



## **Systems and Infrastructure Needed to Enable A Chinese Crewed Lunar Landing**

Marsha Freeman

China's successful completion of the third phase of its Lunar Exploration Program with the Chang'e-5 lunar sample return opens a new chapter in China's study of the Moon. China can now prepare for a permanent base on the Moon, the International Lunar Research Station, which may start crewed operations in 2036. This will require technical breakthroughs in numerous fields.

### **Crewed Lunar Lander**

A major challenge the Chinese are facing is to design a vehicle able to land astronauts on the Moon and transport them back to an orbiter on their way back to Earth. The lander is viewed as the "long pole of the tent" of a manned lunar landing. It was the inability to ready a completed lunar lander which forced NASA to change the nature of the Apollo 8 flight, leaving testing of a lander for later missions.

Starting as early as 2005, the Chinese government began a program to design unmanned, robotic lunar landing systems for the Yutu rovers. According to journalist Andrew Jones in an August 9, 2021 article, China's leading spacecraft designer China Aerospace Science and Technology Corp. (CASC) is now committed to developing a landing system for a manned mission. While few if any details on such a lander have been made public, Zhou Yanfei, deputy general designer of China's manned space project told Chinese media in 2020 that technological breakthroughs on everything from launcher to rocket design, landers to life support, are key to making a crewed lunar mission possible.

International cooperation is key to this strategy. For example, in September 2010, Ukraine and China signed an agreement for a cooperative program on the exploration and use of space, specifically the Moon and Mars. In 2012, Ukraine and China discussed areas of cooperation in a lunar program, during a visit of a delegation from the China National Space Administration. More recently, according to "well-informed sources" cited by Aviation Week magazine of February 2020, China has sought help from Ukrainian propulsion and rocket design engineers to study several engine designs that could put a very large lander on the Moon. In addition, the Ukrainians have been asked by the Chinese to look at new fuel mixtures for lunar landing propulsion, as well as new throttle mechanisms that would give astronauts added maneuverability during their descent to the lunar surface.

## **Space Suits**

A second “long pole of the tent” of the manned lunar program is the development of a space suit appropriate to a lunar environment. This space suit will necessarily be different from those used in Extravehicular Activities (EVA, or “space walks”) because the EVA’S that are carried out from the ISS and from the Chinese Space Station are in orbit, protected from cosmic radiation by the Van Allen radiation belt. On the Moon, the astronauts’ space suits would have to accommodate long stretches of time for exploration on the surface of the Moon. In addition, the astronauts would need to be protected from radiation and extremes of temperature for these longer stays outside their craft.

NASA’s office of the Inspector General revealed in an August 2021 report that despite spending \$420 million on space suit development since 2017, NASA has yet to come up with a suit that could meet the needs of longer-term lunar exploration. The Chinese, who are undoubtedly working on a lunar suit as well, have not released details of their progress.

## **Crewed Spacecraft**

Even if China resolves multiple issues with its crewed lunar lander, and has space suits ready, China also needs a crewed spacecraft to shuttle the crew and lunar lander into lunar orbit. China is in the process of developing a crewed spacecraft to replace the Shenzhou capsule, which was not designed for flights beyond Earth orbit. In early May 2020, according to journalist Andrew Jones, China launched a prototype of a two-module spacecraft on a Long March 5B rocket from Wenchang Spacecraft Launch Site. The unmanned demonstration flight successfully performed seven orbit-raising maneuvers to reach a final apogee of 8,000 kilometers, or 4,970 miles. The new solar-powered craft spent 2 days and 19 hours in orbit. Its rapid descent to Earth simulated a return from the Moon at a much higher speed than coming back to Earth from low-Earth orbit, thereby causing a higher temperature which required new materials for its heat shields. The body of the capsule also required new materials to ultimately protect astronauts from radiation in space.

Jones reported that experiments aboard the spacecraft included a 3D printing system for microgravity environments, gigabit-level high-speed communications between the ground and the spacecraft, and an on-orbit leakage and collision detection experiment using sound waves.

At over 20 tons, the new craft is designed to ultimately carry 6 astronauts, or 3 astronauts and 500 kg of cargo, unlike the 8-ton Shenzhou which could only carry three passengers. The new crew module is partially reusable and the spacecraft features a modular design that allows it to be adapted to meet different mission requirements. The as-yet unnamed capsule was on display at the Airshow China 2021 at Zhuhai City in Guangdong province.

## **Space Launch Systems**

China is developing advanced replacements for its major transportation systems; among these are rockets, propulsion methods, and launch sites.

