China Emphasizes International Cooperation in Future Lunar and Deep Space Exploration

By SONG Jianlan (Staff Reporter)

When flying to and beyond the Moon, China's future space exploration embraces international cooperation in a more open and comprehensive way.

A view of the 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)

China's future lunar and deep space missions will embrace international cooperation at a more extensive and intensive level, as unveiled late July at the 4th International Conference on Lunar and Deep Space Exploration (LDSE-4), an event jointly sponsored by the China National Space Administration (CNSA) and the Chinese Academy of Sciences (CAS).

According to Mr. WU Yanhua, Vice Director of CNSA, China will fly its next lunar detector *Chang'e*-5 and launch a Mars mission around 2020. In the upcoming decades, he continued, the country will extend its deep space exploration to asteroids, and the Jupiter as well as its moons. "On an open, inclusive, cooperative and win-win basis, we welcome participation of scientists from all over the world, to promote abreast the international cause of lunar and deep space exploration, and make major original discoveries together," he emphasized.

Chang'e-5, scheduled to fly early 2020, is to automatically collect and return lunar samples from Mons Rümker, the northern part of Oceanus Procellarum in south polar area of the Moon. The samples will help scientists determine the ending date of lunar volcanism. (Credit: NSSC)

Flying to the Moon and beyond

At the conference, CNSA spokesman PEI Zhaoyu gave a talk on the prospects and opportunities of China's deep space exploration. The overall layout of China Lunar Exploration Program (CLEP) features three major stages, he introduced – The first focuses on robotic exploration, the second manned landing, and the third on human residence. The current stage of CLEP (from 2004 till 2020), named *Chang'e* Program after a legendary fairy dwelling on the Moon in Chinese mythology, is designed revolving robotic exploration, and is in turn divided into three phases. The first phase is focused on "orbiting", aiming at overall detection and understanding of the global environment of the Moon, particularly the part around the preset landing areas; the second is designed for soft landing on the Moon; and the third developed for robotic sample collection and return from the Moon. This stage of CLEP consists of six missions in total, and PEI works as the deputy chief designer of the last two missions.

These two missions, namely *Chang'e*-5 and its sister *Chang'e*-6, are to automatically collect and return samples from the Moon, hence culminating the current stage of China's lunar exploration, the "*Chang'e* Program."

In the next stage spanning the period from 2021 to 2035, the country would continue on the robotic exploration, and meanwhile make breakthroughs in related technical issues aimed at manned lunar exploration. The third stage (from 2036 to 2045) would be focused on both robotic and manned lunar exploration, breaking through

At the Fourth International Conference on Lunar and Deep Space Exploration, CNSA spokesman PEI Zhaoyu gives a talk on the prospects and opportunities of China's lunar and deep space exploration, introducing the layout from recent to long-term future in the field. (Photo: SONG J.)

in energy, transport, communication, operation and life support systems for manned exploration.

In parallel with the lunar exploration, the country will deploy its deep space exploration going beyond the Moon.

For the recent future (by 2025), the layout is mainly focused on capability building for asteroid and Mars exploration, said PEI. The major goal for the mediumterm (between 2025 and 2035) would be shifted to capability building for exploration into the wider solar system, involving a sample return from the Mars, flights to giant planets including the Jupiter, and missions to the Venus. In the long run, he continued, China would give more emphasis to capability building for extrasolar interstellar space arrival, involving missions to observe gravity lensing of the Sun, exploration into the interstellar space, and a potential research station built on the Mars.

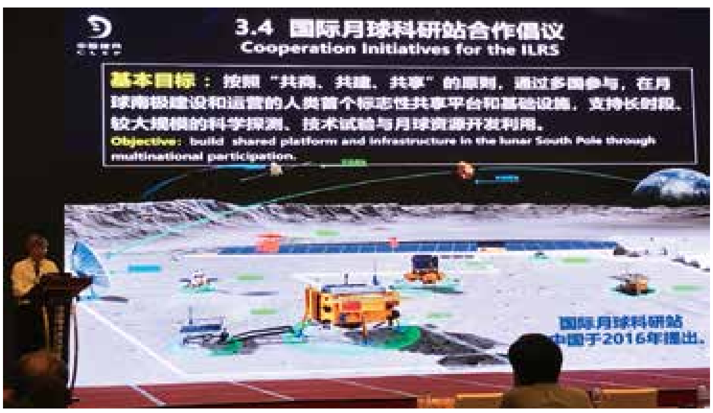
This overall layout, encompassing lunar exploration and beyond, embraces international participation in many ways.

