All About The Chinese Space Programme

Go TAIKONAUTS!

龙腾太空

Issue 29 | June 2020

On 10 December 2019, CNSA released the first batch of 3D images based on Gaofen 7 data. This one shows the new Beijing Daxing International Airport. Credit: CNSA/Gaofen 7

Content

Chinese Space Quarterly Report
July - September 2019
by Jacqueline Myrrhe, Chen Lan

SPACE TRANSPORTATION

CZ-2C - Grid fins

The CZ-2C, used for the launch of the new Yaogan 30 triplet on 26 July was equipped with an electronic control system and 4 steerable grid fins, mounted between the 1st and 2nd rocket stage. During launch and 1st-stage-burn the grid-fins remained folded to the rocket body. After the end of the 1st stage's burn, they unfolded and rotation-aligned so that they began to steer the direction of the fall of the empty stage which finally landed into a designated area in Guizhou province. The new generation electronic system, integrated into a 12 cm box, ensures the measurement of flight parameters, attitude control, telemetry and remote control. China Aerospace Science and Technology Corporation (CASC) announced that the test was successful, showing that grid fins are a solution for the mitigation of hazards caused by used rocket stages falling into inhabited areas. This test also contributes to the advancement of controlled recovery and soft landing technology as well as reusability of rockets.

top: Lattice-like grid fins are used to guide spent boosters as they fall to Earth. Credit: CASC/Science and Technology Daily
right: A CZ-2C carrier rocket launched from the Xichang Satellite Launch Centre in Xichang on 26 July. In the grey painted intersection between 1st and 2nd stage the grid fins can be seen. Credit: Xinhua

CZ-5

By the end of July it became known that the redesign of the YF-77 turbo pump for the CZ-5 LOX engines has been finalised. 5 guide vanes, made of nickel super alloys, were added to the exhaust structure of the pump. The YF-77 was the cause of the failed 2nd flight of the CZ-5 in July 2017.

CZ-9

CASC successfully tested a new expanding bellows type payload fairing separation mechanism for the CZ-9 which was claimed to be the longest, thickest and most pressure resistant in the world. It will be 5 times longer and 2 times thicker than the current Chang Zheng fairing separation mechanism. The pyrotechnical cord mechanism is contained in a long flexible bellows. (The Chinese media reports used the term “airbag” instead of “bellows”.) The bellows is flattened and integrated into a metallic tube. The payload fairing separation is initiated by firing the pyrotechnical explosives in the bellows. The bellows expands, leading to a longitudinal fracture of the fairing structure into halves which are consequently pushed away from the upper rocket stage. This type of fairing separation mechanism ensures that the explosive is fully contained in the bellows, causing no contamination of the payload. Also, the shock impact onto the payload is less severe than with conventional pyrotechnical mechanisms. The 1st flight of the CZ-9 is expected around 2030.

CZ-9 fairing separation mechanism. Credit: Science and Technology Daily

New rocket tank insulation material

The China Academy of Launch Vehicle Technology (CALT), the 1st Academy of China Aerospace Science and Technology Corporation (CASC), has developed two insulating materials which reduce propellant evaporation loss and consequently allow long-term storage of cryogenic propellant in orbit and extending the in-orbit stay of cryogenic upper stages to up to 30 days. One of the materials is made of polyurethane foam and the other a variable density multilayer insulation. It was said that the polyurethane foam can improve the insulating capacity by 50 % and the multilayer material by 18 %, reducing the daily evaporation of cryogenic propellant from currently 2.5 % to 0.5 %.

Also, a thermodynamic exhaust scheme was worked out - a procedure which can achieve effective ventilation of excessive propellant while keeping as little propellant as possible to maintain the internal tank pressure. The "Cryogenic Propellant Evaporation Volume Control" technology has recently been verified through large-scale ground tests proving its feasibility.

