **Communication：**

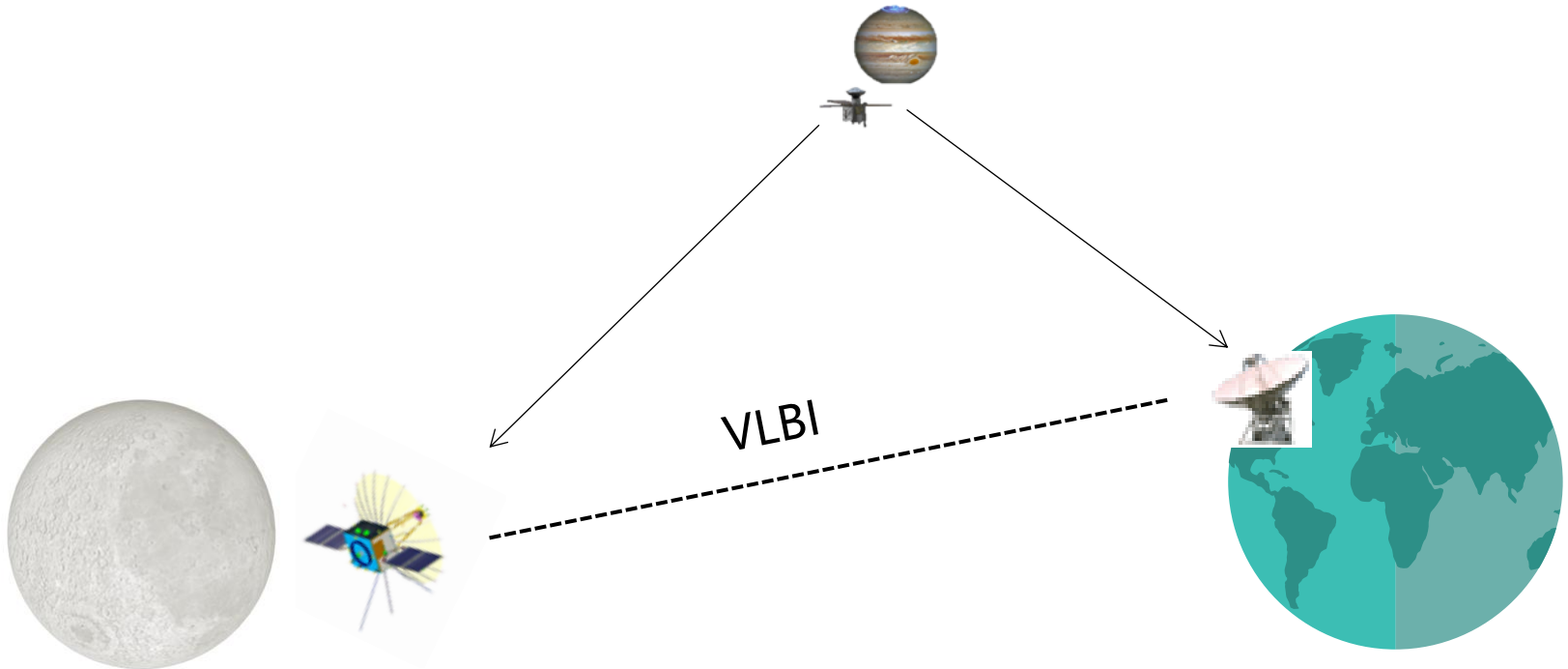
**The circum-Moon flight will experience the lunar occluded region, and there will be subsequent exploration requirements for the Moon polar region and the far side of the Moon. In order to ensure the safety of the astronaut, it is necessary to provide continuous and uninterrupted TT&C coverage. S, Ka need to be supported.**

- **Positioning and Navigation:**

**Support multiple missions of manned Lunar landing in the same area.**

## 2. Requirements for planetary exploration engineering

- **In planetary exploration missions, there is an urgent need for long-distance communication and high-precision autonomous navigation.**
- **The VLBI orbit determination system of earth-moon long baseline is beneficial to support the high precision measurement of deep space probes.**





