An Interview with OUYANG Ziyuan: Chang'e-3 and China's Lunar Missions

By XIN Ling (Staff Reporter)

OUYANG Ziyuan is a distinguished geologist and cosmochemist, known as the founding father of the Chinese lunar exploration program. In the past two decades, he played a leading role in developing China's first lunar probes and blueprinting China's lunar exploration roadmap. He worked as chief scientist of the nation's first lunar mission, which was carried out by a China-made moon-orbiting spacecraft called Chang'e-1. For the first time in the Chinese history, Chang'e-1 accomplished moon observation in lunar orbit for nearly 16 months and obtained 100m-resolution 3D imagery of the entire moon's surface. After the success of Chang'e-1, OUYANG continued to chair the Chang'e-2 mission, the second lunar orbiter launched by China in 2010 which mapped the entire globe of the Moon in 7m resolution.

In late October 2013, one month before the launch of Chang'e-3, he granted an interview to *BCAS* reporter XIN Ling and revealed some of the most exciting features of the new probe. Satisfied with China's achievements by far, he said China could and should further its moon/deep space exploration agenda in decades to come.

Prof. OUYANG Ziyuan, founding father of the Chinese lunar exploration program.

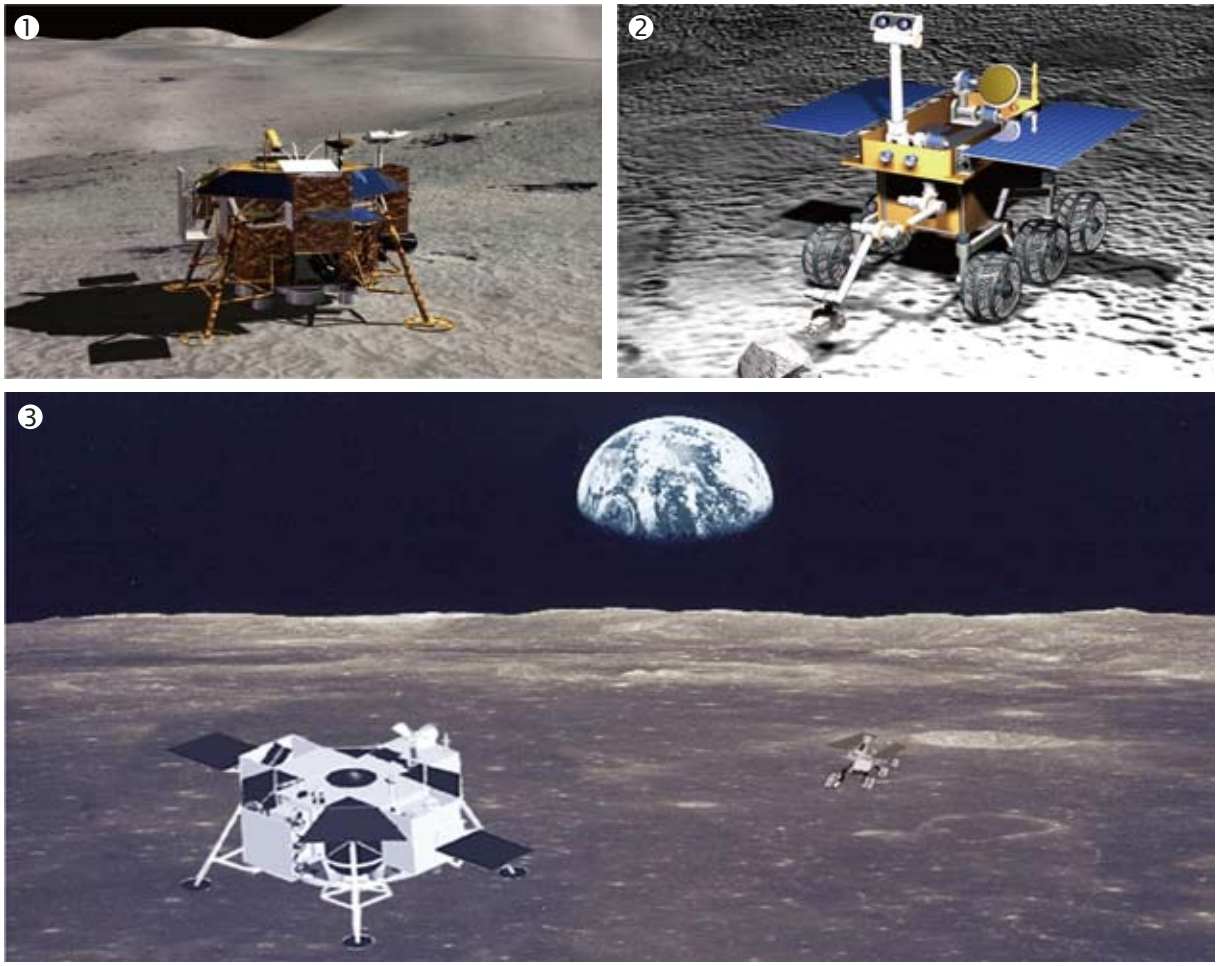
BCAS: *As planned, China's third lunar probe will lift off by the end of this year. How is Chang'e-3 different from all previous lunar missions?*