International Lunar Research Station Shared by Humanity

Missions fitted in the future timetable of CLEP include the International Lunar Research Station (ILRS) situated on the South Pole of the Moon. To be jointly designed and built via close teamwork of Chinese, European and Russian scientists and S&T managers, this infrastructure could embody a new mode of international cooperation under the framework of CLEP.

Initiated by China in 2016, the idea of ILRS echoed the concept of "Lunar Village" proposed earlier by the European Space Agency (ESA), and was followed by a plan conceived by the Russian Federal Space Agency (RSA) to build a lunar base beyond 2030.

According to PEI, the above-mentioned three parties have arrived at a preliminary agreement to jointly formulate the layout of ILRS. Based on effective communication with ESA, RSA and other international counterparts, CNSA formally announced the "Cooperation Initiatives for the ILRS."



When introducing the country's layout for future lunar exploration, CNSA spokesman PEI Zhaoyu introduces details of the initiatives for jointly formulating and building an international lunar research station for all humankind. (Photo: SONG J.)

"The essential goal is to establish the first research platform and infrastructure on the Moon for humankind, via participation of multiple countries following a principle of 'sufficient discussion, joint construction and international sharing'," introduced WU Yanhua.

To meet this goal, the three parties will jointly set up an inter-governmental coordination committee, and recruit international forces to conduct research into related issues pertaining to the layout and construction of ILRS, with the objective to proposing a blueprint in two or three years.

Dr. James Carpenter confirmed in his talk on behalf of ESA exploration team that ESA is working to establish cooperative activities with China for research and exploration on the surface of the Moon, focused on the opportunities offered by the future ILRS. In the mid-2020s ESA plans to lead a robotic lunar mission to perform science, prepare *in situ* resource utilization and establish sustainable ways forwards for human missions from the late 2020s into the 2030s, he said.

"Via cooperation throughout all stages, involving planning docking, joint formulation, mission design, technical cooperation, joint implementation, and shared achievements, we will jointly carry out the construction of the international lunar research station to full advantage of China and the countries all over the world to explore space in a peaceful and inclusive way," PEI introduced.

PEI gave a step-wise description of the overall sketch for the ILRS. The first step will be to build a basic-type of ILRS to meet basic needs of international lunar research. This would be completed during the period from 2021 to 2030, drawing on experiences gained from the *Chang'e*-6, -7, and -8 missions of China, in combination with knowhow obtained from other lunar missions envisioned. This basic infrastructure should be able to support long-time, relatively large-scale science explorations, technical experiments, and development as well as utilization of lunar resources.

The objective of the second step would be an expanded international station for lunar research, he said. Apart from serving basic requirements of lunar research, this facility should be able to sustain long-term automatic operation, and to support short-term manned explorations. This goal should be met between 2031 and 2035.

Finally, during the time between 2036 and 2045, a full-fledged version of "Lunar Base" or "Lunar Village" would be completed for integrated and comprehensive use. By that time, humans would be able to remain at the station for long-time stays, to conduct comprehensive, large-scale science explorations and technical experiments, and to develop and utilize resources of the Moon.

"The goal of the cooperation initiatives," concluded PEI, "is to achieve shared growth through discussion and collaboration, and to create a community of shared destiny in the Earth-Moon system."

Notably, the initiative for ILRS was announced just shortly after a call for international proposals. This open call was issued by CNSA on April 18 for proposals of scientific payloads onboard *Chang'e*-6, a backup for *Chang'e*-5, and also for proposals of payloads onboard its future asteroid missions.