Sea Launch

A strategic cooperation framework agreement was signed between CALT, the City Administration of Yantai, and China International Marine Containers Group Shenzhen to jointly build an Eastern coastal space port in the Yantai-administered town of Haiyang. Haiyang already has well developed, modern port conditions, including a transportation network. Upon completion, the port will consist of support facilities for sea launches and 4 research and production centres for rockets, satellite equipment, sea launch platforms as well as a satellite data application and development centre. The new hub is supposed to attract companies for intelligent manufacturing, logistics equipment, energy equipment, aerospace materials and space tourism. Sea launch meets the growing demand for low inclination satellites and can offer launch services for Belt-and-Road countries.

In another development, representatives of the Yantai Economic and Technological Development Area have signed in July a strategic partnership memorandum with China Aerospace Science and Industry Corporation’s (CASIC) 3rd Academy and the local public company Dongfang Electronics to promote the commercial space sector.

Yuanwang tracking ships - Yuanwang 3

Yuanwang 3 (YW-3) ended its space tracking mission for the 25 June launch of the 46th satellite of the Beidou Navigation Satellite System (BDS) and arrived at a port in east China's Jiangsu Province on 8 July. During its one month-long mission, the tracking ship travelled more than 300,000 nautical miles.
YW-3 left its home port in Jiangsu Province again on 29 September for the Pacific Ocean to support satellite launches, among them a Beidou 3 mission. Before setting sail, the crew prepared supplies, tested facilities and underwent a special training course on the upcoming missions. YW-3 spent in 2019

below and right: Yuanwang 3 under sail. Credit: Xinhua News

Belt-and-Road Initiative, Chinese Space Station
While the country's national interests remain the first priority for its economic growth, CSS will pave the way for China to strengthen its international partnerships with both developed and developing nations. Overall, CSS will help China to position itself in-line with the USA and Russia. Blaine Curcio and Omkar Nikam of Orbital Gateway Consulting having a look at the big picture.

already 83 days at sea for the tracking and data transmission of 3 launches, including the Tianlian 2 relay satellite.

Yuanwang 5

YW-5 supported the launch and early operation phase of the new group of 3 Yaogan remote sensing satellites on 26 July from Xichang Satellite Launch Centre. Deployed in the South Pacific Ocean, YW-5 took over communication and tracking control 20 min after launch of the CZ-2C. During the first orbit it monitored operations for 600 s to send real-time signals and tracking data to the Xi'an Satellite Tracking and Control Centre.

Best Frenemies Ever: CASC, CASIC, and the Aerospace Bridge
The Chinese space industry has a long and storied history with the Chinese government - specifically, it was almost entirely government-owned until 2014. As an indication of its state-ownership, almost all significant Chinese space companies are headquartered in Beijing, with most of them headquartered in the Western half of the city. Of all the Chinese space companies headquartered in Beijing, China Aerospace Science and Technology Corp (CASC) and China Aerospace Science and Industry Corp (CASIC) are two of the largest, and two of the very best frenemies one could ask for. Each with annual revenues of around US$ 35 billion, the companies are both entirely state-owned, thus having the same "parent company" (the government), yet they are also competitors across several space verticals. Blaine Curcio of Orbital Gateway Consulting explains the dynamics between those siblings.

The Great Firewall From Low Earth Orbit
Part 1 Part 2
The space industry's biggest fundraising story over the past 5 years has been the enormous increase in the number of constellations aiming to offer broadband services from Low Earth Orbit (LEO). While most of the funding has gone to western constellation companies, China has been eyeing these developments with some interest, and a handful of Chinese companies have emerged aiming to offer a similar constellation business model. Who are these Chinese LEO constellations? Blaine Curcio of Orbital Gateway Consulting helps us answer this question.

Wenchang - Where Hilton Met the Long March
A western luxury hotel brand is perhaps not the first thing that comes to mind when thinking of a Chinese People's Liberation Army-controlled launch site. The space industry in China has generally been not so commercial, not so western, and pretty much austere. To envision an iconic American brand benefiting from the construction of such a launch site is counterintuitive. And yet, on Hainan Island, such an unlikely scenario has played out at China's fourth launch site, Wenchang. Blaine Curcio of Orbital Gateway Consulting takes us on a astronautic journal to Hainan Island.

