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An overview of the mission and technical characteristics of Change'4 Lunar Probe

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Change'4 Lunar Probe will softly land on the farside of the Moon for the first time of all mankind and carry out *in-situ* and rovering exploration. In this paper, the scientific significance and engineering difficulties of Change'4 are introduced and the probe's general design, including the aspects of landing site selection, relay communication, trajectory design of relay satellite is explained. Besides, four key technologies, namely safe landing strategy on complex terrain, orbit design and control of libration point 2, relay communication on L2, radioisotope thermoelectric generator (RTG) and electric-thermal utilization, as well as how to realize them are also discussed. Finally the prospect of the prominent technological breakthrough of Change'4 is described.

Change'4, farside, relay communication, libration point, South-Pole Aitken Basin, RTG

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1 Introduction

As the only natural satellite of the Earth, the Moon is tidally locked to the Earth, which means that it always shows the same face to the Earth. This side is known as its nearside, which covers almost 60% of the whole sphere. The other side of the Moon which never faces the Earth is called its farside. During the long process of 60 years of lunar exploration, with remote sensing technology, people have obtained numerous data about the topography, element distribution of the farside of the moon which cannot be obtained directly from Earth. However, no spacecraft had ever landed on this barren terrain for scientific exploration.

The farside of the Moon, for its special location, has unique advantages that the nearside of the Moon does not have in areas such as the geographic evolution study, low-frequency cosmic radio measurement.

Change'4 Lunar Probe is scheduled to be launched in 2018 and will land softly on the farside of the Moon for the first time of all mankind, attempting an *in-situ* and rovering exploration, meanwhile sending data back to Earth via a relay satellite. In this paper, the significance of Lunar farside soft landing and Change'4 mission profile are introduced, followed by the key technologies and how to realize them. Finally, the expected results of the probe will be explained.

2 The significance of soft landing exploration on Lunar farside

At Lunar farside, numerous highland terrains are distributed all over, including the highest peak, which is up to 10.9 km. In the highland area, craters and mountains are widely spread. The well-known South-Pole Aitken Basin (SPA) is located in the southern part of the farside, with the central area at latitude 40°–60°S, longitude around 180° and the diameter ranging from 2000–600 km. This is the largest-scaled and

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eldest impacted basin in the solar system and of high scientific interest [1]. Elevation diagram of SPA basin is as shown in Figure 1.

2.1 Scientific significance

The farside of the Moon, for its special location, is of unique peculiarity that the nearside cannot match.

On one hand, the farside shields all kinds of radio waves emitted from the Earth, thus becomes the best place for cosmic radio spectrum detection. On the other hand, the original information of the Moon is hidden in the largest, deepest and eldest SPA. It is crucial for the study of the history, evolution, composition and components of the deep-layer of both the Moon and the Earth system. Besides, how SPA is formed remains controversial and deserves further research. Soft landing on the SPA as well as rovering exploration of it are of great scientific significance mainly in the following two aspects.

2.1.1 Planetary formation and evolution

1) The study of SPA may benefit the discovery of material composition of Lunar crust and mantle. So it opens an important window to the study of the deep-layer material composition of the Moon.

2) SPA is a basin (its altitude is 13 km lower than its surrounding highlands) and of thin crust. Whether in the passive or active modes that bring out the Lunar mare basalt, there should have emerged large amount of basalt in SPA. However, currently obtained data cannot effectively prove that the basin has abundant basalt. On the other hand, absence of basalt may indicate something happened in the process of Lunar thermal evolution and differentiation in early times.

3) Comparing the craters in SPA with the Lunar mare we can see that the degradation situation of SPA is not obvious. Also no crater with Lunar rays has been discovered. Therefore the formation, evolution, topography and chemical characteristics of craters in the SPA are apparently different from those of other terrains.

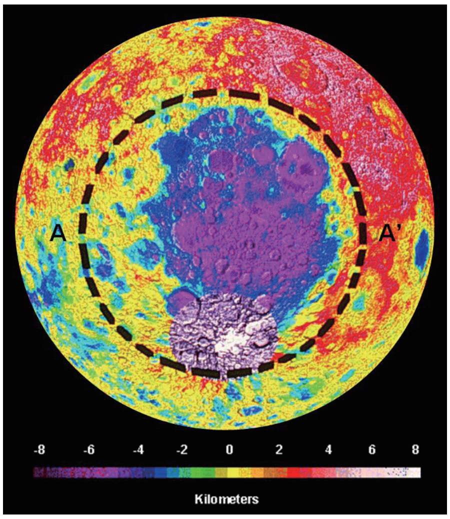

Figure 1 Elevation diagram of South-Pole Aitken Basin.