OUYANG: Yes. Many people have learned about the scheduled date of launch from the internet – December 2. In fact, soon after Chang'e-2 left Earth for the Moon in October 2010, we moved on to prepare China with a more advanced probe, one that will be able to land on the Moon.

So Chang'e-3's main task is to land safely on the Moon. The probe is mainly comprised of a lander and a rover. The lander has four legs with puffy foot pads, which can help with soft-landing on the lunar surface. After the touchdown, the lander will stay stationary at the landing site and conduct in situ detection. The rover then walks out of the lander to carry out autonomous patrol for scientific investigation. It will be the first time to combine a lander and a rover for simultaneous in-situ and patrolling detection. The two are designed to work interactively, including taking pictures of each other.

Landing on the Moon is very difficult, because the Moon is surrounded by vacuum and we can't use parachutes to slow down the probe. Also, the probe will have to judge the circumstances underneath by itself as it approaches the lunar surface at very high speeds. For Chang'e-3, as we have designed, the lander's engine will produce reverse thrusts to hold up the probe during its descent. At about 100 meters above the lunar surface, the lander turns on one of its cameras to observe the landscape and choose the best landing site on its own. At four meters high, the engine will shut down and let the probe drop freely to the ground. In this way, the landing would be safe and sound.

After the landing, all the instruments will settle down to work. Daylight on the Moon lasts 14 earth days, followed by 14 days of darkness. So we hope Chang'e-3 arrives in the early morning so it can work continuously for at least ten days. When night falls on the Moon, another challenge emerges: it is extremely cold and the temperature can drop to as low as minus 180 degrees Celsius. Without effective protection all the electronic equipment will be damaged. To keep them warm, we have equipped the lander and the rover with atomic batteries which can work nonstop for decades. When the sun rises again on the Moon, all devices will



Chang'e-3, China's first unmanned landing mission on the Moon (3), will be jointly carried out by a lander (1) and a rover (2).

come back to life. We expect Chang'e-3 to work like this for at least six months.

Scientifically, the Chang'e-3 probe is unique in three ways, as it will "explore the Sky, explore the Earth, explore the Moon". First, the lander is equipped with an ultraviolet astronomical telescope. It will be the first time ever for human beings to conduct astronomical observations from the Moon. The observation condition on the Moon is ideal, because the Moon has an ultra-high vacuum surface environment with minimal perturbations. Second, the lander carries an extreme ultraviolet camera to look back on the Earth and monitor its space environment. Compared with satellites, this camera is capable of large-area and continuous monitoring of the Earth's plasmasphere. Thirdly, we have put a radar device on the bottom of the rover to detect the subsurface structure of the Moon, including the structure of the 20m-deep soil layer and that of the subsurface layer between 100 to 200 meters below the lunar surface.

