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C H I N A A E R O S P A C E
S T U D I E S I N S T I T U T E

China and the Moon

Marsha Freeman

On January 4 2019, China became the first nation in the world to land a spacecraft on the far side of the Moon. The Chinese said that this accomplishment was not motivated by an imaginary "Asia space race," or to obtain bragging rights in the international space community. The China Lunar Exploration Program (CLEP) is a carefully formulated series of increasingly challenging missions, to be carried out over the next decade. The stated goal is to enable world-class scientific discovery, and for China to develop and make use of the resources on the Moon for the benefit of their economy on Earth.

One might assume, knowing the political and organizational structure of the Chinese government, in which defense and economic policy are made top-down by the political leadership, that multi-decade science projects, such as the lunar program, were made in a similar way.

In fact, China's lunar development missions are by and large the culmination of a tireless nearly 30-year effort by a Chinese scientist to develop the plans for lunar exploration, gain the approval of the broad scientific community and the Chinese Academy of Sciences, and then convince the government leadership to commit to a multi-phase lunar exploration program that would eventually create a manned base on the Moon.

The execution of the lunar missions has changed over time. The successes of the earliest missions increased the confidence of the political leadership to approve the "opening up" of the program to international collaboration. Building on their success, the scientists have increased the risk and potential reward, of succeeding missions, such as the complex landing on the Moon's far side of the on-going Chang'e-4 mission.

China's lunar program does not stand alone, but is under the umbrella of a series of broad national directives. It is a significant contributor to the leadership's objective to become a world leader in science and technology. It contributes new technological capabilities for major economic projects, such as under the Belt and Road Initiative. For these reasons, unlike the program in the United States, the Chinese civilian space program is not subject to the vagaries of changing annual budget priorities, or changes in Party leadership, because it is integral to the overall goals that have been set for the country.

The Chinese are well aware of the "Apollo effect," when the optimism created by the Moon landings created a whole generation of scientists and engineers. In that respect, it is a follow-on to the Apollo program, an important aspect of which is an "opening up" of China's space science missions to not only international cooperation, but also, through a broad range of activities, to engage the public. China's widely celebrated National Space Day, observed on April 24, is on the anniversary of China's first satellite launch in 1970. The highlight last year was exhibits with models of the Chang'e-4 Moon lander and rover. And as in the U.S., for the most recent lunar missions, Chinese school children have been invited to choose the name for the landers.

The success, so far, of China's lunar missions have put its technical expertise and dedication of its scientists and engineers on the world stage. But it took 30 years, and extraordinary perseverance to get there.

The Father of Chang'e

Ouyang ZiYuan,
photo from NASA.GOV

It is in the mind of now 84-year-old scientist Ouyang Ziyuan that China's lunar program was born.

Despite an early interest in astronomy, Ouyang decided to study geology and mineral resources after high school. In a 2013 interview with Lu Yishan, a reporter with the *Yangcheng Evening News*, Ouyang explained: "In 1957, Sputnik opened for humanity, a new era of exploration. This gave me an extreme shock. I always believed China would have the capability of launching a satellite. I began to conduct a study of a meteorite in 1958, creating in the field of] "Cosmo-chemistry…." Gradually, we pulled together a theory and an array of researchers for investigations of meteorites from the Moon and other celestial bodies."

Ouyang's biographer, He Ping, reports in *Ouyang and China's Chang'e Project*, that "From the beginning of the 1960s, "Chinese scholars conducted comprehensive and analytical studies of the Moon, its topography and land formations, its origins and the history of its evolution, continuously following the progress and studies of the Moon by the international community, compiling reports, like 'Progress in Studying the Moon's Structure,' 'The Mysteries of the Moon,' 'The Study of Celestial Bodies,' and several monographs."

Ouyang continued, in his 2013 interview: "In [May] 1978, President Carter's National Security Advisor, Zbigniew Brzezinski, visited China and left a small Chinese flag that had been taken to the Moon by an astronaut, and second, a piece of the Moon mounted in Plexiglas about the size of a thumb.... The State Council asked the Academy of Sciences Guiyang Institute of Geochemistry [where Ouyang was a researcher] to investigate the time and place where the rock was found. With great care, they examined the 0.5 grams. [They] issued a 14-page report and affirmed that the rock was picked up by the Apollo 17 astronauts, and determined where the rock was from, whether there was sunlight there, which they could tell from certain characteristics." By all accounts, that one-gram piece of Moon rock would set Ouyang Ziyuan on his life's course.

Not long after, a group of scientists led by Ouyang proposed to the political leadership to start to develop and launch a lunar probe. But just coming out of the period of the Cultural Revolution left China unable to tackle such a complex and far-reaching space project.