2.1.2 Ideal observation site for low-frequency radio

The astronomical observation of radio waves is one of the most effective methods to study and understand the universe. At present, most portion of the spectrum has been detected, such as ultraviolet wave (in 1890s), radio wave (wavelength less than meters, in 1930s), X-ray (in 1940s), infrared and millimeter wave (in 1950s), Gamma-ray (in 1960s). But no myriametric wave (<30 MHz) has been detected yet. The detection of myriametric wave is of much importance for all-sky imaging obtained by continuous sky scanning of discrete radio source, cosmic dark times study (21 cm radiation in dark times), solar physics, space weather, extreme-high-energy cosmic ray and neutrino study [2].

Interfered by ionosphere and Earth radio waves, it is impossible to detect myriametric wave on the Earth. In earlier times, wave detection satellites are RAE-A/B (NASA). RAE-A was launched in 1968 and operated in near-Earth orbit. Its scientific objective was to detect the intensity of cosmic ray (0.2–20 MHz). But it was interfered by radio waves in Earth orbit. RAE-B was launched in 1973 and was injected into the lunar orbit, whose scientific objective was to detect the long-wavelength radio waves (working frequency 25 kHz–13.1 MHz). It demonstrated that the lunar farside is ideal for myriametric wave detection [3].

At present, low-frequency radio detection was mainly achieved via spacecraft operating in circumlunar orbit by foreign countries but none of them has done this on the Lunar surface.

The exploration of Change'4 will further promote people's understanding of the farside of the Moon. With comprehensive analysis and study on the nearside exploration data, more general understanding about the Moon will be obtained and the reliability of a theoretical system will be increased.

2.2 Engineering difficulties

To land on the farside and carry on *in-situ* exploration has become one of the great targets for lunar exploration of all nations [4]. Nevertheless, no country has success in landing on that side. One of the major reasons is that landing on the farside of the moon needs to meet more technical challenges. Compared with the nearside, the technical difficulties of landing on the farside involve the following three aspects.

2.2.1 Safety insurance of landing on complex landform area

As shown in Figure 2, at the nearside, flat mares are widely spread. Change'3 Lunar Probe had landed on the more flat Sinus Iridum. On the more rugged farside, highlands and craters are distributed everywhere. The rugged terrain brings severe challenges on navigation, landing stability and safety

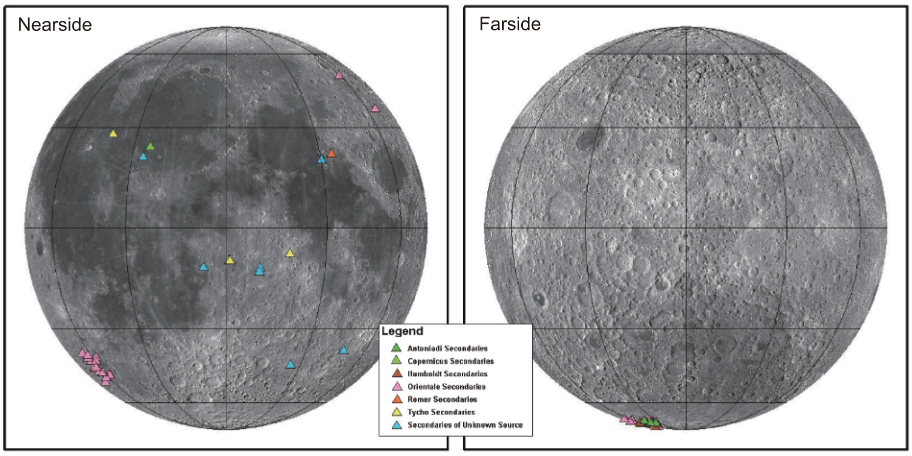

Figure 2 The topography of nearside and farside of the Moon.

as well as operation performance on Lunar surface after landing.

2.2.2 Relay communication

Because one can never see the farside of the Moon from the Earth, neither the lander nor the rover can directly communicate with ground TT&C stations. Thus relay communication is a necessary way to enable the communication between the farside of the Moon and the Earth. The relay satellite's trajectory design, TT&C link design, relay modes selection can greatly influence the mission, and therefore the optimization of them is essential. Meanwhile, the more complicated the task is, the more complicated ground operation is, and the more risky the mission is.

2.2.3 Lunar soil temperature measurement at night

To further understand the Lunar soil features and to obtain a first-hand engineering data, Change'4 will measure the soils temperature at night.

For a moon night that lasts 14 earth days, without solar power, the temperature will fall to −180 °C. The obstacle of ensuring the power supply and temperature of measurement facilities and of obtaining the real temperature of soil with less influence from the probe needs to be removed.