At the moment, the lander and the rover are going through system tests at the launching center, and the launch vehicle will be in place soon. Everything is proceeding smoothly as planned.

BCAS: *Are you confident in Chang'e-3?*

OUYANG: I think so. No one can say for sure but everyone is doing their best.

BCAS: *Where are we going after Chang'e-3?*

OUYANG: If Chang'e-3 is successful, we will speed up the development of Chang'e-5.

BCAS: *What does Chang'e-5 do?*

OUYANG: The final goal of Chang'e-5 is to land on the Moon, fetch soil samples and return to the Earth. To make this happen, we need to improve our unmanned drilling technologies and find a good way to preserve the original

Scientists are preparing the Chang'e-3 lander for testing. (Photo: China Space News)

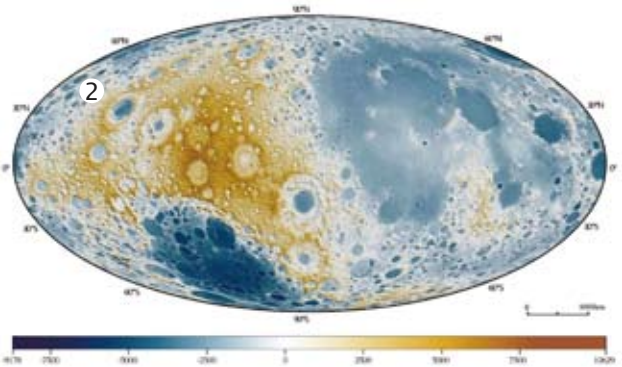
structure of the samples after they are dug out. We also have to test and perfect our returning ability, solving all related problems in the process from lifting from the Moon, accelerating to leave it, to entering earth orbit, decelerating in the atmosphere and landing at a designated location.

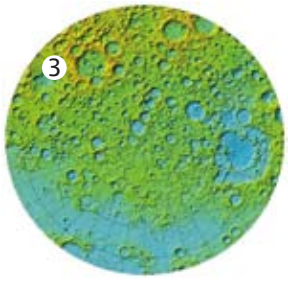
In fact, the design and development of Chang'e-5 has already started a while back. Following the launch of Chang'e-3, system tests of Chang'e-5 will begin. Chang'e-5 may be launched in 2017 or 2018. If everything goes on well, we may finally be able to send men to the Moon. It's a long, long way to go, but we are moving toward it steadily step by step.

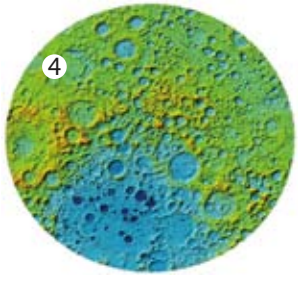
BCAS: *The Chinese lunar exploration program was officially inaugurated in 2004. What has China achieved over the past decade?*

OUYANG: I think China has achieved a lot. Above all, the program enabled the Chinese to set foot outside our home planet for the very first time in history. The Soviet rocket scientist Konstantin Tsiolkovsky once said, 'Earth is the cradle of humanity, but one cannot live in a cradle forever'. Although the Moon is no more than 380 thousand kilometers away from the Earth, the Chinese had never escaped the Earth's gravitational attraction and left that cradle before Chang'e-1. All satellites we had launched, including the Shenzhou spacecrafts, flew or fly in earth orbits. With Chang'e-1, we finally sent an object to arrive at another celestial body and orbit around it. In this sense, the Chang'e Program is an unprecedented, historic attempt of the Chinese nation.

