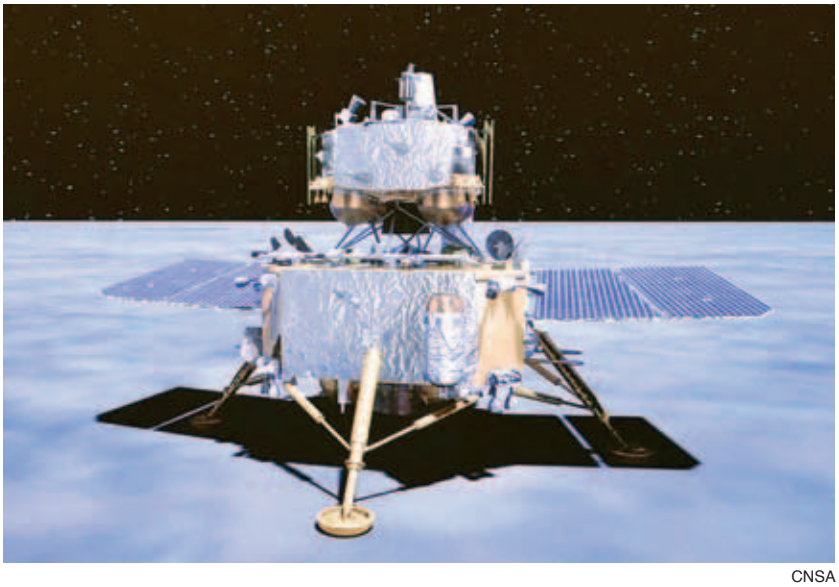
Chang'e-5: Bringing A Bit of the Moon to Earth

by Marsha Freeman

Dec. 5—The perfect execution of China's Chang'e-5 lunar sample return mission completes the first set of China's exploration missions to the Moon. The first group of missions, laid out 20 years ago, were to orbit the Moon (Chang'e-1 and 2), land on the Moon (Chang'e-3 and 4) and return samples from the Moon (Chang'e-5). The sample return mission lays the basis for the next tranche of missions, which will concentrate on intensive studies of the minerals and materials on both the near and far sides of the Moon. Of particular interest are potential materials that can be used to build and operate stations and laboratories on the Moon, first to operate robotically, and later to support people. And one particular resource on the Moon—helium-3—is of particular interest, as fuel for fusion power, with the potential to create virtually unlimited energy.



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An artist's representation of the Chang'e-5 lander. On the top is the ascender, or ascent stage, which has now lifted off from the lander to deliver soil samples to the orbiter. This is the first time a lunar orbit rendezvous and docking has been done automatically.

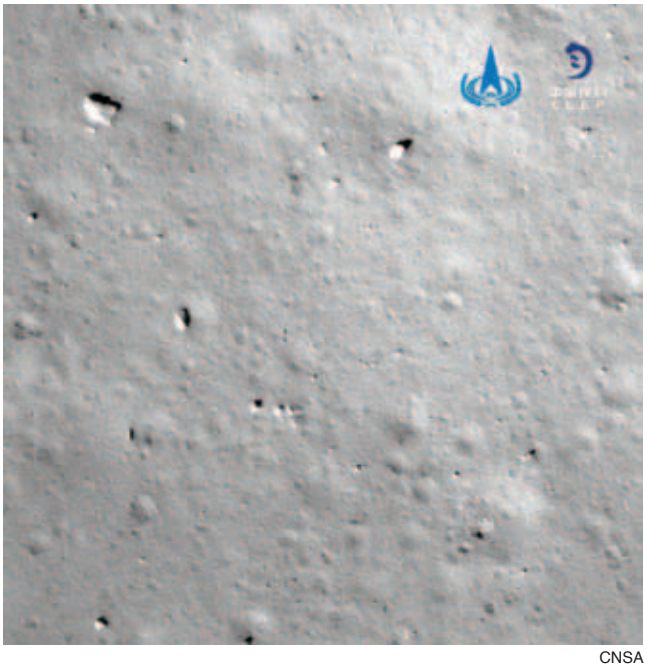
- Chang'e-6 will conduct a very challenging South Pole sample return. Whether it will be conducted on the near or far side of the Moon depends upon the results of the sampling mission of Chang'e-5.
- Chang'e-7 will conduct comprehensive exploration of the South Pole, including its land forms, material composition, and environment.
- Chang'e-8 will test key advanced technologies on the far side. Companies will be invited to industrialize the technologies developed for the mission.

The goal of China's lunar missions was stated very clearly by the then director of the China National Space Administration, Luan Enjie, in a March 3, 2003 interview with *People's Daily*. He provided an overview of the lunar exploration program that was soon to be made public. "The exploration of the Moon can become the incubator of scie volutionary nature." Mankind must "leave the Earth homeland, establish permanent research stations, develop products and industries in space, and set up a self-sufficient extraterrestrial homeland," he said.

The Chang'e-5 mission was an important step in reaching that goal.

