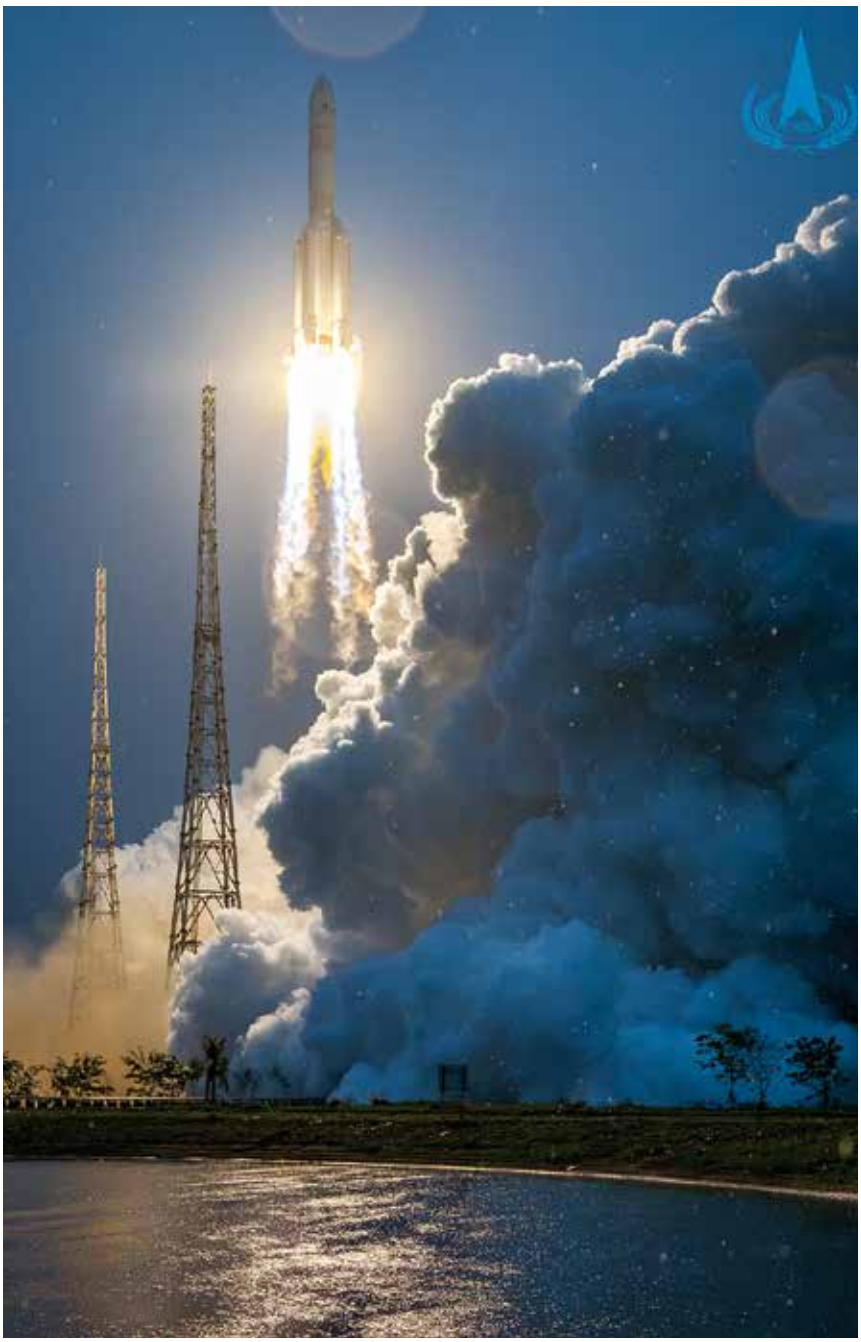
Chang'e-6 Returns with Samples from Far Side of Moon

TEXT: SONG Jianlan



Chang'e-6 being sent from the launching pad.