The success of Chang'e-1 and Chang'e-2 well prepared China for an unmanned landing mission. Since Chang'e-1 had successfully completed all its scheduled tasks, we decided to upgrade Chang'e-2 from a backup satellite of Chang'e-1 to a pilot satellite of Chang'e-3. For instance, it took Chang'e-1 almost 14 days to travel 2,060 thousand kilometers to reach the Moon. According to plan, Chang'e-3 will spend only four and a half days en route. After reconstruction, Chang'e-2's flight in 2010 was exactly four days and a half with a direct orbit to the Moon. Besides, compared with Chang'e-1, Chang'e-2 flied



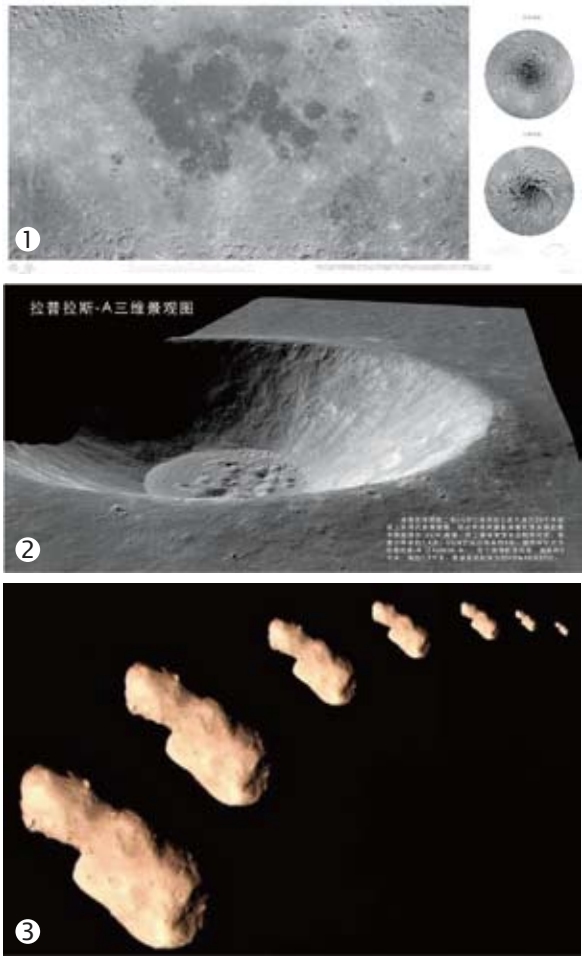




Chang'e-1, the first probe ever sent by the Chinese to orbit another planet in the solar system, was launched on October 24, 2007 (1). Via Chang'e-1, China obtained its first full lunar image and conducted many scientific investigations, including measuring over nine million elevation points on the Moon (2) including those in the North Pole region (3) and the South Pole region (4).

much lower, orbiting at about 100 km altitude with a 7m-resolution CCD camera on board for close-up photographs. The data it yielded are really exciting. The high precision map of the Moon is the highest resolution product of its kind in the world. It would be as big as a soccer ball field if printed out. Now these data are open to the whole world. In particular, at the schemed landing site of Chang'e-3, a plain region called Sinus Iridum, Chang'e-2 lowered sharply to 15km height to capture 1m resolution images of the region. So Chang'e-2 has well readied Chang'e-3 in many aspects.

Except lunar probing, we have also accomplished some deep space exploration with Chang'e-2's extended missions. When Chang'e-2 finished all its lunar missions, it did not end up clashing onto the Moon, like Chang'e-1 did, but flied far, far away for additional assignments. First, it reached Lagrangian 2 (L2) point, an area about 1.5 million km away where the gravitational pull of the Sun and the Earth is balanced, and stayed there for 235 days to observe the Sun. After that, Chang'e-2 travelled on to somewhere 7 million km away for a rendezvous with a specific asteroid named Toutatis. Toutatis flies by the Earth every four years, and is regarded as a 'potentially hazardous object' with collision risks by many astronomers. Observed from the Earth, it appears to be nothing but a bright spot. It turned out that Chang'e-2 succeeded in encountering Toutatis at an altitude of just 3.2 km, and snapping a series of clear images of the mysterious asteroid. Now we know Toutatis is a celestial body with maximum length and width of about 4.6 km and 2.4 km respectively, in the shape of a peanut. With such a huge body it would be a disaster if Toutatis is really to hit the Earth someday. Now, Chang'e-2 has been orbiting the Sun for some time, at a distance of approximately 60 million km from us.



