China's Lunar Program Is Breaking New Ground

by Marsha Freeman

May 13—A small Chinese satellite, named Queqiao, or "magpie bridge," scheduled for launch on May 21, will play a critical role in the world's first landing of a spacecraft, Chang'e-4, on the far side of the Moon, now planned for the end of 2018. Because there is no line of sight between the Earth and the lunar far side, the Queqiao relay satellite will be placed close to half a million kilometers from Earth, in a gravitationally stable "halo" orbit, at the second Earth-Moon Lagrange Point. It will hover more than 60,000 kilometers from the lunar far side. From there, with a line of sight both to Earth and the lunar far side, it can send data back to Earth that is collected by the Chang'e-4 lander and rover, and at the same time, relay commands from Earth to the spacecraft on the Moon. This complex, two-spacecraft mission will reveal in some detail the hemisphere of the Moon that has only been seen until now in glances, first by the Soviet Luna 3 mission in 1959, and then by Apollo astronauts and later unmanned spacecraft orbiting the Moon.

China National Space Administration

An artist's illustration of a planned communications spacecraft that will relay data between controllers on Earth, and China's Chang'e 4 lander and rover on the Moon's far side.

The naming of the satellite harks back to Chinese mythology. Queqiao refers to the Magpie Bridge myth, which reportedly dates back as far as the Sixth Century B.C. As the story goes, a Weaver Girl and a Cowherd are separated by the Silver River, which represents the Milky Way. The two lovers are only reunited for one day each year, by a bridge formed by the wings of a flock of magpies. Thus this relay satellite will be the bridge between the Earth and Chang'e-4.

The Chinese lunar program is a step-by-step series of progressively more difficult missions. The three-phase Chang'e set began in 2007 by orbiting the Moon. The next goal was to land on the Moon, which Chang'e-3 did successfully in 2013. And the final step will be to return a sample of lunar rocks and soil, likely in 2020.

Landing on the far side was not one of the missions on the original agenda of the three-phase lunar program.

A Mission of 'Firsts'

The Chang'e-4 spacecraft was built as a back-up for the Chang'e-3 lunar lander. The success of that mission meant that it did not have to be repeated, and the lander could be repurposed. The scientists chose a mission, landing on the far side, that had never been done before.

At the same time that China's lunar scientists have broadened the goals of the program to include the far side landing, they have opened up the missions to international cooperation.

Along with its main role as a communications relay, Queqiao will also carry the Netherlands-China Low Frequency Explorer, which will carry out radio astronomy experiments. In December, if all goes well with the relay satellite, Chang'e-4 will be launched. The lander

carries a Landing Camera, Terrain Camera, Low Frequency Spectrometer, and Lunar Lander Neutrons and Dosimetry experiment, which were all developed in Germany.

The Chang'e-4 lander will carry out another "first." The probe will carry a "mini-biosphere," bringing an array of biology experiments to the lifeless Moon. Inside a small tin will be potato and arabidopsis seeds, along with silkworm eggs. The experiments were designed by 28 Chinese universities, and it is hoped that as the seedlings grow, they produce the oxygen that the silkworms need. "We want to study the respiration of the seeds and photosynthesis on the Moon," Lui Hanlong from Chongqing University explained.

The Chang'e-4 mission will also carry along secondary payloads that are hitching a ride on the rocket to the Moon. Two microsatellites, each weighing about 90 pounds, will carry out astronomy objectives, as they fly in formation orbiting the Moon. They will observe the sky in the very low frequency range of the electromagnetic spectrum, as a test run for future potential astronomy missions. "Many astronomers around the world had proposed to observe at this low frequency range from space," said Chen Xuelei of the National Astronomical Observatory of China, last month, "and now we are proud that [the] Chang'e-4 mission will give us the opportunity to make the first peek at the heavens in this frequency range."

NASA Goddard Space Flight Center Scientific Visualization Studio

Far side of the Moon.

Students at the Harbin Institute of Technology developed an amateur radio payload for the first microsatellite. The second will carry a microcamera developed by King Abdulaziz City for Science and Technology in Saudi Arabia.

Follow-on lunar missions are now under discussion. One region of the Moon of particular interest is the South Pole. Orbiting spacecraft have indicated caches of water ice at the pole, in ultra-cold regions at the floor of craters which are in perennial darkness. Last year, the deputy director of China's Lunar Exploration and Space Program Center, Pei Zhaoyu, reported that China "will carry out three missions at the Moon's polar regions, to research the geological structure and mineral composition of its South Pole, and we will take samples back from the Moon on one of these missions."