# Envision of Prospective Scheme

# 03

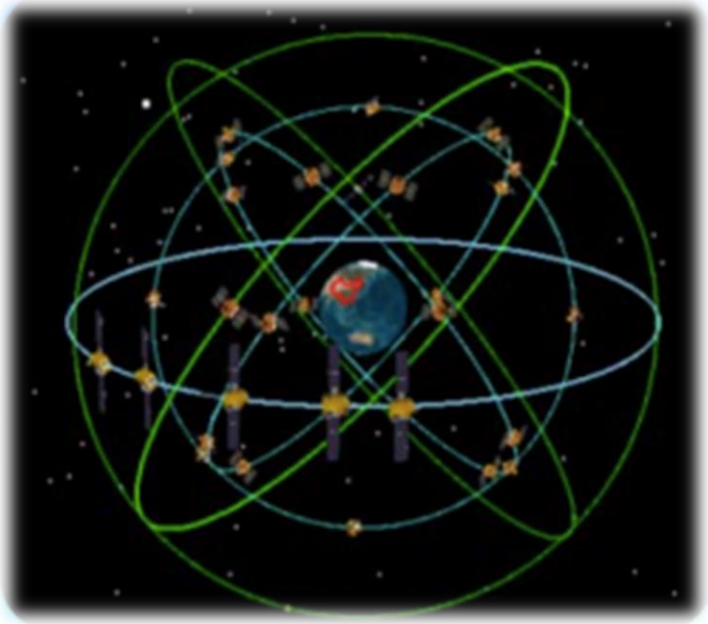
# 1. Analysis of existing GNSS and Lunar Communication capabilities

## (1) Support capability of BD for SSV

- **The advocacy of interoperation among GNSS can effectively make up for the shortcomings of single navigation satellite system in space service volume.**

- **In the process of BD system from regional to global, the coverage overlap and positioning accuracy of the signal are significantly improved.**

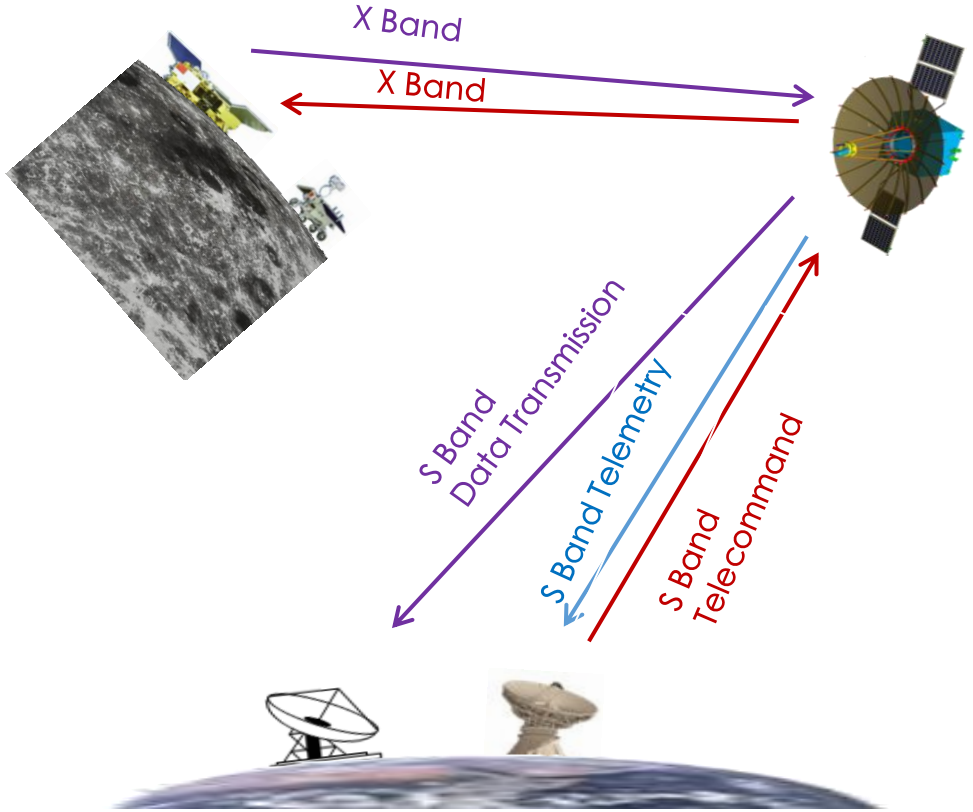
- **Navigation signals and message information are interoperable with other GNSS.**