Due to his background in geology, Ouyang was tapped to find a suitable site for underground nuclear testing, which required that he learn nuclear physics. This would no doubt be useful in his later promotion of the development of fusion energy.

By the mid-1980s, China's leadership under Deng Xiaoping turned to the policy of "the four great modernizations," to try to catch up to the advanced sector of Europe, the United States, and Japan. One of the great modernizations was a focus on science.

For implementation, Project 863 was promulgated in March 1986. Its purpose was to provide federal support to fulfill the need of China to invest in broad areas of technology development. The funding of R&D projects under Project 863 continued for decades, including in aerospace. Brian Harvey reports in his comprehensive book, *China's Space Program*, that between 1986 and 2001, about $800 million was invested in 5,200 individual projects under Project 863, including funding for the development of a robotic arm for China's future space station.

Ouyang explains in his interview, that by the early 1990s, the scientists believed that China was ready to embark on deep space missions: "In 1993, we submitted a proposal for a first lunar science mission.... Experts approved it. The Institute of Geochemistry issued a report in 1994, 'The Necessity and Feasibility of China's Development of a Lunar Probe.' In 1995, the Academy of Sciences proposed to continue the study of a program, which led to a more detailed proposal, 'The Development Strategy and Long-Term Plan for China's Lunar Exploration.' The Academy approved a plan with three parts:

1) Unmanned probes;

2) Manned landings; and

3) Creation of a lunar base, with the development of resources and the lunar environment.

The first, unmanned phase was later divided into three parts: orbiting, landing, and sample return."

This renewed push by the Chinese scientists for a lunar program, by chance coincided with a discovery that would change the view of the Moon as a cold, dry, dead world. In 1994, the U.S. spacecraft, Clementine, discovered the likely existence of water ice inside permanently shadowed craters at the Moon's South Pole. Soon, spacecraft would be under development in Europe, the U.S., Japan, and India to investigate further. Water on the Moon could be used to sustain life as well as be the ingredients for rocket fuel. It could provide the resources necessary for a manned base on the Moon.

In 1998, Ouyang and his team were asked for specific designs for lunar missions. They organized a gathering of experts from various technical domains from around the country, which in August 2000, approved the proposed lunar research plan. They released a report, titled, ”Scientific Objectives and Payload of the Lunar Exploration Satellite.” On that basis, Ouyang and his colleagues wrote a prospectus for the lunar program.

On March 3, 2003, in an interview with *People's Daily*, China National Space Administration director, Luan Enjie, 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 science and technology, and promote the development of the nation's economy by bringing in new ideas of a revolutionary 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.

In the same *People's Daily* article, Ouyang Ziyuan detailed the objectives of the first Chinese lunar mission. At a previous press conference, Ouyang had told the press that China sees the necessity of international cooperation in lunar exploration.

On January 24, 2004, the State Council approved the report laying out the lunar exploration program, as did Premier Wen Jiabao. 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 the Jade Rabbit (Yutu), having been banished from Earth, for having angered the gods by drinking the elixir of immortality.

The secret Chinese space program was about to start to undergo major changes. In November 1999, China carried out an unmanned test of its manned Shenzhou capsule. For the first time, Chinese space officials spoke publicly about the test while it was underway. Previously, the world would only learn about a Chinese space mission after the fact, if it had been a success.

In 2000, the Information Office of the State Council took a major step toward “opening up” its space program. In November of that year, the State Council published, in English, a 24-page white paper, titled simply, “China's Space Activities.” The white paper laid out a 20-year perspective for China's space plans, with an emphasis on Earth orbital applications, such as remote sensing, just then being developed in China. It also revealed the plan for the near-term launch of a manned orbital mission, which in fact took place three years later.

More important than the individual missions, however, was the entirely different approach to space activities than that of the United States, where political considerations had defined the crash program to land a man on the Moon. China well recognized that it would take years for it to “catch up” to, or compete with, the world's space powers. They claimed this was not the motivation for the programs. As outlined in the white paper, “as a developing nation, China’s fundamental tasks are developing its economy and continuously pushing forward its modernization drive.” The space program is “an integral part of the state’s comprehensive development strategy,” the white paper explains. No specific years, only general outlines, are given for each program category. The space program is not a “race,” the report makes clear. And it has proceeded from the beginning at a pace that is determined, not by political exigencies, but by technical readiness.

In 2006, the State Council released a ten-page up-date report, titled, “China’s Space Activities in 2006.” The purpose, the report states, is “to give people around the world a better understanding of the development of China’s space industry over the past five years, and its plans for the near future.”

The report explains, again, that China places its space program within the context of its “overall development strategy,” with a focus over the following five years on technology transfer from the space industry to “upgrade traditional industries.”