Graphic: CNSA

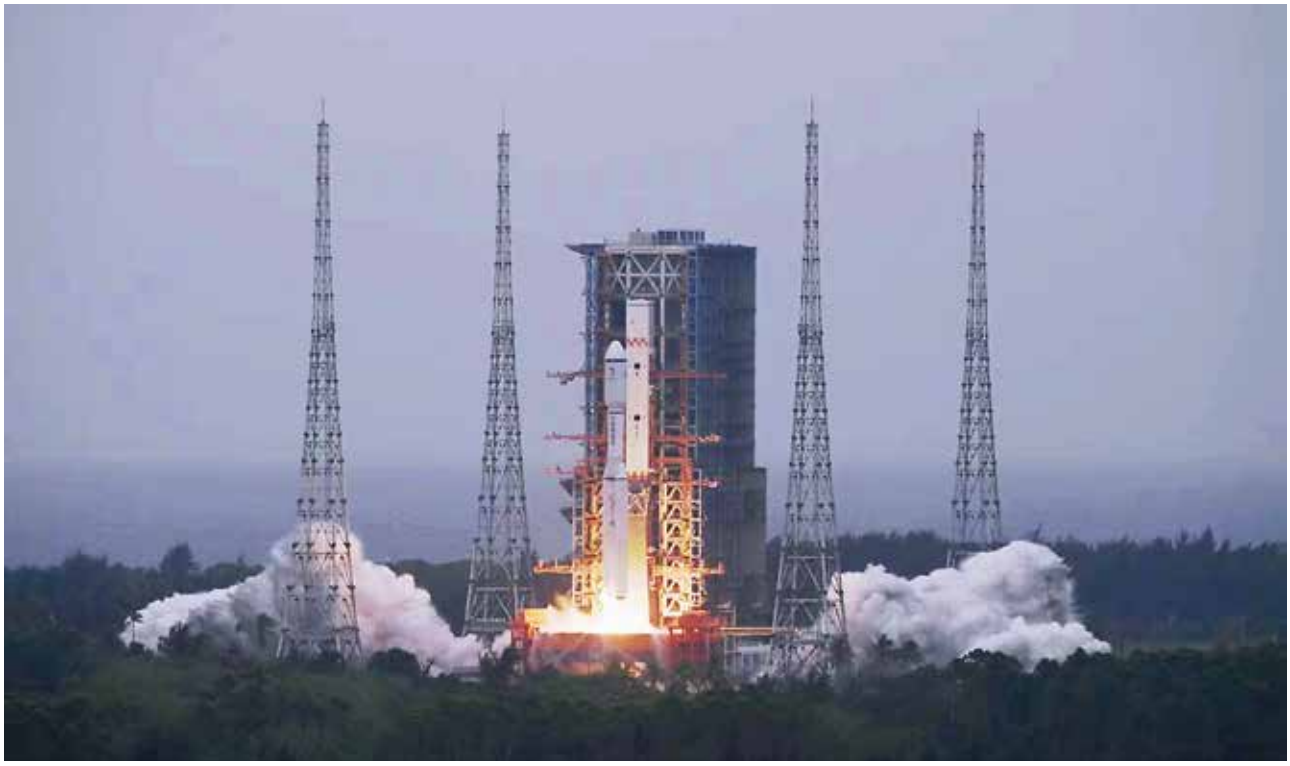
At 2:07 pm GMT+8 on June 25, 2024, the returner of *Chang'e*-6, China's lunar detector, touched down on the ground surface of the preset landing site in Inner Mongolia of China. Onboard were samples first-ever collected from the far side of the Moon, the mysterious kingdom that had resisted visits from the human world. This soft landing has thus crowned the high-profile mission with a complete success.

It had been a long journey, heralded by the launching of a relay satellite – *Queqiao*-2. Named after a bridge of love built by flocking magpies from Chinese mythology, the satellite was designed to provide communication support between the Earth and the far side of the Moon, not for just *Chang'e*-6, but also the succeeding explorations. Had not for this "bridge", communication would be just impossible between the Earth and this side of the Moon, as no electromagnetic signal – such as visible light – could directly reach the Earth from there. This bridge was built as early as on March 20, to pave the way for the upcoming mission and tasks.