# 1. Analysis of existing GNSS and Lunar Communication capabilities

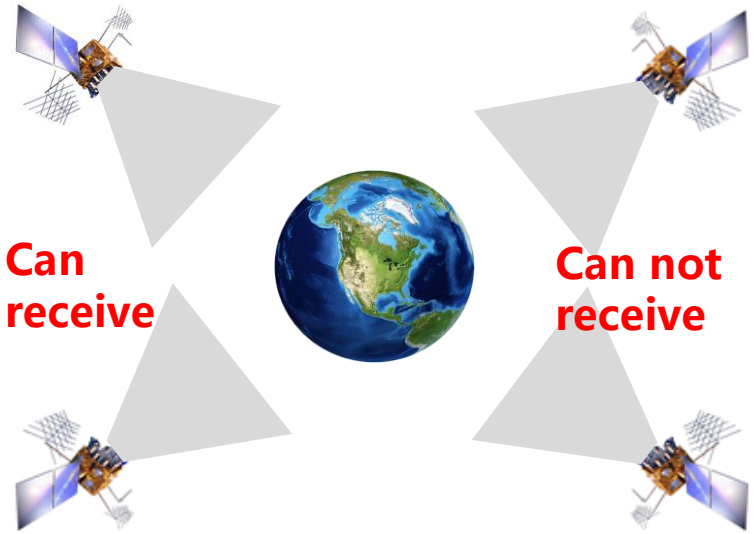
## (2) Capability of Lunar relay communication

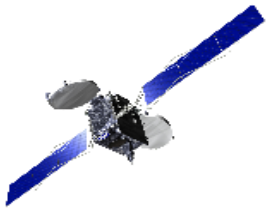
**The QueQiao-1 satellite developed by China was launched into halo orbit at L2 point, which is the first relay satellite providing communication on the far side of the Moon.**



# 2. Shortage of Earth-Moon scope GNSS and relay communication

- **GNSS satellites mainly serve the ground or near-Earth space, which limits the number of navigation satellite that can be received by the probe in the Earth-Moon space.**
- **When the probe is on the far side of the moon, all GNSS satellites are not visible.**
- **The orbit determination accuracy of Earth-Moon space probe using GNSS navigation is limited.**

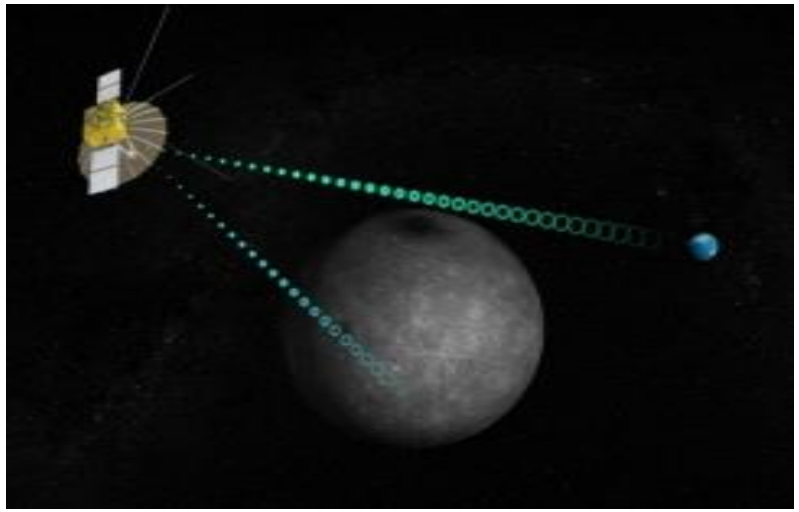


A probe in the Earth-Moon transition segment

# 2. Shortage of Earth-Moon scope GNSS and relay communication

- **The current QueQiao-1 has insufficient support for the lunar south pole, which is difficult to meet the relay communication requirements of the International Lunar Research Station and other missions at the lunar south pole.**
- **Difficult to support the cislunar space mission.**
- **The communication rate does not meet the future demand.**
- **It can not support S, Ka relay links.**