Chang'e-2, originally designed as a backup satellite of Chang'e-1 but actually launched in October 2010 a pioneer satellite of Chang'e-3, wowed the world with a 7 m resolution image of the entire lunar surface (1), some astonishingly high definition pictures (of 1 m resolution) of particular areas (2), as well as the snapshots taken during its adventurous rendezvous with Asteroid Toutatis (3).

BCAS: *It's really exciting to learn about all this. It seems that though China is a late comer in lunar exploration, it has made unique contributions to the world.*

OUYANG: Definitely. I believe that's why we are doing this. China's first lunar probe was launched in 2007, almost half a century after the Soviet Union and the United States had accomplished such feats. Even today our technologies are not the best. But since we have decided to go to the Moon, we can't just do it by repeating or copying what others have done. We need to do it in a new and better way, at least at some points. That would worth the money we poured into it.

BCAS: *What's the program's investment so far?*

OUYANG: All I can say is that the total spending of Chang'e-1 is about 1.4 billion RMB. The same amount as the money used to construct two kilometers of subway in Beijing. Quite cost effective, for that matter. For me, I always think every cent should be spent to the point, to both promote technological innovation and be responsible for the people, the taxpayers.

BCAS: *Does China have any plan to explore Mars?*

OUYANG: Not for the moment. China's first Mars probe (Yinghuo-1) did not work out because the Russian Fobos-Grunt spacecraft, on which Yinghuo-1 was intended to hitch a ride, failed to leave earth orbit shortly after it was launched in November 2011. After that, China's Mars exploration program has not been progressing as fast as many would expect. So it's a pity that China has no official plan to go to Mars for the time being.

BCAS: *The launch of Sputnik-1 in 1957 shocked the world. How did it influence you?*

OUYANG: I was greatly shocked and inspired, like many young men were. Sputnik-1 declared the arrival of a new era, the era of space for human beings. At that time I was a graduate student at the CAS Institute of Geology, majoring in mineral deposits. I realized that such a technology can greatly deepen our understanding of our home planet. With a satellite watching down from the sky, we would be able to monitor the situation on the Earth much easier. My hunch was right. Nowadays remote sensing satellites are widely applied for Earth observation.

The next year, the Russians set out to launch lunar probes. In 1959, they wowed the world with another scientific stunt: sending two orbiters to fly around the Moon. For the first time in thousands of years, men got to know what it looks like on the other side of that big silver plate hanging above. I was extremely excited by the thought that someday we could use spacecrafts to visit every planet in the solar system, one by one, which seemed so distant and mysterious just a minute ago. Such achievements opened new a gate for scientists all over the world and painted a fascinating future for young students like me.

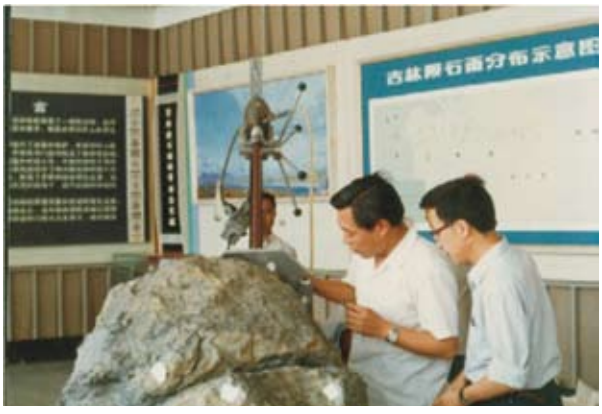
But the economy and science were lagging behind in China at that time. We didn't have much chance to live our dreams. However, I knew from the bottom of my heart that China's space era would eventually come, sooner or later. All I had to do was getting prepared for that moment.