It is worth mentioning that all the three scientific payloads onboard the relay satellite are developed by the Chinese Academy of Sciences (CAS). After the *Chang'e-6* mission, the satellite is supposed to extend its flight to provide support for lunar-based investigations into the magnetic field of the Earth, including the magnetotail and the plasmasphere. It will also help with the lunar-based experiments on VLBI measurements and observations.

On May 3, the lunar detector *Chang'e*-6 was thrown into preset orbit by a CZ5-Y8 rocket from a launching base located in Hainan, a far-southern province of China, and since then embarked on its journey into the unknown.

Queqiao-2, the relay satellite, was sent into orbit before-hand on March 20 to provide communication support for the *Chang'e*-6 mission.



Graphic: Xinhua

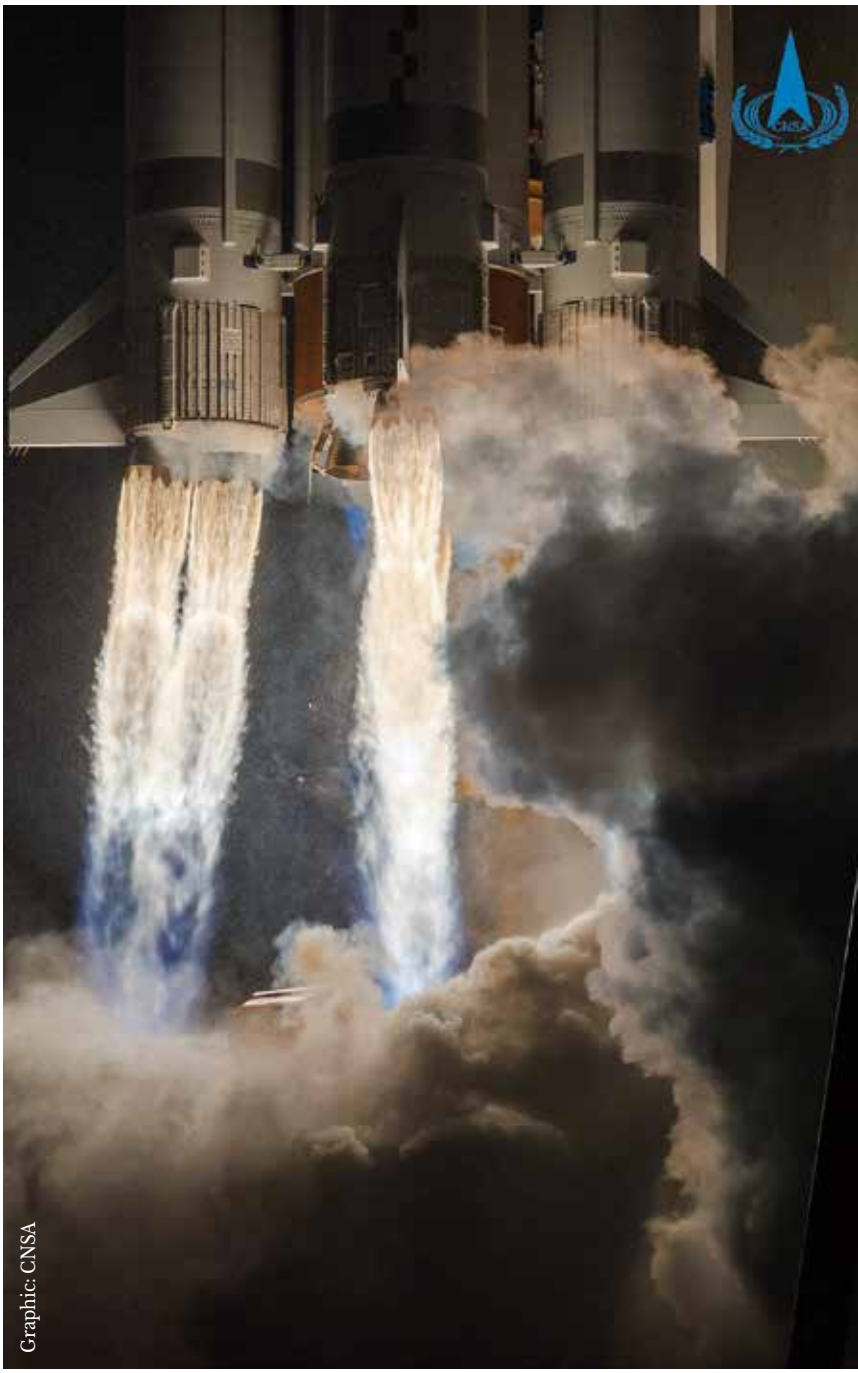
Touching Down on the Far Side of the Moon – in Retrogradation