Such a breakthrough in engineering is key to the success of China's Lunar and deep space explorations.

3 System design of Change'4

3.1 System configuration of Change'4

The Change'4 Lunar Probe is comprised of a lander, a rover and a relay satellite. Both the lander and the rover are developed from mature lunar probes of Change'3 [5] which are designed and developed by CAST, and have successfully softly landed on Sinus Iridum as well as completed a rovering exploration in December, 2013. To cater to the terrain and relay communication conditions as well as the operation demand at night, some parts of the hardware and software have been adaptively modified.

The relay satellite is based on the mini-satellite platform designed by CAST and replaces several vital products with adaptively modified and newly developed products to satisfy the mission requirements.

To ensure the successful implementation of the whole mission, the relay satellite will be launched 6 months ahead of the lander and the rover. After the successful operation and in-orbit test of the relay satellite, the lander/rover will be launched for joint exploration.

3.2 Constraints on landing site selection and analysis

During the design phase, while trying to resolve problems that may emerge the specific landing site selection, at least eight aspects should been taken into account.

1) Scientific exploration requirements. To ensure that as much as possible scientific exploration findings are obtained at the selected landing site.

2) Trajectory constraints. The subastral point tracks in different circumlunar orbits are distant from each other. To reach the designated region, measures need to be taken when designing the trajectory and control strategy.

3) TT&C segment requirements. Before the landing, to precisely forecast the position of the probe, TT&C segment needs to be spared for landing at the accurate site.

4) Sun elevation constraints. The sun elevation will seriously influence the optical navigation sensor and thermal conditions of working on the Lunar surface.

5) Accessibility to the relay satellite. The design of the relay satellite's trajectory should maximize the accessibility of relay communication. That is, it should aim at providing as long as possible communication period for scientific data transmission.

6) Adaption to thermal environment. The thermal environment adaption of the probe is mainly decided by the latitude of the landing site. To ensure continuous work for the whole

day, a landing site in the areas near the mid-latitude is more preferable.

7) Power supply requirements on Lunar surface. The power supply is mainly determined by the landing site latitude and the performance of solar panel direction.

8) Alternative landing site selection in case of failure. To ensure the reliability of the mission, besides the main landing site, alternative landing sites should also be decided. The distance between the two sites is closely related to the time needed for failure processing as well as orbital evolution characteristics.

Change'4 is primarily designed to land at SPA.

3.3 Relay communication design

3.3.1 Relay communication requirements

The flight process and working modes of Change'4 are designed to fully inherit from those of Change'3. The relay communication phases in the whole process are listed in Table 1.

The forward link is defined as sending telecommand signals from the relay satellite to the lander or the rover while sending telemetry data from the lander or the rover to the relay satellite is named backward link. The functions that the relay satellite needs included:

1) Forward link. i) Be able to connect the lander and the rover respectively by frequency scan. ii) Be able to choose a separate frequency point of the lander and the rover and send single-carrier-waves simultaneously. Be capable of time-sharing telecommand transmission. iii) Be able to send two channels of radio-frequency carrier waves simultaneously within a long-term period. iv) Be able to realize both real-time and delayed transmission of commands or data of the lander and the rover.

2) Backward link. i) Be able to receive the backward data from the lander and the rover simultaneously. ii) Be able to return backward data of the lander and the rover to Earth via data-transmission channels and switch between real-time and delayed transmission modes.

3.3.2 Relay communication regime analysis

The link between Change'4 relay satellite and lander/rover is designed to work on X-band. The forward link uses unified carrier-wave TT&C regime and the backward uses BPSK. The forward relay signal emitter should be able to scan with complex frequency carrier waves, similar to ground stations.

The relay satellite should be able to transmit data to Earth and relay with the lander and the rover simultaneously. To avoid interference, the relay link adopts X-band channel, and TT&C to Earth chooses S-band unified carrier wave regime and the data transmission utilizes S-band and BPSK carrier wave regime. Channel encoding is not used for telecommand transmission and RS+concatenated convolution channel encoding is adopted for telemetry and data transmission. Meanwhile for the purpose of synchronous encoding with ground, both telemetry and data pseudo-random coded.

3.3.3 Relay communication link design

The link profile among the relay satellite, the lander and the rover and ground stations is as shown in Figure 3.

The forward data is emitted from the relay satellite, the lander and the rover receive data via omnidirectional antenna and signals are modulated in PCM/PSK/PM.

The backward data is transmitted via an omnidirectional antenna, a medium gain antenna or a directional antenna and is received by the relay satellite. The backward link data of the rover is transmitted by the omnidirectional antenna or the directional antenna and is received by the relay satellite. The lander backward link adopts omnidirectional antenna, medium gain antenna and directional antenna corresponding to low, medium and high bit rates. The modulation mode of backward link is BPSK.