The lunar images obtained by a Saudi Arabian camera aboard *Chang'e*-4 is delivered in June 2018. (Photo: CNSA)

Payload Opportunities Open to the World

Chang'e-6, as well as the upcoming missions aimed at asteroid exploration, are expecting payload proposals from international researchers, for free of charge. According to the proposal call released by CNSA last April, the orbiter and lander of *Chang'e*-6 will offer a total payload mass of 10 kg for scientific research onboard. The asteroid missions will offer another total payload mass of 66.3 kg for eight scientific instruments, including a color camera of moderate field of view (FOV), a thermal emission spectrometer, a visible and infrared thermal imaging spectrometer, a multispectral camera, a detecting radar, a magnetometer, a charged and neutral particle analyzer, and a dust analyzer. Moreover, the design for asteroid missions has reserved an extra carrying capacity of 200 kg for potential scientific payloads. All these are now open to the whole world for application.

At a small ceremony occurred on April 18, 2019, CLEP delivers the data obtained by the international payloads onboard *Chang'e*-4 to its Swedish, German, and Dutch cooperators. Also at the same ceremony, it announces a second round of international proposal call for scientific payloads onboard *Chang'e*-6 and asteroid missions. (Photo: Xinhua)

The primary scientific goal of the flights of *Chang'e*-5 and -6 is to detect the geomorphology and geological background of the region around the landing site, and robotically collect and return samples from the south polar area of the Moon. Their flights will also make it possible to perform long-term and systematic indoor examination and analysis of the returned lunar samples. The research into the lunar soil and rock samples will reveal their chemical compositions, and physical as well as structural features; the analysis might even help us understand the interactions between solar activities and the Moon, and reveal the origin, formation and evolution of the Moon.

If everything goes well, in early 2020 we will see the launching of *Chang'e*-5, and soon after that *Chang'e*-6, signaling the finale of the first stage of CLEP. On the horizon, rising are the missions for the second stage of CLEP – embracing more intensive and extensive international cooperation, including but not limited to the ILRS.

This open proposal call marked only the second of such kind under the framework of CLEP – it takes root in the successful international cooperation on *Chang'e*-4 mission, which performed the first-ever successful soft landing on the far side of the Moon.

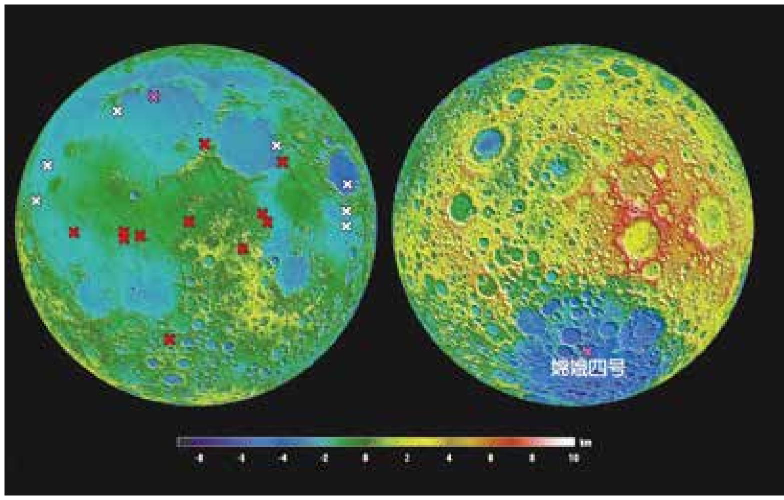
Actually, at the very ceremony announcing the international call for payload proposals aboard *Chang'e*-6 and asteroid missions, CLEP also delivered the data obtained by the payloads aboard *Chang'e*-4 to the oversea cooperators. This round of international cooperation, deployed in line with the "free piggyback, data sharing" principle, is bearing fruits.