The mission is targeted at an area on the brim of the Apollo impact crater in the South Pole-Aitken Basin on the far side of the Moon. This site is part of the biggest, deepest and most ancient impact crater on the Moon; the *in-situ* investigation and analysis of the returned samples can help scientists understand the geological structure and matter compositions of this part of the lunar surface, and get some clues about several major issues in the early ages of the universe, including the origin and evolution of the solar system and the Moon.

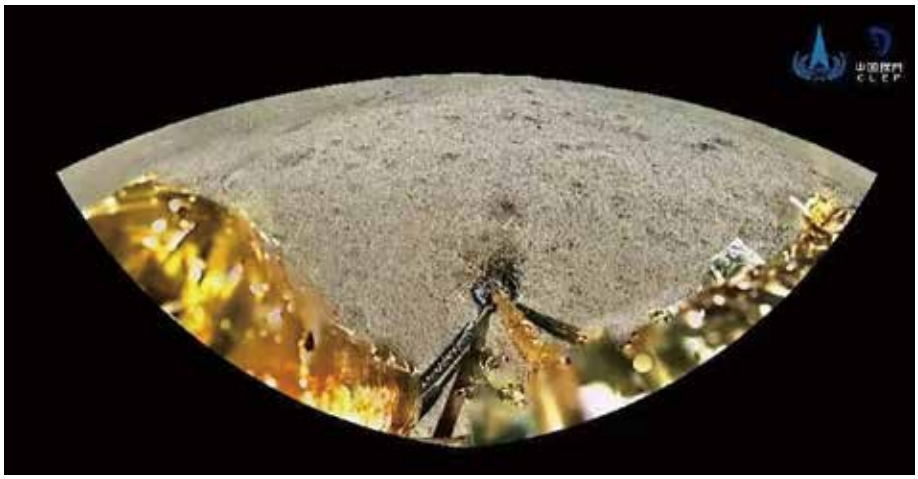
After launch, the spacecraft entered directly an Earth-Moon transfer orbit, and soon flew to the Moon, navigated by the ground-based control with support from the relay satellite. On approaching, it braked and decelerated to a speed slow enough to get caught by the Moon's gravity, which is much weaker than that of the Earth. Once entering the pre-decided lunar orbit, it orbited the Moon and bided its time for a soft landing.

Its predecessor *Chang'e*-4 had been to the far side of the Moon. Seemingly, it should not be that hard for it to properly touched down. However, *Chang'e*-6 is actually a backup for *Chang'e-5* – this means, it was originally designed for landing at the same site as *Chang'e-5* on the near side of the Moon, on the northern hemisphere. The appliances aboard, including those for light harvest and energy supply, are all tailored to the sunlight at that site. Now to land safely on the southern lunar hemisphere of the far side and effectively fulfill its tasks, *Chang'e*-6 would have to rotate 180 degrees to touch down at a proper attitude relative to the lunar surface. This could be challenging given the time lapse in communication, and might incur some unknown uncertainty.

The tail flames from the CZ5 rocket.



Graphic: CNSA



Graphic: CNSA

Ambient environment in lens of the panorama camera onboard the lander of *Chang'e*-6, as released on June 4 by CNSA. The data was sent back to the Earth by the relay satellite, and the ground application system produced the image after data processing.

The scientists resolved this problem with a smart strategy – letting the spacecraft enter the lunar orbit opposite to the direction of *Chang'e-5* and hence against the rotation of the Moon itself. This, however, posed a challenge to the orbit measurement and navigation control.

The *Chang'e-6* team made it.

