China Gears up for Lunar Science

By XIN Ling (Staff Reporter)

A view of Earth over the far side of the Moon, taken by the Chang'e 5 test vehicle (Chang'e 5-T1) on October 28, 2014. *Credit: CAST.*

When White House National Security Assistant Zbigniew Brzezinski was visiting Beijing in 1978 for the normalization of US-Sino relations, he presented his Chinese host with a special gift: 1 gram of lunar soil enclosed in plexiglass. At that time, few scientists in China knew how to deal with such a sample, so geologist OUYANG Ziyuan was summoned from the CAS Institute of Geochemistry in the remote province of Guizhou to work on it. With limited instruments and techniques, his team used half the gram to complete a series of experiments. They found out that it was actually from Apollo 17, the last US manned mission to the Moon.

It is not until the late 1990s that China could start thinking about going to the Moon. Named after Chang'e, the mythical Chinese lunar goddess, an ambitious and well-planned program was unveiled by OUYANG and his followers. All unmanned technologies are to be tested by 2020, before manned exploration is deployed for the ultimate goals of resources utilization and human habitation. The first three probes were launched successfully in 2007, 2010 and 2013, respectively, and two more are on the way. In November 2017, Chang'e 5 will bring back two kilograms of soils and make China the third country to own their own lunar samples. By the end of 2018, Chang'e 4 is going to land on the far side of the Moon for the first time in human history – with the help of a relay satellite to communicate with the Earth.

Sample Return

As the last phase of China's uncrewed lunar exploration, Chang'e 5 mainly aims at testing its return technologies. From taking off from the Moon's surface to landing on the Earth, its technical readiness seems solid. The most challenging part of the mission was rehearsed in 2014: the return capsule bounced and re-entered the Earth's atmosphere to prevent overheat induced by initial high speed.

One highlight of the upcoming two-day round trip in November will be the robotic sampling of about two kilograms of lunar soils from the landing spot. The process, which may take a few hours to complete, involves both shoveling and drilling. The soils collected by the drill will then be put into a 2m long soft tube so that it can fit into the return capsule while the soil layers are preserved in the original order, OUYANG told *BCAS*.

Chang'e 5's landing site near Mons Rümker in Oceanus Procellarum, which is a large area of lunar mare in the northwest region of the Moon, has attracted world attention. "The Apollo and Luna missions visited a total of nine sites, all on the nearside quite close to the equator," said Ian Crawford, a lunar exploration specialist from Birkbeck College, University of London. "It is important to collect samples from other parts of the Moon and Chang'e 5 can make a major contribution."

According to Crawford, Oceanus Procellarum will be an ideal area for sampling because that region includes basalts of a wide range of ages, which will allow refinement of the lunar stratigraphy and chronology for a better understanding of lunar mantle evolution.