BCAS: *So you engaged yourself in 'planetary geology', the geology of planets in space, like the study of meteorites?*

OUYANG: Yes. With the advent of space exploration in the 1950s and 1960s, many geologists in the world began to look at other planetary bodies in the same way as the Earth. It's natural. Take the Moon for an example. Mathematics, physics, chemistry, life sciences or astronomy – none of these is the most immediate subject for scientific research on the Moon. Instead, earth science is something we need to address in the first place if we want to know the planet, just like we made efforts to investigate the Earth. We must look into the space environment, topography, landform, composition, geological structure, interior structure as well as the origin and evolution history of the Moon. What is the composition of the stones there? How did they form? Are there mineral resources that can be used for human sustainability? These are all questions to be answered by geologists. So geology is highly relevant in space exploration.

In 1958 I discovered typical octahedron iron meteorites in blast furnaces in Nandan, Guangxi Province. From then on, my colleagues and I have studied different types of meteorites, from iron to stony meteorites, including the 1976 meteorite shower falling in suburban Jilin City in north China. Around 2.7 tons of extraterrestrial rocks scattered over an area of 500 square kilometers; the biggest piece weighed as much as 1.77 ton, making it the heaviest stony meteorite ever landing on Earth. We studied the chemical composition, structure, age, origin and evolution of these 'heavenly visitors', and revealed the age of the meteorites to be 4.6 billion years, slightly older than the Earth and the Moon. Via cosmic ray exposure analysis, we confirmed that the parent body of 'Jilin Meteorite' underwent two collision and breakup events, 8 million years ago and 400 thousand years ago, respectively. Based on these studies, we proposed the formation and evolution mechanisms of the 'Jilin Meteorite'.

As I've always been curious about other planets like Mars and Venus, I also engaged myself in a bit of studies about these 'neighbors'. The more I study them, the more I realized how helpful they are to increase our knowledge



Since the late 1950s, OUYANG Ziyuan has been working on different types of meteorites, including the Xinjiang iron meteorite in 1964 (left) and a stony meteorite from the Jilin meteorite shower in 1980 (right) – the heaviest of its kind that has ever landed on the Earth.

Prof. OUYANG explains to the students how craters are formed on lunar surface. (Photo: Internet)

about the Earth. By comparison we can always deepen our understanding of our home planet, and answer questions like 'why Earth is the only planet where life is known to exist'.

BCAS: *Chinese people and media hail you as the 'founding father of the Chinese lunar exploration program'. I know you don't like this title, but it says everything about the recognition and respect you deserve. Among all your contributions, one is very special and will never be forgotten: for many years, you have been an enthusiastic and tireless communicator, using an easy-to-understand language and your humor to convey scientific knowledge to the general public, to inspire their curiosity and nurture the nation's scientific spirit. So what makes you so active in scientific communication?*

OUYANG: First of all I don't think scientific outreach has occupied too much of my time. A report takes me half a day at the most, and I usually have no more than four or five reports each month. Besides, the things I talk about, no matter they are lunar missions or deep space probe, are based on my professional knowledge accumulated from decades of learning. So it's not the hardest thing for me.

When I first lobbied for lunar exploration in China, very few people were on my side. Government officials threw more than a hundred questions at me. I explained to them and answered their questions one by one. Finally nobody said 'no' any more. I realized that most Chinese don't see why China needs to go to the Moon, and it's my responsibility to tell them the significances – why we don't have a choice on lunar exploration. I believe scientific communication is no less important than scientific research itself.

In my eyes, outreach doesn't mean giving lessons. Instead, it's a discussion, through which I present my understanding of the issues to the audience. Only in this way can the outreach become more effective.

It turned out that I've received enormous support and encouragement from the audience, much more than I had ever expected. I always feel touched by something. When I see young students inspired by my words, and tell me they are so interested in the subject that they want to go into it, I can feel the strength in me. They make me want to continue to do it and do it better, because it's so well worth it.