At 6:23 GMT+8 on June 2, the lander-ascender complex of *Chang'e*-6 successfully touched down in the South Pole-Aitken Basin on the far side of the Moon, all as planned. Navigation instruments developed by CAS, including a laser ranging sensor, a laser velocimeter sensor and a laser 3D imaging sensor, safeguarded the landing; the VLBI network administered by CAS also helped in the orbit measurement and navigational aid.

Onboard the lander are six payloads developed by CAS: a panorama camera, a landing camera, a soil structure detector, a mineral spectrum analyzer, a panorama camera turntable, a payload data processor, and a system to display the national flag of China. The instruments have been designed to investigate the lunar terrains and geological structure, the matter compositions of the lunar surface, and the lunar suprastructure; and to perform related resource prospection.

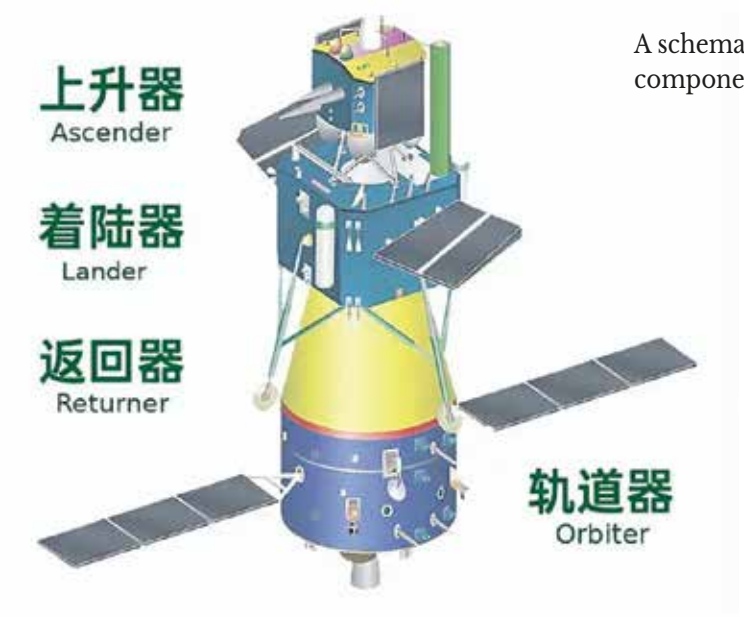
The returner and orbiter stayed in the lunar orbit – the ascender would rejoin them after collecting the required soil samples.

Smart Collection of Samples in the Dark

Now how to secure proper sample collection on the far side of the Moon is another big challenge. Given the communication delay, no timely instruction would be available to deal with potential difficulties or contingency, therefore the machine had to perform the task on its own against all odds, with no human guideline or rescue from the Earth. The team developed a set of smart technologies to solve the challenge.

From June 2 to 3, the machine completed the collection of samples in the South Pole-Aitken Basin, and sealed the invaluable samples into a storage carried by the ascender. During the collecting and sealing operation, the team on the ground made simulations of the geographic environments based on the data sent back by the relay satellite. The simulation would provide an important basis for later strategic decisions and operations.

The detector, enduring the hot weathers on lunar surface, collected two categories of samples from the far side of



A schematic illustration for components of *Chang'e*-6.

the Moon: one from the depth via boring and picking, the other via direct collecting from the surface.

In absence of timely instructions, now the ascender had to deal with any difficulty in the process of returning to the orbit to rejoin with the orbiter and returner. At 7:38 GMT+8 on June 4, with the canned samples, the ascender bided farewell to its fellow, the lander, and took off from the lunar surface. In about six minutes, it successfully entered the designated orbit. After four rounds of orbital adjustments, the ascender successfully docked onto the orbiter-returner complex at 14:48 GMT+8 on June 6; and hours later, the canned samples were safely transferred to the returner at 15:24 GMT+8, ready for its flight home. This marked a second success of docking in lunar orbit after *Chang'e-5*.

The ascender later detached from the orbiter-returner complex; the latter hence began to prepare for a Moon-Earth orbital transfer. After a flight of three weeks, finally the returner would detach from the orbiter to jump into the embracement of the Earth's atmosphere and return the samples home.