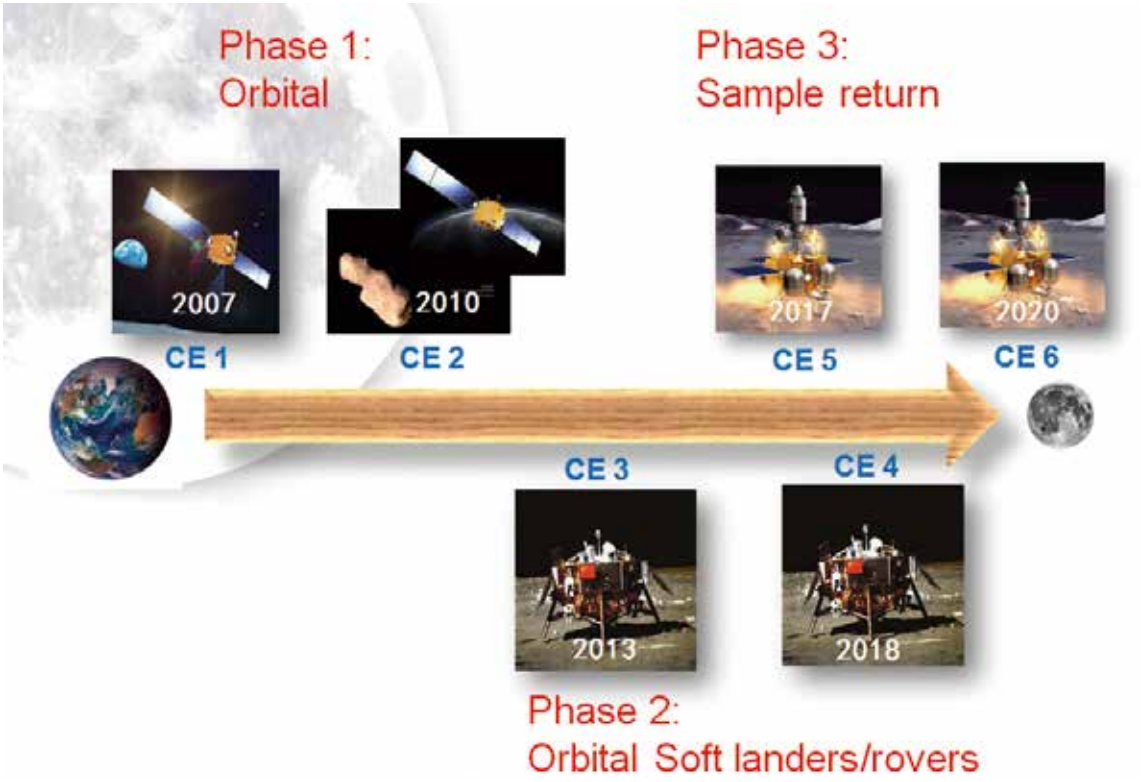
Clive Neal, a planetary geologist at the University of Notre Dame, USA, was also excited. "Chang'e 5 has an opportunity to bring back some young basaltic material that we don't have in existing samples, nor in the lunar meteorite collection," said Neal, who had postulated the existence of a new type of lunar basalts based on data from the Chang'e 3 rover. "These samples will be important for understanding why volcanism occurred two billion years ago, and to retrieve the mantle source and thermal history of the Moon," he told *BCAS*.

The solicitation and selection of research proposals will begin soon after the samples go through primary classification, OUYANG mentioned. It will be open first to domestic scientists and one year later to foreign applicants. A considerable part of the soils will be preserved at the National Astronomical Observatories of China (NAOC) in Beijing.

Explore the Far Side

Tidally locked to the Earth, the Moon has always the same side facing us earthlings when the other side is "invisible". Studies have shown that it is a very different world at the back of the Moon: it is geologically more ancient, and dominated by highlands – unlike the plain landscape that prevails on the near side.

Though NASA and ESA have well looked into the feasibility of going to the lunar far side, the Chinese are now to make the first trip to the "virgin land". Following the success of Chang'e 3 — China's first and only



China's unmanned lunar exploration program contains three stages: (I) orbiting missions, (II) landing missions, and (III) sample return missions. *Credit: NSSC.*

landing mission on the Moon by far, Chang'e 4, initially defined as Chang'e 3's backup, was approved in 2016 to perform a similar task on the far side of the planet.

Different from Chang'e 3, though, a relay satellite has to be put up at the Moon-Earth Lagrangian 2 point around mid 2018 for the communications between Chang'e 4 and the Earth. The Chang'e 4 probe (including a lander and a rover) will land six months later in the South Pole-Aitken Basin area, the largest and arguably oldest impact basin on the Moon, carrying not only regular payloads like a topography camera and a lunar penetrating radar, but specially developed equipment for the unique science opportunities accessible only on the far side.

One such example is low-frequency radio detection. The lunar far side has been regarded as the "cleanest" place to measure the red-shifted Hydrogen 21cm emission line from the early universe. It will help scientists peep into "the cosmological dark ages", a period after the Big Bang and before the birth of the first stars, which is critical to our understanding of how the first stars and the first large-scale structures of the universe formed.