The South Pole-Aitken Basin could well be a target.

Why the Far Side?

Just comparing photographs of the near and far sides of the Moon demonstrates why exploration of the 40% of the Moon's surface that never faces the Earth will help provide answers to questions such as the formation, evolution, and development of the Solar System. The dominating feature on the far side is the South Pole-Aitken Basin. It is the oldest extant feature on the Moon, and one of the largest impact basins in the Solar System. The far-side geology lacks the smooth *maria* characteristic of near-side volcanic eruptions, which has been taken to indicate that the surface is older, formed before there was volcanic activity. But just recently, scientists have suggested that volcanic eruptions took place more re-

cently than previously understood, millions rather than billions of years ago. Taking *in situ* measurements may help to refine further the various geologic ages of the Moon.

Analysis of rocks in the Basin using photographs taken from orbit, suggests that the rocks are unique. The crater is so deep—at about 6 kilometers—that the rocks would likely be older and of a different composition than those that have been sampled on the near side in the past, by Apollo astronauts and Russian robots. Such sample analysis will shed light on an age still present on the Moon, which history has virtually disappeared from the geologically active Earth.

Shielded from the electromagnetically noisy Earth, by facing away from the Earth, the far side of the Moon presents a unique opportunity to open a window to a portion of the electromagnetic spectrum otherwise hidden from view. Since the early days of lunar exploration, scientists have been anxious to put a radio telescope on the far side, to "look" out at the universe in very low frequencies. A broad array of phenomena could become visible, including those that are well known, but will look "new" in a different wavelength, such as the imaging of planets and the detection of asteroids, comets, and radio-emitting galaxies.

There has been conjecture that the future fuel for fusion energy—helium-3—that is deposited in the lunar soil by the solar wind, may be more "concentrated" on the far side than on the Earth-facing side (although "concentration" is relative, since the amount is in parts per billion). It may be that the side of the Moon facing the Earth is partially shielded from the Sun, which lowers the rate of deposition of the helium-3. Determining whether there is a difference will be one of the most interesting findings of the mission.

While China is in final testing for the launch of the Chang'e-4 to the far side, it is also readying the Chang'e-5 sample return mission. The date of that launch will be determined by the readiness of the Long March 5 rocket. This four-craft mission needs the larger Long March 5 launcher, which suffered an accident last July.

The sample return mission will set four new records in the Chinese lunar program. The lander will automatically collect samples of lunar dust and soil. It will place them in a hermetically sealed capsule. The capsule will automatically blast off from the surface of the Moon, and rendezvous and dock with a craft in orbit. As it approaches Earth, the capsule will undock from the orbiter and come back to Earth, at an interplanetary high velocity. Due to the complexity of the mission, as with automated sample returns in the past, the samples will be taken from a near-equatorial region on the lunar near side, where the craft are able to communicate directly with Earth.

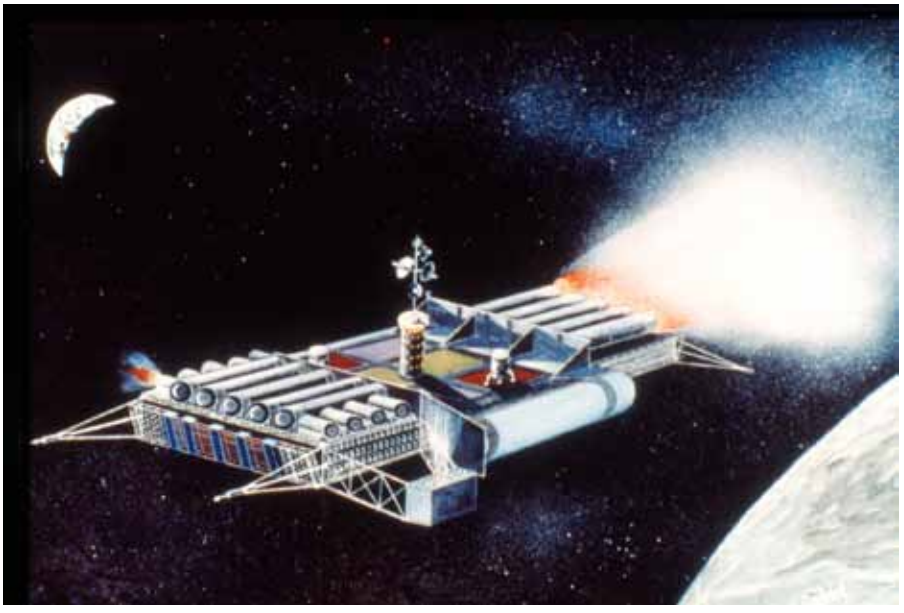
Scientists are now planning a fourth phase of the Chinese lunar program, which will consist of three or four missions, between 2020 and 2030. The aim is to start to use the resources on the Moon. The chief designer of the Chang'e program, Wu Weiren, told China Central Television in March, that the South Pole would be a key target for a robotic research station. "As only the Moon's South Pole can receive sunlight in most of its area throughout the year, we want to land at such a place where there might be abundant sunshine and possibly water to build a research station to carry out relevant research using resources there," he explained. "Nobody has ever landed there yet. So it will be the first landing if we make it."