Just as *Chang'e-5* mission, the returner bumped up and down on the upper brim of the atmosphere until its velocity was reduced to a suitable degree for landing. Eventually, the returner got home on June 25.

A Journey of International Cooperation

The *Chang'e*-6 mission has joined hands with multiple partners. It carried payloads from the European Space Agency, as well as space agencies of France, Italy and Pakistan; also, it received help from Europe for synchronized orbital observation, measurement and navigation control.

The China National Space Agency (CNSA) aired its policy for international cooperation in its response to congratulations from international counterparts and friends. "We encourage scientists from home and abroad to analyze the returned lunar samples and obtained data," said BIAN Zhigang, Executive Director of CNSA, "and strive for more original discoveries."

Actually, China has opened its *Chang'e* program for international proposal applications in terms of lunar sample examination and related studies.

According to Mr. LIU Yunfeng, head of the department for international affairs at CNSA, from the start of China's program

for lunar and deep space explorations, China has been promoting the related international cooperation. CNSA has since drafted regulations on the management of lunar samples as well as specific measurements concerning internationally joint research based on related samples and scientific data, followed with detailed procedure for application and involved international cooperation. "We welcome applications from researchers across the world in light with the released procedure, to share the benefits from the program," LIU said.

"We are carrying forward subsequent missions of the lunar exploration, *Chang'e*-7 and *Chang'e*-8," added BIAN Zhigang, "and also subsequent programs for planetary explorations like *Tainwen*-2 and *Tianwen*-3. CNSA will continue to carry out diverse international collaborations, on the principle of equality and mutual benefit, as well as peaceful use and inclusive development of space. We expect to join hands with more international colleagues to advance the frontiers of human knowledge, and improve human well-being. We shall make new contributions to build a community of outer space with a shared future for humankind."

All through the way from *Chang'e*-4 to *Chang'e-5* and *Chang'e*-6 missions, China has cooperated with space science institutions of multiple countries in different ways: carrying international payloads; orbit observation, measurement and navigation control; orbit data sharing; and joint analysis of lunar samples. For the subsequent *Chang'e*-7 mission, a total of six international payloads have been selected for flight. As for the *Chang'e*-8 mission, a notice of cooperation opportunities was released in 2023, offering a total of about 200 kg payload quota. So far, China has received over 30 applications for cooperation on this mission. Meanwhile, in terms of the cooperation on the International Lunar Research Station, CNSA has inked cooperation agreements with over 10 countries.

Explorations Going on

Before *Chang'e*-6, all lunar samples collected were from the near side of the Moon. The samples obtained by *Chang'e*-6 will help us understand our neighbor in more complete a way. Part of the samples are from deeper lunar strata, and hence provide valuable information about the compositions of the inner matter. On the other hand, the mineral compositions of the samples might be quite different from those from the near side. Therefore the samples might help reveal the special geological structure and composition of this part and give clues on the Moon's evolution.

The site where *Chang'e*-6 garnered the samples is an ancient crater left by a great impact from a meteor. According to Prof. LI Chunlai, a researcher at the National Astronomical Observatories, CAS who works as the vice chief designer of the *Chang'e*-6 mission, due to the ancient impact, some inner matter from the depth of the Moon might have been thrown out to spread on the surface, hence could be picked up by the detector. In that case, we might be able to understand the inner structure and matter compositions of the Moon, via analysis of the samples. The samples might also offer opportunities to understand the early impact history of the Moon, and even give clues to the early impacts occurring on the Earth. All this might help understand the early evolution of our solar system.

So far, according to Mr. BIAN, the data from China's lunar explorations has resulted in a total of over 1,900 published research papers. From the samples returned by *Chang'e-5*, scientists found the sixth lunar mineral substance new to us, and named it "*Chang'e* stone".

It has been two decades since China launched its lunar exploration program. Now *Chang'e*-7 and *Chang'e*-8 missions are on the horizon. The *Chang'e*-7 mission will focus on resource prospecting on the southern pole of the Moon, and the *Chang'e*-8 mission will perform some experiments to verify technologies for *in-situ* applications of lunar resources.