During the powered descent process, except for setting up X-band omnidirectional forward/backward relay communication links, the lander and the relay satellite also communicate via a medium gain antenna to return landing camera data back to Earth.

While working on the Lunar surface, the lander and the rover respectively receives forward telecommand signals via an omnidirectional antenna from the relay satellite. The relay satellite can send data at two frequency points at the same time to realize simultaneous control of the lander and the rover. Following the command, the lander and the rover send backward data (including telemetry and scientific exploration data) via an omnidirectional antenna or a directional antenna.

Table 1 Relay communication phases

Phase	Lander	Luna rover
Earth-Moon transfer	Directly communicates with ground TT&C stations	Idle
Moon orbiting	a) Directly communicates with ground TT&C stations; b) Test on relay communication link	Idle
Powered descent	a) Telemetry and Telecommand data transmission with relay satellite; b) Return imaging data of landing camera via relay satellite	Idle
Working on Lunar surface	TT&C and scientific exploration data transmission via relay satellite	TT&C and scientific exploration data transmission via relay satellite

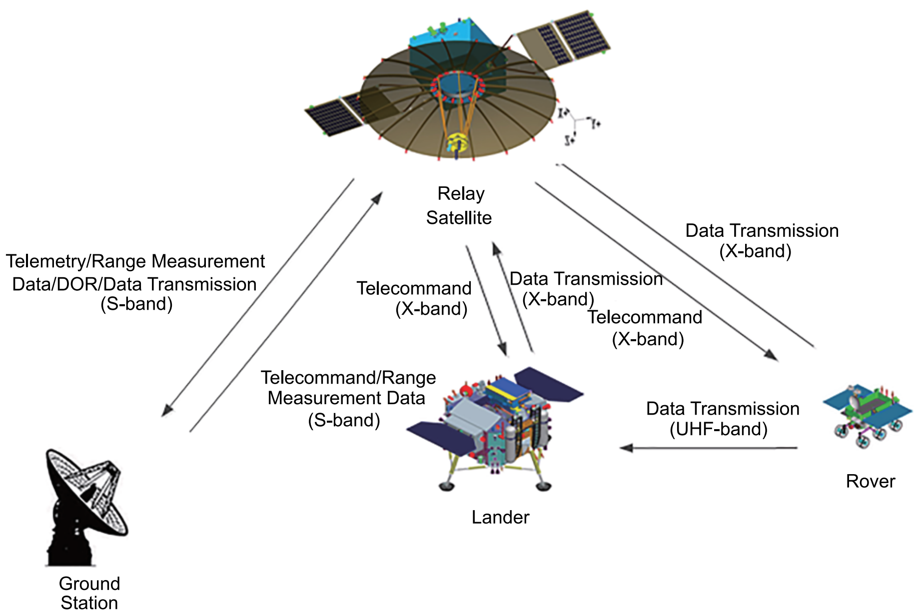

Figure 3 Relay communication link profile.

The relay satellite can receive backward data from both the lander and the rover simultaneously.

3.4 Trajectory design for relay satellite

3.4.1 Mission orbit design

To communicate and relay with the probe at the farside of the Moon, the relay satellite usually orbits around the Moon or Lunar libration point 2. When orbiting the Moon, the relay communication's link to Earth is influenced by limited TT&C period and may be interrupted for several days. Therefore, circum-L2 orbit is ideal for long-term, continuous moon-earth communication if the relay satellite is placed there [6]. The merits are listed as below.

1) The relay satellite is always continuously accessible to the farside of the Moon.

2) The relay satellite can be accessible to ground stations for all the time in certain orbits.

3) The communication is interrupted for only a few times when it is in the shadow of Earth or Moon, otherwise the satellite is in sunlight.

4) With less influence from Earth and Lunar gravity, the orbit error comes mainly from orbit control error and observation error. Besides, long-term orbit maintenance demands less energy.

Therefore, the L2 orbit is selected as the targeted orbit of Change'4 relay satellite, as shown in Figure 4 [7].

3.4.2 Earth-Moon transfer trajectory design

Generally, there are three methods to reach Earth-Moon L2 point, i.e. direct-transfer trajectory (directly transfer the satellite from Earth to Lunar L2 point), Lunar swing-by transfer trajectory (directly transfer the satellite to Lunar L2 point with one time Lunar swing-by) and low-energy transfer (transfer the satellite to Lunar L2 point via Invariant Manifolds). The comparison of the three methods is shown in Table 2. By comparison, the velocity increment is less for Lunar swing-by trajectory and the flight lasts for almost 10 d, while direct transfer trajectory demands more velocity increment and the low-energy transfer period is longer. Therefore, Lunar swing-by transfer method satisfies the engineering requirements.