A Complex Mission, Never Done Before

Chang'e-5 was launched on November 24, and 112 hours later, arrived at the Ocean of Storms on the near side of the Moon. The spacecraft consists of four distinct vehicles: an orbiter, the largest of the four, which transports all of the rest; a lander, which carries out the drilling and scooping of the lunar soil; an ascender, or



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This photo of the Chang'e-5 landing site in the Ocean of Storms may indicate a young surface, if indeed the relative absence of craters is a reliable measure.

ascent stage, which will blast off from the surface of the Moon, with the samples; and, a returner, which carries the soil samples through the Earth's atmosphere.

Mission designers operated under stringent constraints. Pei Zhaoyu, Deputy Director of the National Space Administration Lunar Exploration and Space Engineering Center, explained that to return 2 kilograms of lunar soil, the weight of the probe reached 8.2 tons. "If we want to increase the amount of samples," he said, it will increase the weight of the rocket and "exceed the carrying capacity of the rocket."

A second constraint was time. The entire mission had to be carried out during one lunar day or 14 Earth days. To save weight, the lander uses solar energy. It landed during the lunar day, but had a limited amount of time to complete its task.

On Thursday, December 3, after less than a week on the Moon, the probe had completed its tasks, drilling underground and scooping loose soil on the surface. It easily met the goal of 2 kilograms of sample material.

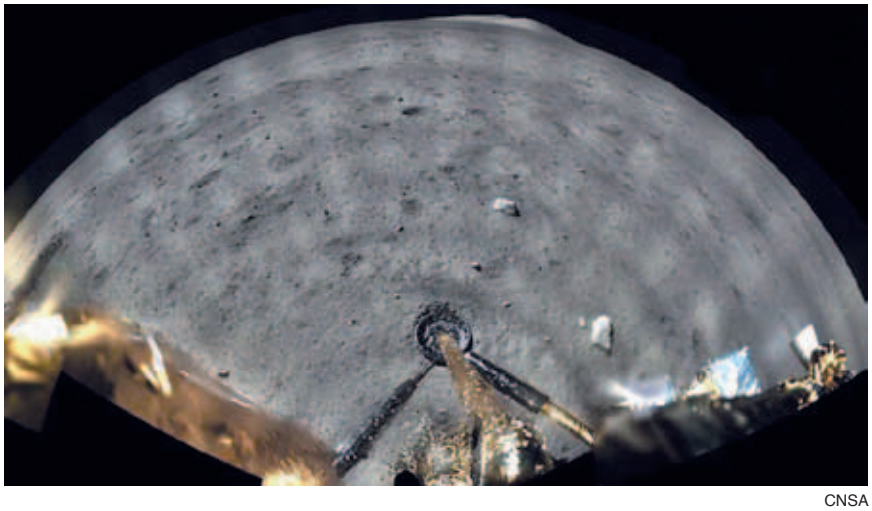
The scientists explain that there are two reasons why Chang'e-5 did two different kinds of sample collection. Naturally, if one method should fail, such as a broken drill, you would want a back-up. But more importantly, each reveals something different about the history of the Moon, the Sun, and the Solar System. The samples from underground reveal the Moon without the influence of the Sun. The soil on the surface is just the opposite.

Close examination of the samples may also shed light on one of the basic measurements used in lunar science to determine the age of various features on the Moon, which has come into question—the number of craters. It has been assumed that a region with few craters is a younger surface, with older craters disappearing, for example by volcanic eruptions. But previous samples have contradicted this traditional crater-counting method.

On December 3, its mission complete, the ascent vehicle sitting on top of the lander, holding the precious lunar samples, blasted off from the Ocean of Storms. Six minutes later it was in lunar orbit, to start an orbital chase to catch up to dock with the orbiter, which had been waiting patiently for its arrival. This is a delicate maneuver with a window of 3-5 hours to perform it perfectly.

Today, December 5, two days after the ascent module had lifted off, the two spacecraft began final approach, and three and a half hours later the docking was completed. The extremely delicate rendezvous and docking took place automatically, without any human intervention, due to the time delay in communication. Now the sealed container with the samples will be transferred to the reentry capsule.

But as China space expert Andrew Jones explains,



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Panoramic photo from a foot of the Chang'e-5 lander to the horizon, soon after landing on the Moon.

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This photo of the technical personnel needed to monitor the rendezvous and docking of the ascender with the orbiter indicates the complexity of the mission.

"The lunar samples won't be coming home immediately." It will take a few days for the spacecraft in lunar orbit to have an opening for a pathway to send the sample module to Earth. If the timing is precise, the orbiter will release the module with the soil samples, to land in Inner Mongolia, where Chinese astronauts land after space flights. The trip back to Earth from the Moon takes 112 hours; the same amount of time it took to get there.

But It's Been Done Before …

Cynics will object that there is no reason to bring back samples from the Moon. The Soviet Union did it 40-odd years ago, they will argue, and the Moon doesn't change much in 40-odd years. (This is not even true on the face of it, since without an atmosphere or magnetic field, the Moon is constantly bombarded by the flotsam and jetsam of the Solar System.) But what has changed dramatically is the science.

Most of the samples brought back by the Apollo astronauts have been well-studied. But NASA, with advances in science in mind, made the decision to keep some samples completely untouched as an investment in the future, allowing them to be analyzed with more advanced technologies as they are developed.