**ROCKETS:** In 2006, former NASA Administrator Mike Griffin was invited to go to China to meet with people in their space program. In a private conversation with this author before he left, he expressed doubt that China had much of a civilian space program and believed it was all run by the military. Within weeks of returning from China, he had a very different view and told this author how impressed he was by the quality of the civilian program's facilities and personnel. Jeff Foust wrote in 2007 that Griffin told a luncheon meeting upon his return from China that "I personally believe that China will be back on the Moon before we are. I think when that happens, Americans will not like it, but they will just have to not like it. I think we will see, as we have seen with China's introductory manned space flights so far, we will see again that nations look up to other nations that appear to be at the top of the technical pyramid, and they want to do deals with those nations. It's one of the things that made us the world's greatest economic power. So I think we'll be reinstructed in that lesson in the coming years and I hope that Americans will take that instruction positively and react to it by investing in those things that are the leading edge of what's possible." In a 2007 interview with Aviation Week and Space Technology magazine, Griffin said he thought the Chinese could send a manned mission to orbit the Moon using their Long March 5 rocket, "While they have not stated an intention to do so, the Chinese could send a (manned) mission to orbit the Moon with the Shenzhou spacecraft, as we did with the Apollo 8 mission, which inspired our nation and the world during the Christmas season of 1968. China could easily execute such a mission with their planned Long March 5 rocket."

After a shaky beginning, the Long March-5 has become the mainstay of China's leading space programs. It launched the 20-ton core module of the Chinese space station, the Chang'e-5 sample return mission, and the 2020 Mars mission, the Tianwen-1. The Long March-5 can carry a payload of 25 tons to low-Earth orbit and 10 tons to high orbit. The Long March-9, a Saturn-5 class vehicle, which is projected to be ready for its first test flight in 2028-2030, is considered a "heavy launcher" that can lift a payload of 140 tons to low-Earth orbit or 50 tons to lunar orbit.

At the present time, China does not have a man-rated rocket that can go to the Moon. However, Andrew Jones wrote in December of last year that the Chinese are working on a prototype which could use the Long March 5 to put Chinese astronauts on the Moon by 2026. He cited Long Lehao, a senior space industry figure and Long March launch vehicle designer, telling China's state media CCTV Dec. 10 that the new heavy-lift rocket, referred to as Long March 5 "Dengyue" ("Moon Landing"), would use ready-made technologies, such that "the development progress will be relatively fast." "Dengyue" is not used exclusively to refer to a crewed landing, it is also used for landing robotic systems or reaching the Moon generally. It is still an open question when China could crew-rate any of its new heavy lift launchers capable of going to the Moon.

**LAUNCH SITE:** China's leading space programs--the space station, the lunar program, and planetary probes-- all depend upon the most advanced rockets, the Long March 5 and Long

March 9. These two rockets could not be launched from China's three existing launch sites because the first stages are too wide to be shipped by rail, which is the only way to reach the older launch sites located in the interior of the country. The Long March 5, at 5.2 meters width, was already too wide for the standard rail gauge, while the Long March 9 is slated to be double that width. In August 2007, the Chinese government commissioned the Wenchang Spacecraft Launch Site to be built on Hainan Island in the South China Sea, which seaport could accommodate ships bringing the rocket parts to the new facility.

Also, the launch site is only 19 degrees north of the equator and the Earth turns faster at the equator, consequently rockets get an extra boost and can carry a larger payload. Explained Liu Jianzhong, deputy designer of the rocket system, in a news conference Dec. 18, 2013 and reported by China Daily, "Among other advantages, the latitude of Wenchang is lower than that of Xichang, enabling the rocket to use less fuel to send satellites or probes into orbit. In addition, launching from the Wenchang facility means the rocket's wreckage will fall into the sea rather than onto inhabited areas, saving us many problems we would have to handle."

Previously, all of China's manned missions were launched from the Jiuquan Satellite Launch Center in the Gobi desert Unlike Jiuquan, Wenchang—known as China's Cape Canaveral--is open to the public and will include a space theme park, tours of the launch center, a science museum, and visitors will be able to stay at a Hilton Hotel from which they can watch the launches. Already, the government reports that tourism has increased 15% per year since 2016, when the Long March 5 took its maiden flight.

### **Closed-Cycle Life Support**

National space agencies all agree that before there can be long-term missions to the Moon, there should be facilities built on Earth to simulate conditions at a lunar base. On the Moon, a closed life-support system will be necessary that doesn't rely on imports of consumables from Earth.

China has been experimenting with closed biospheres for nearly a decade. The "Lunar Palace" (Yuegong-1), constructed in 2013, began running its first tests in 2014 at a 500-cubic-meter enclosed capsule covering an area of 160 square meters, consisting of an integrated living module and two plant cultivation modules. The Lunar Palace was sited at the Beihang University of Aeronautics and Astronautics. "Palace" is an acronym for Integrative Experimental Facility for Permanent Astrobase Life-support Artificial Closed Ecosystem.