Yutu Talks: Data Obtained by *Chang'e*-4

During a special session of LDSE-4 given to *Chang'e*-4, Dr. Stas Barabash from the Swedish Institute of Space Physics gave a presentation on energetic neutral atoms (ENAs) directly detected from the lunar surface by the Advanced Small Analyzer for Neutrals (ASAN) mounted on *Yutu*-2, the rover of *Chang'e*-4 mission. The rover is named after the legendary companion of the goddess *Chang'e* on the Moon, a rabbit of deity. For the first time ever, the rover offered a valuable opportunity to directly measure this kind of uncharged particles produced by the bombardment of the solar wind onto the lunar surface; and the rover's locomotion on the lunar surface across different lunar days (approximately equal to 27 1/3 Earth days) made it possible to cover different illumination angles and scattering angles of the solar wind.

The team expected that observations made by ASAN would help them solve an enigma left behind by a mission shut down 10 years ago. In February 2009, ESA's Sub-keV Atom Reflecting Analyzer (SARA) onboard the Indian lunar orbiter Chandrayaan-1 tried to use low-energy neutral atoms to map out the chemical compositions of lunar soil. The observation detected ENAs sputtered by protons derived from solar wind; yet it left unsolved why around 20% of ENAs are not absorbed by the porous lunar regolith yet bounced back by the lunar surface. Data obtained by ASAN onboard *Yutu*-2 from observations over five lunar days provided the team with new clues and hope.

Aside from ASAN, payloads onboard *Yutu*-2 also included an instrument developed by Germany named Lunar Lander Neutrons & Dosimetry (LND). Payloads onboard *Queqiao*, the relay satellite of *Chang'e*-4



Before *Chang'e*-4, all lunar rovers landed on the near side of the Moon (left). On the right shown is the landing site of *Chang'e*-4. (Credit: NASA/GSFC/MIT)

The Advanced Small Analyzer for Neutrals (ASAN), a Swedish payload aboard *Chang'e*-4. (Credit: NSSC)

On January 9, 2019, *Yutu*-2, the lunar rover of *Chang'e*-4 mission, landed softly at the Von Kármán crater on the far side of the Moon. This image is produced by splicing the photos taken by the panorama camera mounted on *Yutu*-2. (Credit: CLEP/GRAS)

The Lunar Lander Neutrons & Dosimetry (LND) aboard *Chang'e*-4 developed by Germany.

included a low-frequency radio spectrograph jointly developed by China and the Netherlands, namely the Netherlands-China Low Frequency Wavelength Explorer (NCLF). Onboard was also a camera developed by Saudi Arabia. Data from the above payloads will offer information about the radiation doses of the preset landing area for future manned lunar missions, and help scientists further understand lunar environments, the cosmic space and solar activities.

Flying to Mars, Jupiter, and beyond

The timetable for China's Mars exploration caught the eye of many at the conference. "*Yinghuo*-2", the future Mars mission of China, is scheduled to fly in 2020, taking advantage of the first launching window in the future, said Prof. WU Weiren, Member of the Chinese Academy of Engineering and the International Academy of Astronautics. WU is currently the principal investigator of CLEP.

According to PEI, Mars exploration is a major focus of China's future deep space exploration. Extending into 2050, this program consists of three stages, namely orbiting, landing and roving, and involves sample return and a prospect research station on the Mars.

China's deep space exploration is not stopping at Mars. The prospect missions include those to asteroids, aiming at orbiting, controlling and utilizing these small bodies, and further, to the Jovian System and the interstellar space. Experiences gained and capability built in its past lunar missions, for example the close flyby and imaging of the asteroid No.4179 Toutatis by *Chang'e*-2, will benefit its future explorations into the depth of the cosmic space. The knowledge obtained from past missions by other institutions around the world will also escort its future explorations.

"By designing an exploration mission that will fly to Jupiter in the 2030's, China will be able to capitalize on the legacy of previous missions to Jupiter and to develop unique international collaborations with other missions in flight (such as NASA's Juno mission) or in preparation (such as ESA's JUICE and NASA's Europa Clipper)," said Prof. Michel Blanc, when introducing the science objectives and mission scenarios for China's future mission to the Jupiter System, "*Gan De*", in which he is deeply involved.