# 3. Plan for the next step

**The Earth-Moon navigation system based on enhanced GNSS**

**Communication-navigation system for near-moon space mission**

**Communication-navigation system for cislunar space mission**

# 3. Plan for the next step

## (1) The Earth-Moon navigation system based on enhanced GNSS

### Use demand

- **Simplicity of user equipment**
- **Accessing service quickly**
- **Signal type and power**: using compatible navigation signals
- **Coverage**: more than 4 satellites are visible at the same time

### The current status

- **Strength of signal and sensitivity of the receiver：** cover 0.5 earth-moon distance
- **Main constraints：** the visible number and structure of navigation satellites
- **Analysis：** the side-lobe strength of different satellites is significantly different

### Plan in future

- The **GNSS satellites** transmit enhancement navigation signals to extend service range

# 3. Plan for the next step

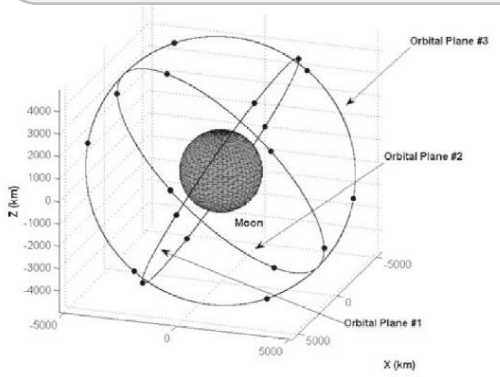
## (2) The envision of communication- navigation system for near-moon space mission

**Requirements**

- Lunar orbiter and earth-moon transfer orbit
- Lunar polar orbiter
- Landers at the far side of the moon
- Astronaut and lunar rover on the moon

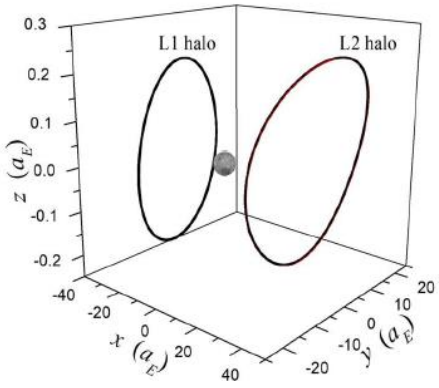
**Method 1**
**Walker constellation of the moon**

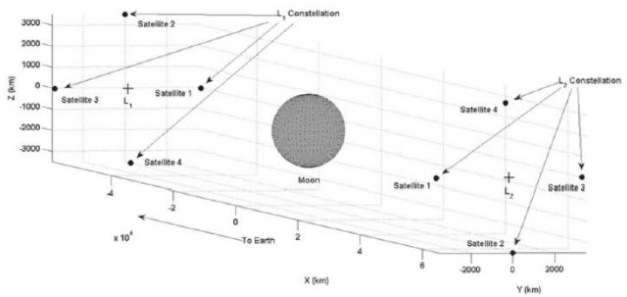
- 18 satellites, 3 orbital plane
- circular lunar orbit
- 4000km, 60°




**Method 2**
**Satellites at L1&L2**

- 4 satellites at L1 and 4 satellites at L2
- Cover the entire surface of the moon
- 97.7% coverage at certain time



# 3. Plan for the next step

## (3) The envision communication-navigation system for cislunar space mission

### Requirements

- Communication and navigation of earth-moon libration points L3/4/5.
- Relay satellite navigation of earth-moon communication.
- Communication and navigation of other lunar exploration tasks.
- Support S，Ka，X，etc.