3.4.3 Primary design of the flight profile of the relay satellite

The relay satellite is directly launched into the Earth-Moon transfer trajectory with the perigee at 200 km and the apogee at 380000 km. The flight takes about 5–6 d and requires 2–3 times of trajectory correction maneuver (TCM). The relay satellite brakes at the perilune and becomes stable in manifold instead of orbiting the moon as it decelerates. After 3–4 d, the relay satellite approaches the L2 point and reaches the plane that is formed by the normal of Lunar orbit and the ligature of the Earth and the Moon. After arriving at the L2 point, the relay satellite carries out three times of orbit control at the

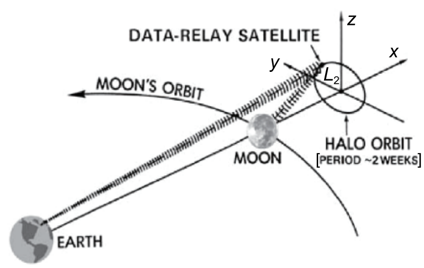

Figure 4 Earth-Moon L2 orbit profile [7].

first orbit revolution to enter the mission orbit. The mission orbit is a halo orbit and the relay satellite will carry out relay communication and scientific test. The entire flight profile is shown in Figure 5.

3.5 Scientific payloads configuration

Bearing in mind the features of the farside of the Moon, scientific payloads usually include a low-frequency radio spectrometer (LFS), an infrared spectrometer, a panoramic camera, a lunar radar, etc. The LFS is newly developed for the farside exploration and is implemented in the lander and the rover for the comparison and analysis of data collected.

The LFS is used for detecting the low-frequency electric field of the solar storm and to study the Lunar plasma. By detecting the low-frequency electric field from the Sun, the planetary space and the galactic space, the information of electric magnitude, phase, time variance, frequency spectrum, polarization and Direction of Arrivals (DoA) are collected for analysis. With features of variation of the spatial low-frequency electric field, the Lunar plasma environment above the landing site will be analyzed. The LFS is configured with three-component decomposition active antenna to receive electromagnetic signals from the Sun and the space. Each of the three antenna units receives one of the three orthogonal components of the electromagnetic signals. According to radio transmission theory, information such as the electromagnetic intensity, the frequency spectrum, the time variance, the polarization features and the direction of radiation source are obtained by analyzing and processing the exploration data.

The flux intensity of the electromagnetic wave in near-Moon space is shown in Figure 6 [8]. The voltage value of the LFS while receiving low-frequency radio spectrum can be computed and utilized for setting the detection sensitivity for electric field of the LFS receiver, and can be used in the exploration of the galactic space electromagnetic wave.

Noise made by the instruments of the lander and the relay satellite will influence the LFS's performance. Something has to be done to remove the noise when handling LFS data.

4 Technical characteristics

The technical characteristics and difficulties of Change'4, when compared with those that the Lunar exploration missions completed in the past, are listed as below.

4.1 Precise design and control for Earth-Moon L2 orbit

Developed by Leonhard Euler and Joseph Lagrange the liberation points are the five equilibrium solutions of a circular restricted three-body problem (CR3BP). Three of the liberation points (Lagrange point) locate along the line of two main

Table 2 Three transfer method

Phase	Perigee velocity at launch	Time to reach L2	Velocity impulse (theoretical) (m/s)
Direct transfer		Short (almost 6–7 d)	900–1000
Lunar swing-by	Almost 10.9 km/s	Short (almost 8–9 d)	200–300
Low-energy		Long (almost 3 months–half a year)	0–125