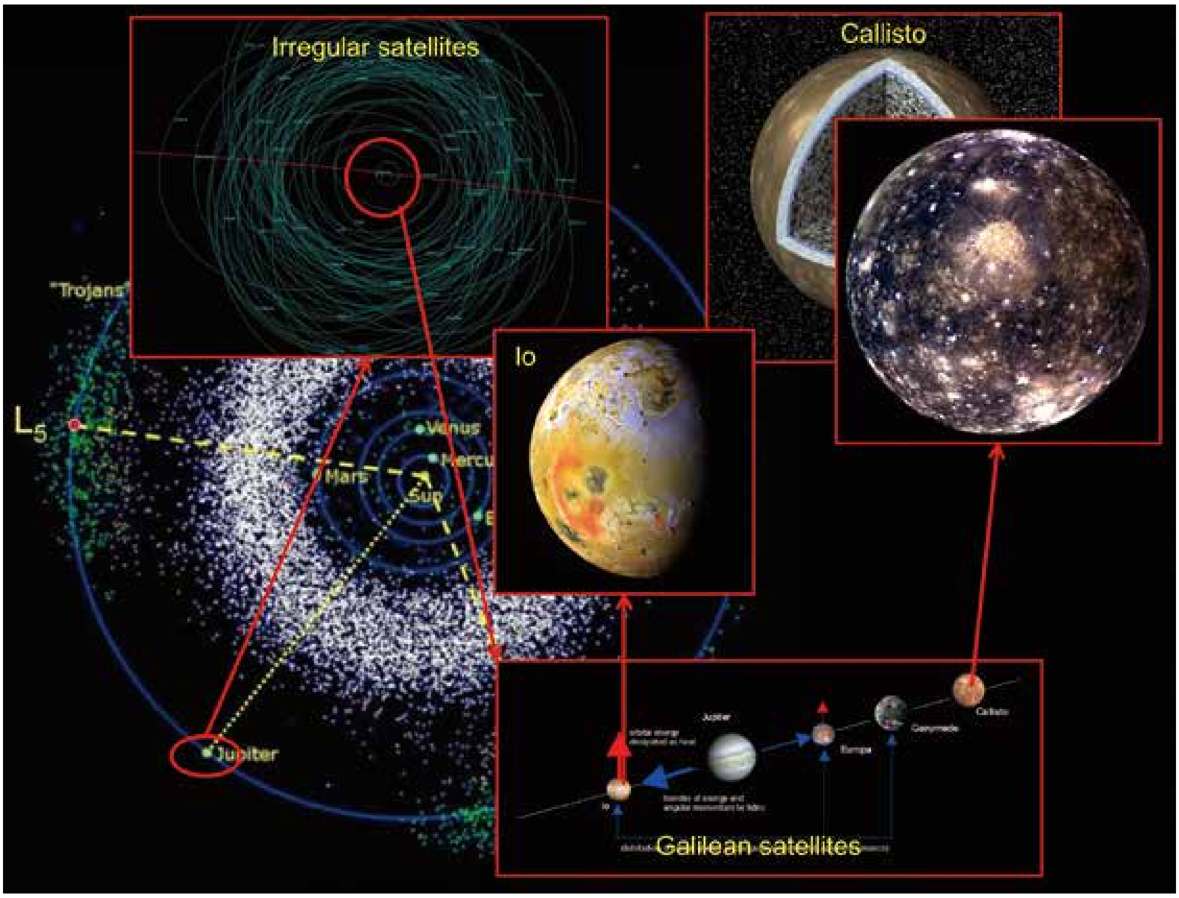
A visiting scholar from the Research Institute in Astrophysics and Planetology (IRAP) under the French National Centre for Scientific Research (CNRS), Blanc had been for over one year the executive director for the International Space Science Institute (ISSI-BJ) on the campus of the National Space Science Center (NSSC), CAS in Beijing, which is a joint venture established and run by the International Space Science Institute in Bern and the NSSC. He is also a Member of the American Geophysical Union and the *Academia Europaea*, and a Full Member of the International Academy of Astronautics and Air and Space Academy. Currently he is working part-time as a visiting professor at the State Key Laboratory of Space Weather, NSSC.