### Method 1
### Communication-navigation constellation of libration points

- Satellites at L3、L4、L5、L2
- 99% coverage of earth surface
- 99% coverage of lunar surface

### Method 2
### Other resonance orbits

- The inner space is covered periodically
- Shorter communication distance
- When the number of satellites is less than 3, there is a gap for lunar coverage

# 3. Plan for the next step

## (4) The envision of earth-moon communication-navigation system

**The earth-moon navigation based on GNSS enhancement**

Improve the existing GNSS

- **Object：GNSS system**
- **Method：Transmit enhanced navigation signal using current/future navigation satellites to extend the utilization of GNSS in cislunar SSV.**
- **Expected result：The accuracy of navigation and positioning is better than 100m.**

**The envision of earth-moon communication-navigation constellation**

Establish new communication-navigation system

- **Object：Earth-moon communication-navigation constellation**
- **Method：Deploy the communication-navigation constellation around the moon and at the earth-moon libration points. The constellation contains 4 to 18 satellites. Positioning of planetary probes by deploying VLBI payloads on the constellation.**
- **Expected result：**
  - **4L1+4L2：Cover the entire surface of the moon**
  - **L2+L3+L4+L5：Cover the entire surface of the earth and the moon**
  - **18 satellites at lunar orbit：Cover the entire surface of the moon**

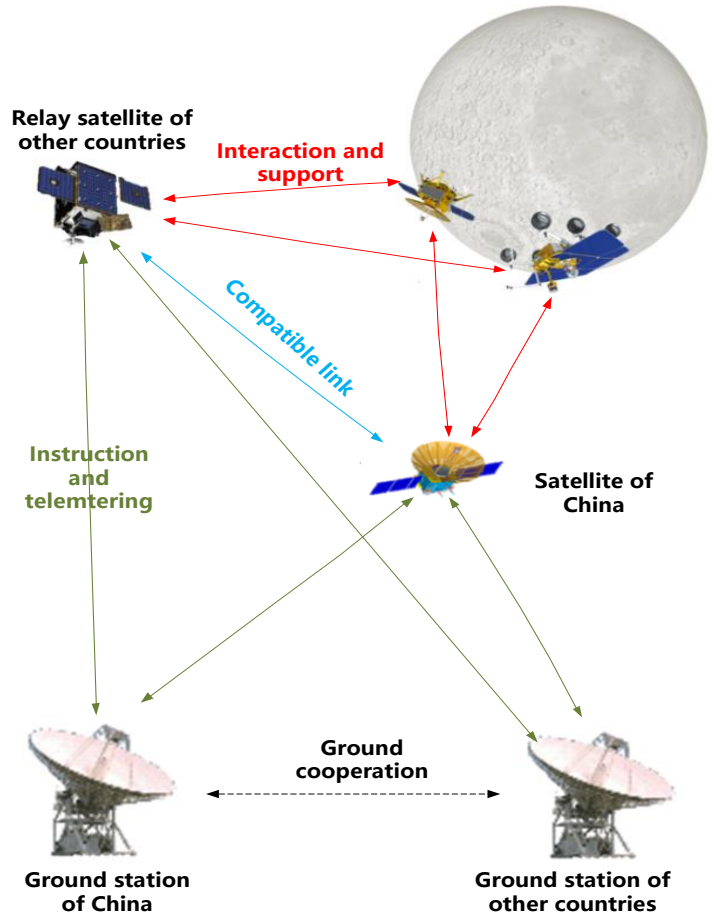


# Mode of International Cooperation

# 04

# Mode of International Cooperation

- **Task Level**
  - **Support international lunar exploration.**
  - **Support international deep space exploration.**
- **System Level**
  - **Around the moon: design the unified system structure and cooperate to establish earth-moon communication-navigation system.**
  - **Around the earth: Using ground station of cooperative partner to support the earth-moon communication-navigation system.**




**Ways of cooperation**

# The Ending

- **The establishment of the Earth-Moon communication-navigation system, as the Earth-Moon space infrastructure, provides communication and navigation services for international unmanned lunar exploration, manned lunar exploration, deep space exploration, etc. It is a powerful guarantee to boost the development of the Earth-Moon space economy and aerospace industry, and an important support for efficient utilization and cognition of space.**

- **Adhering to the concept of a community with a shared future for mankind, China is willing to continue to work collaboratively to make new contributions to promoting mankind's exploration of deeper and farther space and serving the progress of human civilization.**



# Thanks!