In May 2017, the longest stay in a bioregenerative life support system (BLSS) was begun at the Lunar Palace 1 facility when a "crew" of eight student volunteers took turns living in the closed-loop biosphere over a year's time, recycling their oxygen, water, and food. Oxygen was supplied by the plants, and water was collected from condensation on surfaces made for that purpose. The dedicated students subsisted on crops such as corn, lentils, peanuts, and cucumbers as well as on bread made from mealworms that were fed from plant waste. The experiment was designed both to create a closed system in which animals, plants and microorganisms could co-exist, and also to test how humans are affected, both physically and mentally, in such an environment.

The Soviet Union pioneered research on simulating long-term missions such as a 500-day crewed mission to Mars, where the focus was on the psychological and physiological effects of long-term isolation during a simulated manned space flight to Mars.

Between 2007 and 2011, three different crews of Russian and international volunteers lived and worked in a mockup of a spacecraft, including an ascent-descent craft and Martian surface simulation, located at the Russian Academy of Sciences Institute of Biomedical Problems (IBMP) in Moscow. The mission, known as Mars-500, also simulated landing and space-suited walks on Mars.

### **International Lunar Research Station (ILRS)**

Russia and China are planning to build a transportation system between the Earth and the Moon, and to place infrastructure on the surface of the Moon to support scientific research. The ILRS will be open to all countries who wish to participate and there will be different levels of participation in concert with a country's capabilities.

The China-Russia ILRS is a distinctly different concept from the "Moon Village" proposed in 2015 by then European Space Agency director Jan Wörner. The "Moon Village," conceived as a public-private operation, could depend on private corporations for infrastructure and sub-systems, where the risk of a lack of coordination could endanger the project.

The first formal presentation on the ILRS was given by Wu Yanhua, Deputy Director of the China National Space Administration on June 16, 2021 at the Global Lunar Exploration Conference (GLEX) in St. Petersburg. His talk, entitled "Road Map for Creation of the International Lunar Research Station," described the scientific objectives of the project. In general, there is a science of the Moon and a science from the Moon, he explained. The first being the study of lunar topography and geological structure and the chemistry, materials, and geochronology of the Moon. The second category includes lunar-based astronomical observations and lunar-based Earth observations. In addition, he discussed the potential for lunar-based biological and medical experiments and, importantly, the *in-situ* utilization of lunar resources.

In the fall of 2021, at the biennial China International Aviation & Aerospace Exhibition in Zhuhai, Wu again had an opportunity to present the ILRS to international observers, most notably the three largest supporters of the European Space Agency—Germany, France, and Italy—where he emphasized the possibilities for interested parties to participate in the ILRS, according to the author in the Executive Intelligence Review, October 2021.

Below are details from the GLEX talk that Wu Yanhua gave, where he proposed that the China-Russia ILRS would function as a cislunar transportation facility, including round-trip transfer between Earth and Moon, lunar orbiting, soft landing, ascending from the lunar surface, entry and reentry to Earth. It would serve as a command center for global communications, energy supply, thermal management and support modules if needed. It would also support modules for moving around on the lunar surface, lava tube exploration for cargo transportation, and support for excavation and sampling. Further, it would support in-orbit and surface scientific experimentation, observation, technology verification and deep space exploration.

The China-Russia ILRS is conceived in two phases. The first, from 2021-2025, would involve the use of various lunar missions to conduct further reconnaissance for determining the

ILRS design and construction site, including technological verification for a secure and precise soft-landing area. Results of the sampling done through the Chang'e-5 mission will be key to choosing the ILRS site. Missions already planned include China's Chang'e-6 and Chang'e-7, Russia's Luna 25, Luna 26 and Luna 27, and potential missions by other partners.

Phase two would be in two stages. The first, from 2026-2030, would include lunar sampling, and massive cargo delivery, and securing a high-precision soft landing, all facilitated by China's Chang'e-8 and Russia's Luna 28 missions, along with missions by other potential partners.

The second stage (2031-2035) would see the launch of Russia-China joint operations. Missions ILRS-1, ILRS-2, etc., would facilitate the comprehensive establishment of the ILRS through the completion of in-orbit and surface capabilities for energy, communication, transportation, as well as for research, exploration, verification of *in situ* use of resources, and other potential common technology.

Phase 3, which would begin after 2036, would include the following objectives: lunar research and exploration, technology verification, supporting human lunar landing with the completed ILRS, expanding and maintaining modules if needed.

International collaboration will be key to the success of this strategy. In his speech, Wu defined the domains of cooperation that the ILRS would encompass.

Partnering countries can participate in the planning of the ILRS Road Map and would share scientific and engineering objectives, including technical data analysis. Collaboration would extend, as well, to plans for launching the ILRS's component parts and coordination of its operation management.

Once the ILRS is completed, it will be the first step in fulfilling mankind's dream of truly becoming a "spacefaring species".

Opinions, conclusions, and recommendations expressed or implied within are solely those of the author(s) and do not necessarily represent the views of the Air University, the Department of the Air Force, the Department of Defense, or any other U.S. government agency. Cleared for public release: distribution unlimited.