In order to prepare for the return to the Moon in the Artemis program, NASA has created the Apollo Next-Generation Sample Analysis (ANGSA) initiative, which is leveraging advanced technologies to study Apollo samples, using new tools that were not available when the samples were originally returned to Earth. Dr. Sarah Noble, ANGSA program scientist at NASA headquarters, explained, "The analysis of these samples will maximize the science return from Apollo, as well as enable a new generation of scientists and curators to refine their technique and help prepare future explorers for lunar missions anticipated in the 2020s and beyond." Dr. Noble continued, "We are able to make measurements today that were just not possible during the years of the Apollo program."

Examples of advances in technology that have been developed over the last 50 years include non-destructive 3D-imaging, mass spectrometry, and ultra-high resolution microtomy. Other new tools include X-ray computed tomography (XCT) and X-ray computed microtomography. Studies of the Apollo samples using these capabilities were done before the samples were removed from their containers. This helped scientists understand the samples' structure and provided detailed images of individual grains and smaller samples, known as rocklets.

Charles Shearer, science co-lead for ANGSA, explained, "The findings from these samples will provide NASA new insights into the Moon, including the history of impacts on the lunar surface, how landslides occur on the lunar surface, and how the Moon's crust

NASA

NASA technicians in the Astromaterials Research and Exploration Science Division extrude lunar core samples obtained by an Apollo mission. Advanced tools not available in the 1970s will reveal more about the Moon today as they analyze the Chang'e-5 samples.

Chinese Academy of Sciences

Ouyang Ziyuan, the scientist most responsible for China's lunar program: "The mineral resources of the Moon, its energy resources and its specific environment, will open up a new source of development for mankind."

has evolved over time."

The teams that will be studying the samples include members who have long NASA experience, some of whom were part of the original teams to first study Apollo samples. Apollo-17 astronaut, geologist Harrison Schmitt is actively involved in a science team.

Lunar Fuel for Fusion: Helium-3

The scientist most responsible for the creation of China's lunar program is Ouyang Ziyuan. His studies were focused on geology and mineral resources, and in 1958 he conducted a study of a meteorite, creating the field of Cosmo-chemistry. He became dedicated to the proposition that China should have a space science plan that would begin with the exploration of the Moon. Starting with an increasingly complex series of robotic missions, the lunar program would culminate with science laboratories, and people living and working on the Moon.

Ouyang spent the next four decades writing scholarly reports for the Academy of Sciences, explaining the importance of the science to be learned. Concrete proposals were presented to the political leadership of China.

On January 24, 2004, the State Council and Premier Wen Jiabao approved the report laying out the lunar exploration program. This ratified the development of the lunar probes, inaugurating the multi-phase China Lunar Exploration Program (CLEP). The lunar missions were officially named Chang'e, drawing on the legend of the goddess who flew to the Moon with her jade rabbit (Yutu), having been banished from Earth, for having angered the gods by drinking the elixir of immortality.

From the beginning of China's lunar program, Ouyang lobbied for the development of the resources on the Moon: "… the mineral resources of the Moon, its energy resources and its specific environment, will open up a new source of development for mankind in the future," states the 1994 report, "The Necessity and Feasibility of China's Development of a Lunar Probe," as quoted by Ouyang's biographer, He Ping.

For years, discussions about resources on the Moon referred mainly to the presence of water ice. But in the 1970s, scientists, closely examining the rocks brought back by the Apollo astronauts and the unmanned Soviet Luna probes, also found helium-3. It has been estimated that just at the Sea of Tranquility, where the Apollo 11 astronauts landed, there are 8,000 tons of helium-3.

Although the helium-3 on the Moon was not considered a resource in the 1970s, in the 1980s, when fusion experiments using helium-3 were making progress, the scientists soon needed more helium-3 than is available on Earth. Now helium-3 on the Moon became a resource, and mining it became a major objective of China's lunar plan. From the time that it was discovered that there was a potentially large quantity of helium-3 on the Moon, Ouyang became a strong and vocal promoter of developing this new resource as a fusion fuel.

Due to the dispersed nature of the helium-3 in the lunar soil (regolith), where the very limited measurements so far indicate a concentration in parts per billion, it will be from further samples brought back to laboratories on Earth that scientists will be able to determine accurately the contents of the soil, including the concentration of helium-3. The samples that Chang'e-5 is bringing back are from the Earth-facing, near side of the Moon. It has been proposed that the far side could contain a higher concentration of helium-3 than the near side, since it is more exposed to the solar wind, lacking any protection from Earth..

The existence of vast reserves of helium-3 on the Moon that could power the economy of every nation on Earth for thousands of years, is one of the best kept secrets from the American public. Why should people accept the austerity that is in their future, if with a space program that is the engine of scientific breakthroughs and the source of a constant stream of new technology, every nation could have unprecedented economic growth?

Ouyang Ziyuan, now 85 years of age, attends the Chang'e launches, and is looking beyond the Moon. He told Xinhua on November 23, 2012: "I hope Chinese people can set their 'footprints' all over the Solar System."