China's future Jupiter mission, introduced Prof. Blanc, got its name from Gan De, an ancient Chinese astronomer who is believed to have made the first observation of Ganymede – the third moon of Jupiter – nearly 2000 years before Galileo. "I can send you an interesting paper, in Chinese, on how he did this," he promised the author.

Later Blanc did show the author a paper, in which late historian XI Zezong, also a CAS Member, brought to light a piece of ancient Chinese literature narrating Gan's discovery of Ganymede and giving the positions of Jupiter documented by Gan. The historian compared Gan's observations of Jupiter with the giant planet's orbiting loci, and gave the most possible year in which Gan detected Ganymede: 364 B.C. (Xi Ze-zong, *Acta Astrophysica Sinica*, 1981).

According to Blanc, the mission "*Gan De*" is to answer at least two essential questions: first, how the Jupiter System has formed; second, how this system works.

"Jupiter gathers by itself 76% of the total mass



Conception of the "*Gan De*" mission, China's future exploration into the Jovian system, including its regular and irregular satellites. The researchers named the mission after Gan De, an ancient Chinese astronomer who discovered Ganymede, the third moon of Jupiter in 364 B.C. (Xi Ze-zong, *Acta Astrophysica Sinica*, 1981), almost 2000 years earlier than Galileo. (Credit: NSSC)

of planets and small bodies of the solar system," he explained: "To properly answer our key scientific questions about the Solar System as a whole or even more generally about Planetary Systems, one must first apply these questions to the Jupiter System and find answers using the power of *in situ* planetary exploration."

Peaceful Exploration and Utilization of Space for Humankind

China's deep space exploration is making three transitions, concluded PEI. When shifting its exploration destinations from earth-moon system to interplanetary space and its exploration purposes from mastering space technology to developing space technology, space science and space application, it is also changing the emphasis of the development from independent exploration to cooperation.

"The ultimate goal is to explore and utilize space peacefully," said Prof. PEI Zhaoyu, when commenting on the overall layout of the country's lunar and deep space exploration. "How fast we make progress subjects to objective technical and economic developments, rather than the needs of winning any space race," he asserted.

PEI's conclusion echoes the opinion given in a paper published in *Science* on the same day of the opening of LDSE-4. Titled *China's present and future lunar exploration program*, the paper discussed technological and scientific goals for the four completed, as well as the four planned *Chang'e* missions, and gave the longer-term goals and plans of the CLEP beyond the *Chang'e* Program. "The exploration plan is flexible and iterative, with an emphasis on international cooperation," said the coauthors – Led by Prof. LI Chunlai from NAOC, all the coauthors play an important role in CLEP. Among them, LI is currently deputy chief engineering designer of the

Chang'e-5 mission and director of the Ground Research and Application System of CLEP, and Prof. WANG Chi, current director of NSSC, is deputy chief engineering designer of the *Chang'e*-4 mission and director of the Scientific Payload Subsystem of CLEP.

Notably, China is also open to cooperation with NASA on lunar exploration, the coauthors mentioned in their *Science* paper. "China also looks forward to exploring more opportunities to cooperate with NASA to preserve the space environment for generations to come," they said.

These might make a good footnote for the agreement inked in April 2019 between the United Nations and CNSA concerning cooperation on China's lunar and deep space exploration, with emphasis on peaceful development and utilization of space.

CAS plays a role of objective-setter in CLEP. The Academy proposed the scientific goals of the program and layout, and sees to its implementation with support from its 100+ institutes spreading across the country. Father of CLEP, CAS Member Prof. OUYANG Ziyuan, who has proposed the whole lunar exploration program and worked as the first principal investigator of CLEP, comes from the Institute of Geochemistry of the Academy.

Reference

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Xi Ze-zong. (1981) The discovery of Jupiter's Satellite Made by Gan De 2000 Years before Galileo. *Acta Astrophysica Sinica*, 1: 85–88.