The first flight of the lunar exploration program, Chang’e-1, was only one year away.

Lunar Fuel for Fusion: Helium-3

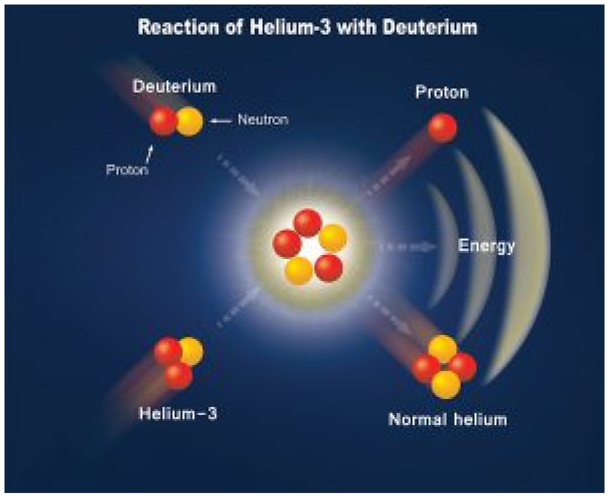
From the beginning of China’s lunar program, Ouyang lobbied for the development of the resources on the Moon. “…the mineral resources of the Moon, its energy resources and its specific environment, will open up a new source of development for mankind in the future. If China would continue to look at this opportunity without lifting a finger, then it will be difficult to safeguard the interests of our people, and we will forfeit our ability to have a say in matters of space exploration,” 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.

This isotope of helium has been deposited in the top layers of lunar soil by the solar wind over billions of years. It is rare on the Earth, due to the interference by the Earth’s atmosphere and magnetic field. But not much value was attributed to this find at the time. That changed a decade later, when scientists carrying out research on fusion energy, were looking for helium-3 for fuel.

Fusion is the process by which the Sun and stars create their energy. It is often described as the opposite of fission, which is the splitting of atoms. Fusing light ions releases orders of magnitude more energy than fission, without fission’s radioactive by-products. Helium-3 is an “advanced” fusion fuel, because it is more difficult to produce fusion energy with it than using the more common isotopes of hydrogen. But its products allow a more efficient use of the energy produced.

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 potential large quantity of helium-3 on the Moon, Ouyang became a strong and vocal promoter of developing this new resource for fusion fuel.



At the 36th Scientific Assembly of the UN Committee on Space Research, held in Beijing in July 2006, Ouyang presented a special lecture, in which he said: "One hundred tons of helium-3 will be needed each year if nuclear fusion technology is applied to meet global energy demand. The Moon has reserves estimated to be between 1 and 5 million tons. Each year three Space Shuttle missions could bring back enough fuel for all human beings across the world." These millions of tons of He-3 on the Moon could provide "at least 10,000 years of energy for all mankind," said Ouyang.

He explained in the lecture, that China's first lunar missions would enable the analysis of minerals covering only five elements. "We will try to improve that to 14" minerals, he said, which was, in fact, done in later missions. The target, he explained, is to "improve our understanding of He-3 reserves," and refine the estimate of the amount of it on the Moon.

Due to the dispersion of the helium-3 in the lunar soil, it will be from samples brought back to laboratories on Earth that scientists will be able to determine the contents in the soil. Chang'e-5, to be launched by the end of this year, will bring back lunar samples from the Earth-facing near side of the Moon. It has also been proposed that the far side of the Moon 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.

China is not the only country that has expressed an intention to exploit the helium-3 reserves on the Moon. Scientists in Russia have noted the importance of that mission for many years, and have included mining the Moon is long-term plans. India, too, has recognized the importance of the enterprise.

China's Plans for the Future

On January 14, 2019, following the successful landing of Chang'e-4 on the far side of the Moon, the leadership of the China National Space Administration (CNSA) held a press conference to discuss on the ongoing Chang'e-4 mission and the future of China's lunar exploration. During the briefing, Wu Weiren, general designer of the lunar program, said that CNSA is organizing Chinese experts to work on the follow-on lunar missions. Next will be the Chang'e-5 near-side, equatorial sample return mission. Following that, three future missions are being planned:

- 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.

China's *Science and Technology Daily* reports that Wu Yunhua from CNSA added: "On Chang'e-8, we are planning even more crucial experiments for our lunar exploration, including to determine the possibility of establishing a lunar base for scientific research, if we can do 3D printing on the Moon, and whether it is possible to use the lunar soil for the construction of buildings, in order to jointly construct a lunar base for further exploration of the Moon."

For the scientists carrying out China's lunar exploration missions, the Moon is not the limit, but a necessary stepping stone to the rest of deep space.

Ouyang Ziyuan, now 84 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."

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