"These emissions cannot be observed on Earth due to ionospheric cut-off, but at the Moon, there is no atmosphere. On the far side, which is shielded from all types of artificial terrestrial radio emissions, there is less interference from radio noise", explained Marc Klein Wolt from Radboud University Nijmegen, the Netherlands, who is in charge of developing the Low Frequency Radio Detector (LFRD) on the relay satellite.

There will be two more such detectors on Chang'e 4: one on the lander, which is under development at the CAS Institute of Electronics, and a set of two detectors, to ride separately on a pair of microsatellites to orbit the Moon and form a radio interferometer.

"The mission will be very difficult," said Marc, "but if we succeed, we pave the way for a future large radio facility on or near the Moon."

CHEN Xuelei from NAOC, who is involved in the design of the detectors on the microsatellite pair, recognized the scientific uncertainty. "We have a

Chang'e 5, schedule for launch end of November 2017. **Left:** the two-part lander and sample return module. **Right:** a remote sensing image of the reported landing site near Mons Rümker in Oceanus Procellarum. *Credit: CNSA*.

general idea of what to look at in this wavelength. But frankly, since this has never been done before, we are not sure what we will see."

The main technical challenge is to reduce the radio noise of the satellite or lander itself, which may severely impact the results of observations, CHEN and Marc admitted. And given the time shortage, they are working around the clock to make prototypes and reduce platform noise.

International Collaboration

Notably, it is the first time that China has rolled out the red carpet to international collaborators in its lunar program. In all, four foreign payloads will be taking their ride on Chang'e 4. Besides the LFRD, there will be the Advanced Small Analyzer for Neutrals (ASAN) from the Swedish Institute of Space Physics in Kiruna, the Lunar Lander Neutrons and Dosimetry Experiment (LND) from the University of Kiel, Germany, as well as an optical camera from Saudi Arabia.

ASAN, which will be placed on the Chang'e 4 rover and working from 60cm above the lunar surface, aims at measuring the reflection of solar wind to help better understand its interaction with the lunar regolith.

"No such measurement has been done from the surface of the Moon," said ASAN team leader Martin Wieser. "It may shed new light on the production of water on the planet." The lunar far side is ideal for such a measurement, he said, because it is exposed to the solar wind for a much longer time as any point on the near side.

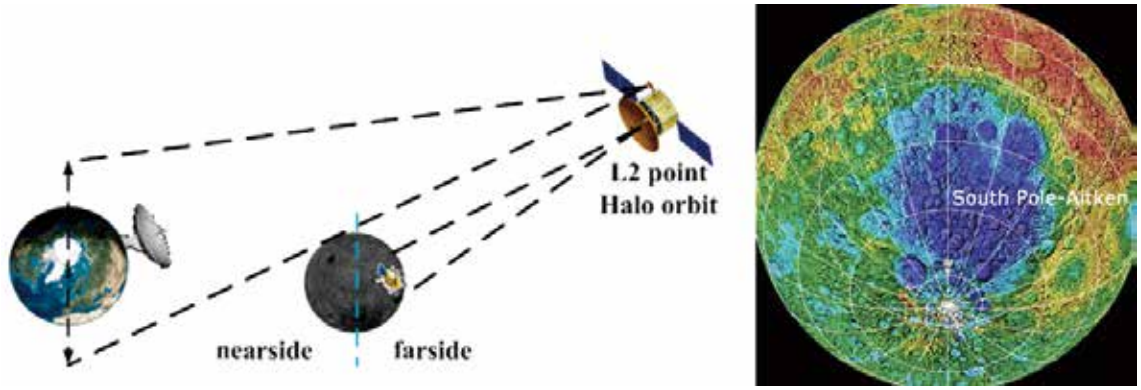
"The flight instrument is ready tested and calibrated, and we just delivered the flight model to the National Space Science Center (NSSC) in Beijing on April 7," Wieser told *BCAS*.