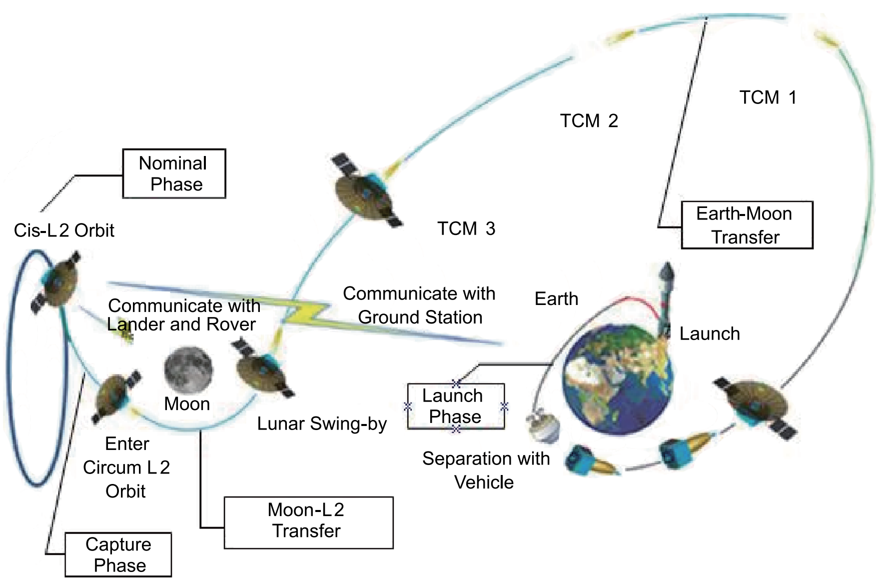

Figure 5 Flight profile of relay satellite.

bodies and are called collinear liberation point (L1, L2, L3). Spacecrafts at these points will depart exponentially in case of small disturbance. The other two points are called triangle liberation points (L4, L5). The positions of liberation points are marked in Figure 7.

Liberation points are dynamic balanced points. Spacecrafts operating around these points can keep the same pace with the system of the two main bodies. As a result, less propellant is consumed for orbit maintenance. Therefore, it is an ideal location for the farside relay communication.

Mission orbit design, transfer orbit design and orbit maintenance design are vital issues to be resolved for Change'4 mission.

1) Mission orbit design. Different from the Earth satellite

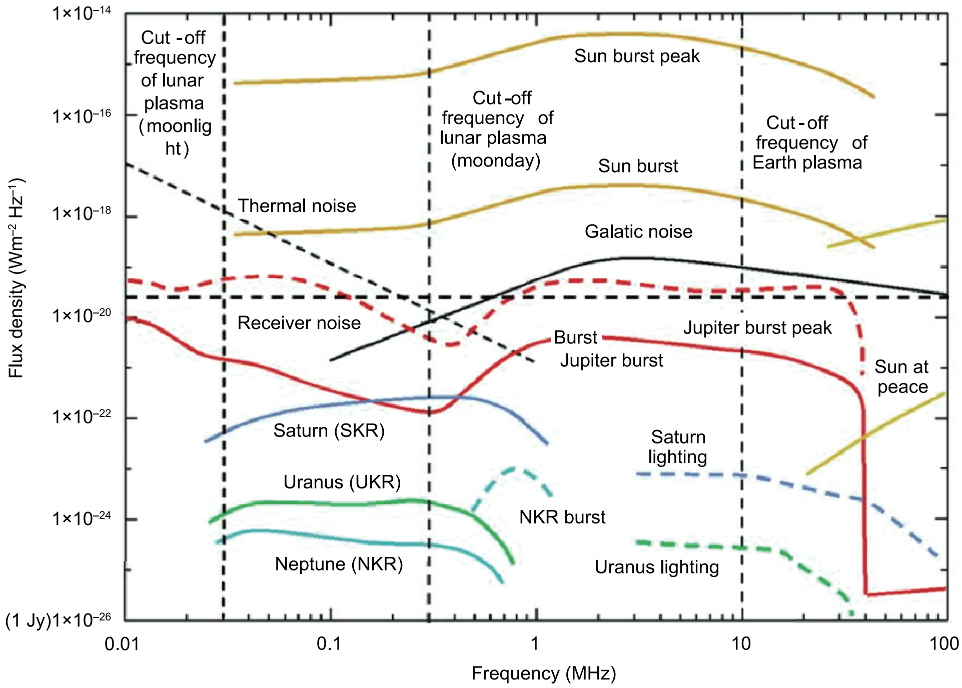

Figure 6 Electromagnetic wave flux density of near-Moon space [8].