Chinese scientists have been awaiting a decision by the government to proceed with the most challenging mission of all—a manned landing on the Moon. During the national Space Day celebrations on April 24, the chief designer of China's manned space program, Zhou Jianping, hinted: "We have had in-depth discussions with many experts about manned lunar exploration, and conducted research on key technologies in recent years." Chinese scientists have started soliciting proposals for manned lunar landing and ascent vehicles from the public.

After the completion of this first three-phase lunar exploration program with the Chang'e-5 sample return, China will be resuming its manned space missions, as it begins assembly of a manned space station about two years from now. In the meantime, China is engaged in a broadening array of science, technology, and engineering projects.

Beijing to New York in Two Hours

Wind tunnel tests are underway in China on a novel hypersonic airplane design. The tests have reached speeds of Mach 7, or 5,600 miles per hour. This is one of a number of projects underway, including rocket-powered reusable space planes and scramjet engines, to demonstrate next-generation vehicles that are reusable and fast, with both military and civilian applications. As Russian President Putin stated on March 1, when describing the advanced weapons systems under



Krafft Ehricke's painting of a proposed nuclear space freighter that he designed.

development in Russia, such speed gives the vehicle a global reach, and nullifies any ballistic missile defense system. And while U.S. military officials expressed shock at the Russian developments, in fact, the United States, China, and Russia have been investigating hypersonic ramjet and scramjet technologies for decades. At the Key Laboratory of High Temperature Gas Dynamics, a record-breaking wind tunnel to obtain speeds of Mach 36 (more than 30,000 miles per hour) is being designed, to put China at the forefront of hypersonic research. For reference, an aircraft at that speed would be able to fly from China to California in 14 minutes. It would also be capable of transporting people and payloads to orbit.

The wind tunnels are also being used to test designs for reusable space planes. The space plane would be able to take off horizontally from an airport, and return to Earth after having delivered cargo and people to orbit. It is being designed with the potential to take tourists to space, launch satellites, deliver supplies to the space station, and carry out emergency space rescue missions. Unlike the U.S. Space Shuttle, the Chinese model will not use rocket engines to obtain the speed required for orbit, but will switch to ramjet propulsion once high in the atmosphere. Chinese projections indicate that the cost of launch to low Earth orbit could be reduced to one tenth the cost of expendable rockets.

It has been reported by China Aerospace Science and Technology Corporation that the space plane will be flight-tested in 2020, as one milestone on a long-term space transportation road map released at the end of last year. Covering a period up to 2040, the road map includes the Saturn V-class heavy lift Long March 9, and fully reusable launch vehicles by 2035.

Most interesting is the brief mention of a nuclear-powered space shuttle, to be operational in 2040. By that time, lunar settlements, mining, and industrial facilities will have transportation requirements that the late space visionary, Krafft Ehricke, proposed would require nuclear freighters, cycling between lunar and Earth orbit. The road map describes the nuclear shuttle as able to support large-scale exploration and the development of space resources such as the mining of asteroids.

Spurring Innovation

Over the past year, China's aerospace industry has begun to move to enlist the energies of private companies and individuals in space technology. New companies, often spun off from established institutions, are producing rocket engines and rockets, vehicles for space tourists, and microsatellites, with the aim of introducing more innovative technology into the economy, especially in the fields of robotics, aviation, and astronautics. Although there are perhaps only a dozen aerospace companies raising capital in China, with encouragement from state institutions—both technical and financial—it is a sector that is going to grow.

China's President Xi Jinping has made investment in science and technology—to spur innovation and drive economic growth—a hallmark of his presidency. As China eliminates the last vestiges of poverty, the upshift in the population's standard of living and access to education will enable increases in productivity, as China becomes a "knowledge-based economy."

This process will increase the free energy available for pushing further into the frontiers of science and technology.