The Lunar Lander Neutrons and Dosimetry (LND) Experiment, on the other hand, will be equipped on the lander to measure the radiation dose which an astronaut would experience on the Moon, said Robert Wimmer-Schweingruber from the University of Kiel in charge of the experiment.

Although there are many models for lunar radiation exposure, there have never been in situ measurements on the Moon, he explained. "The constantly present galactic cosmic rays interact with the lunar soils to produce a significant secondary contribution to the radiation exposure. Therefore, such measurements are important to be made on the surface of the Moon, and neutrons are the most dangerous part of this secondary radiation."

According to Wimmer, the LND flight instrument is currently being assembled and its subsystems are undergoing tests. The device will later go through environmental tests and be delivered in the summer of 2017 to the Chinese.

Crawford applauded China's new moves in international collaboration, which he believed is very important in space exploration. WANG Chi from NSSC, who is the chief engineer of all Chang'e payloads, said



Chang'e 4, the first attempt to soft land on the far side of the Moon. **Left:** The mission involves a lander, a rover, and a relay satellite to be put at the Moon-Earth L2 point for communication. **Right:** it will touch down somewhere in the South Pole-Aitken Basin area, the largest impact basin on the Moon. *Credit: NSSC.*

Chang'e 4 goes international. Chang'e 4 is the first Chinese lunar mission to take international scientific payloads. From left: the Low Frequency Radio Detector (the Netherlands), the Advanced Small Analyzer for Neutrals (Sweden), the Lunar Lander Neutrons and Dosimetry Experiment (Germany). *Credit: NSSC.*

that "Inviting foreigners to participate in our missions will help clarify some misunderstandings about China's purposes to go to the Moon. It can also promote the advancement of our lunar science in a most effective way."

Beyond 2018 and the Moon

WANG is expecting such cooperation to go from the payload level to the mission level, maybe starting with the Mars probes his colleagues are working on.

Though still waiting for government approval, Chinese scientists are already planning on equally ambitious trips to Mars. Their first attempt, which aims for a 2020 launch, will consist of an orbiter, a lander and a rover. Such a design is unique because there has been no space-ground joint detection on Mars yet. "We are now developing the prototypes," WANG noted. And already engaged in the work are teams from Switzerland and Austria. A second probe is expected to fly before 2030, which may involve sample return from Mars.

China's lunar endeavor does not end with Chang'e 4, of course. The long to-do list after 2018 includes a possible sample return mission from the far side, trips to the polar regions in search of water, as well as a Moon-based research station to be set up between 2020 and 2030 with long-running, unattended research infrastructures.

But China still needs to address a couple of major problems before it can become a space powerhouse. One long-standing issue is the lack of a dedicated space agency like NASA or ESA to make the overall deployment and coordination of its space activities. The other is the potential funding shortage. Although the exact costs have never been officially announced, it is reported that China has spent 1.4 billion yuan

As scheduled, the 8-tonne Chang'e 5 spacecraft will be launched by Long March 5, China's most powerful rocket, for a sample return mission from the Moon at the end of this November. *Credit: CCTV.*

on Chang'e 1 and 2, and 20 billion on Chang'e 5. It is important to make sustained commitment to supporting the science, when data start to roll down the pipeline. For example, the ultraviolet telescope on Chang'e 3 lander, the first of its kind on the moon, is experiencing a funding cutoff since its design life span is one year – although it has been working well for over three years.

Nevertheless, scientific returns have kept increasing for China as the exploration steps up. "I am sure science will be a major beneficiary of China's lunar exploration program," Crawford said.

"China's efforts are already granting it the role of being the major player of lunar exploration on the international scene," observed Michel Blanc, an astronomer at Research Institute in Astrophysics and Planetology, Toulouse, and executive director of the International Space Science Institute in Beijing. "When time is ripe for China to select its scientific payloads via open international competition, it will be in the enviable position of being able to carry the best possible scientific investigations on the best-designed space missions: a key characteristics shared with the few leading space-faring nations on this planet", he said.