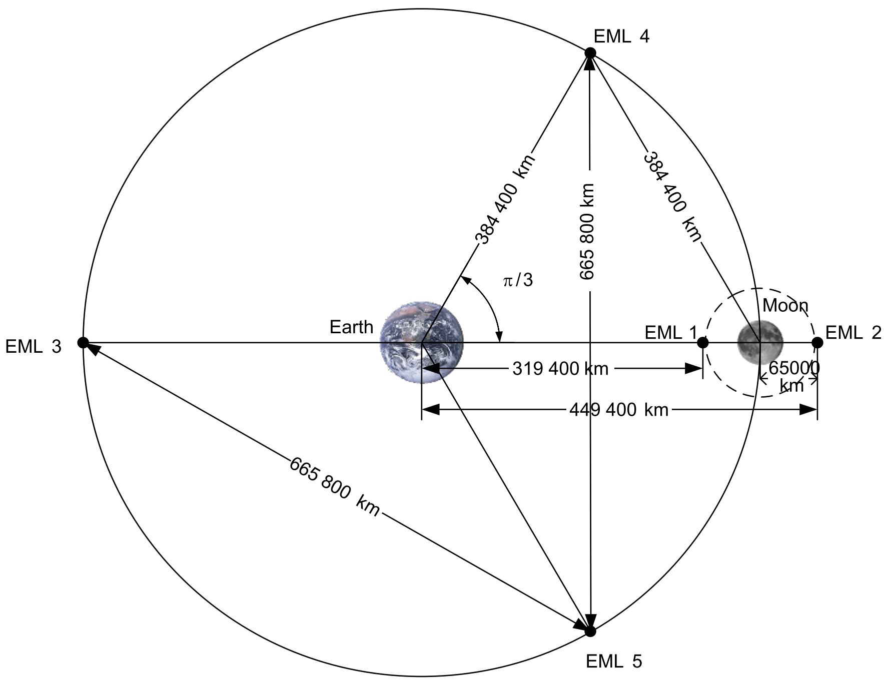

Figure 7 The map of the Earth-Moon liberation points.

and the circumlunar satellite, the relay satellite is much further away from the Earth and operates for a long period. The gravity model for the relay satellite is complicated. Besides complicated relations between the Sun, the Earth, the Moon, the relay satellite and the probe, the design of communication accessibility of the relay satellite to ground stations, the lander and the rover requires careful consideration. The mission orbit of the Change'4 relay satellite is designed to minimize the velocity increment for orbit maintenance and the shadow time in the condition of ensuring the non-stop communication with ground stations, the lander and the rover. The type and detailed parameters of the orbit should be carefully determined.

2) Transfer trajectory design. The Lunar swing-by can provide a nice trade-off between the transfer flight time and velocity increment. For Lunar swing-by trajectory, the velocity increment of Lunar orbit injection (LOI) and the shape of the mission orbit are influenced by perilune status, including the transfer period, perilune height, orbit inclination, etc. With abundant and detailed analysis and simulation, the influence of various parameters on the trajectory shape and the velocity increment requirement is calculated. Therefore the trajectory design is optimized.

3) Orbit maintenance strategy design. Because the liberation point is not stable, minor disturbance may greatly influence the long-time performance of the satellite. The relay satellite which may veer off or even depart from the original course requires regular orbit maintenance. The orbit maintenance strategy needs to be optimized to minimize the required velocity increment. The disturbance influence may be used for decreasing orbit control consumption. Besides the influence of gravity disturbance, the precision of orbit forecast and the orbit control error should also be considered in the design of orbit maintenance strategy.

4.2 Earth-Moon L2 relay communication under remote distance

The relay satellite orbiting around the Earth-Moon L2 point is about 60000–80000 km away from the lander and the rover working on lunar surface. Under the constraints of the launching mass and size, the relay communication link should be optimized in multiple aspects such as the relay transmission modes and the high gain relay antenna development to achieve high-bit-rate communication.

4.2.1 Regenerative forwarding mode

Relay transmission is generally comprised of the regenerative and transparent packet forwarding. Transparent packet forwarding simply transmits signals without modulation except for amplification and frequency conversion. Regenerative forwarding regime is to amplify received signals, modulate from the low frequency to the medium frequency and decode signals. Then the modulated signals will be stored in the solid state drives (SSD), or emitted after coding, modulation and amplification.

For transparent packet forwarding regime, noises will accumulate during the process of signal transmission. Therefore, large emitting energy and a large antenna are required for transmission and the mass, size and cost of the satellite are increased. Regenerative forwarding can remove the accumulated noise and requires less energy and satellite size for the same communication performance. It is therefore more suitable for the Lunar relay communication. On the other hand, the regenerative forwarding regime is more complicated than the transparent packet.

4.2.2 High gain relay antenna

The relay satellite is about 80000 km away from the Moon, which is over twice of the distance between the GEO relay satellite and the Earth, which is 36000 km. Accordingly, the signal energy attenuation increases over 6 dB. Under this circumstance, the relay communication requires higher EIRP and G/T values. Through the analysis, the gain of the X-band high gain relay antenna should be over 45 dBi.

For the high gain and large diameter relay antenna, technical difficulties such as the folding and deployment of parabolic surface, high-accuracy control of shape variance, the thermal design and the minimization design should be resolved.

4.3 Safe landing under complex landform situation

Change'3 lunar probe successfully landed on the Sinus Iridum area. But the Lunar farside is more rugged and difficult for the safe landing objective.

To ensure the landing safety, guidance, navigation and control method should be optimized to adapt to the complex terrain. On the other hand, with careful orbit design and control, the distribution of landing sites is reduced for landing safety.

1) Influence of the topographic relief. In the descent process, the length of path of the lander is almost 450 km on the Lunar surface. During this process, the distance and velocity should be measured for navigation of the descent. At the farside of the Moon, the topographic relief is more apparent than that at the nearside, with the topographic elevation difference increased from 3 km to 7 km. The difference brings out the jump of navigation information and extreme difficulties for control strategy. Therefore, the sectional control target and navigation information utilization time as well as navigation algorithm should be optimized to decrease the influence of the great topographic relief.

2) Decrease of the backscattering coefficient. Research results show that the site on which Change'3 has landed at the nearside of the Moon is opposite to the SPA at the farside of the Moon, and the contents of FeO and TiO_2 are 15%–25% and 0%–15%, while the average value of them on the nearside of the Moon are 15%–20% more than that on the farside

[9]. The low contents of FeO and TiO_2 decrease backscattering coefficient of microwaves and directly influence the echo characteristics of range and velocity microwave sensor (RVS). Therefore, the signal emission energy and signal-noise-ratio should be increased to obtain useful measuring data.

3) Reducing the distribution of landing sites. Due to the complex terrain of the farside, it is difficult to find out a large flat area. For different launch windows, the landing sites may be widely distributed without precise orbit control and descent process control. Different from Change'3, the circumlunar orbits with various inclination angles for different launch windows are designed for Change'4 specific requirements. Meanwhile, the orbit is carefully regulated in the circumlunar phase. With in-orbit calibration of the 7500N thrust-variance engine, the powered descent process path is precisely controlled and the landing sites are reduced to a flat and small area.

4.4 Power supply with radioisotope thermoelectric generator (RTG) and thermoelectric technology application

For data collection of the temperature of the Lunar soil in moon night, the temperature sensor has to have power supply. Currently, the most realistic method is to utilize the RTG, which is based on Seebeck principle to transform the heat energy into the electric energy. When generating electric power, the RTG can also supply great heat energy to regulate temperature. Generally Pu-238 is used as the RTG source [10].

Compared with the RTG used in Change'3, the thermoelectric module should be increased in the RTG of Change'4, which may mean various technical difficulties, including high-performance thermoelectric material manufacture, high-performance thermoelectric components design and assembly, high-efficiency heat transformation, etc.

1) High-performance thermoelectric material manufacture technology. Thermoelectric material is the core material in the RTG. The electric and mechanical performance and the thermal stability directly determine the reliability and stability of the RTG. Currently, PbTe and $CoSb_3$ are used, while PbTe is well developed but with worse performance. For further design, the chemical dose ratio adjustment, the doping impurity selection and manufacture process should be optimized to make the material meet the engineering requirement.

2) High-performance thermoelectric components design and assembly technology. The thermoelectric components are comprised of π type pairs of the P-type and N-type materials and directly determine key parameters such as the output voltage, the inner resistor and the output power of the RTG. The design and assembly of the energy transfer components determine the reliability, including the components joint process design, the matching design for the thermal expansion coefficient of the electrode material and substrate material and the shelter layer and transition layer optimization. For future improvements, the different temperatures in both nighttime and daytime on the Moon should be considered. Calculation, simulation, test and verification should be done to satisfy engineering requirements.

3) High-efficiency thermoelectric transformation technology. The thermoelectric transformation efficiency and decay rate of the RTG directly determines the lifetime and the performance of the RTG and is a vital segment for the success of the mission in moon night. The key technology is thermal flow design of the RTG, which aims to maximize the heat transformation from thermoelectric components to heat collector. Meanwhile, the RTG shell should have the layer of high emission ratio and low-absorption ratio to ensure the safe of RTG under the high temperature at Lunar daytime.

5 Conclusion

Change'4 will make great improvements on key technologies, including safe landing on complex landform of the Moon, relay communication and exploration around Earth-Moon L2 point, and operation during moon nighttime, etc. Our capability to precisely land on a specific spot on the Moon and carry out Lunar exploration will lay a solid foundation for future missions of Lunar and deep space exploration.

With the first low-frequency radio observation on the Lunar farside in the world, we may be able to understand the radio radiation characteristics of radio waves from stars and planets in the solar system. We may also verify the hypothesis of the power spectrum density, that the low frequency of planet magnetosphere varies according to the size of planet. We will supply basic study reference for the radio wave detection of ultramundane planet, especially terrestrial planets. Meanwhile, the astronomical survey of the galactic electromagnetic wave below 10 MHz on the Moon will broaden the radio wave band to thousands of meters and the gap of survey and study on 100 kHz–1 MHz radio wave is filled.

Change'4, developed in short-time, has a low cost and is of special characteristics and prominent prospect to make great achievements. The success of Change'4 mission will set up a new milestone for lunar exploration for all mankind.

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