MANNED SPACE FLIGHT

CSS - China Space Station

• Core Module

On 2 September, China Manned Space Agency (CMSA) announced about the successful technical review of the prototype of the CSS core module Tianhe in Beijing. It was concluded that the functional performance meets the requirements, the technical status is correct, and the design status meets the overall specifications. Launch is expected for 2020. The actual flight model is also in the manufacturing process.

• National AO for CSS research

As announced at China's Space Day in April, the first national call for experiments on the CSS was open for submission from 1 July to 31 August. Applications had to be filed through the log-in web portal: *http://39.97.240.213/login*
Experiments can be hosted inside the Station or outside on an external platform. It was said that scientists, fit for space flight, could even accompany their research on the CSS.
31 August was also the deadline for applications for international payloads on the Chang'e 6 and the asteroid-comet mission.

Shenzhou

On 10 September, during the 8th Annual Conference of China Satellite Navigation and Positioning Services and China Beidou Application Conference held in Zhengzhou, Henan Province, the Chief Designer of the Shenzhou spacecraft Miao Fa told media that the development of the new reusable, multi-purpose, manned spacecraft, designed for carrying taikonauts or taikonauts plus cargo to LEO or deep-space is progressing according to plan.

ASTRONAUTS - Visit to Namibia

Chinese taikonauts, Liu Yang and Chen Dong arrived on 19 August in Namibia's port town of Walvis Bay for a 5 day-visit to the country. They were invited by Namibian President Hage Geingob during his state visit to China in 2018 when Geingob visited the Beijing Aerospace Control Centre and met 3 taikonauts.
Upon arrival they were welcomed by Cleophas Mutjavikua, Governor of the Erongo region and the Chinese Ambassador to Namibia, Zhang Yiming. Together with Namibia's Deputy Minister of Higher Education, Training and Innovation, Becky Ndjoze-Ojo, the two taikonauts visited the Space Telemetry, Tracking and Command Station (TT&C) in Swakopmund and viewed the China Aerospace Science and Technology Exhibition where they met with students.
Namibia is hosting the China TT&C Station in Swakopmund since 2000. The 18 m-antenna is mainly used for tracking the re-entry of China's manned space vehicles and for deep-space exploration missions.
In the morning of 22 August, the taikonauts together with Zhang Yiming, paid a visit to the Namibia University of Science and Technology (NUST).
In the afternoon both taikonauts were welcomed by Namibian President Hage Geingob in the State House in Windhoek. Chinese astronaut Liu Yang told President Hage Geingob that China is looking forward to Namibia's participation in future space missions with China. Chen concurred with Liu, saying he would like to fly together with a Namibia astronaut into space.
Zhang Yiming reminded the President that the station in Swakopmund is the first Chinese space station built in the southern hemisphere. The hosting agreement from 2000 was renewed in 2018. Liu Yang pointed out that the Swakopmund station is the first point of command for Chinese spacecraft returning to Earth. The reception in the State House was concluded with an invitation extended to the President to visit China and witness a launch of the two taikonauts for their next space flight. The President thanked the taikonauts for taking time to visit Namibia and inspire the local youth.
Liu Yang and Chen Dong left Namibia on 23 August.

Namibian President Hage Geingob (2nd from left) meets with Liu Yang (centre) and Chen Dong (2nd from right), in Windhoek, capital of Namibia, on 22 August 2019. The first Chinese astronaut Yang Liwei visited Namibia already in 2010. Credit: Musa Kaseke/Xinhua

Liu Yang (3rd from the right) and Chen Dong (1st from the right) pose for a group photo with students at Namibia's University of Science and Technology (NUST) in Windhoek, Namibia, on 22 August 2019. Credit: Musa Kaseke/Xinhua

Liu Yang and Chen Dong pose for a group photo with local students during an interactive event in Namibia's coastal town of Swakopmund on 19 August 2019. Liu Yang addressed the audience in English and delivered a speech. Credit: Xinhua Photo/Wu Changwei

Tiangong 2

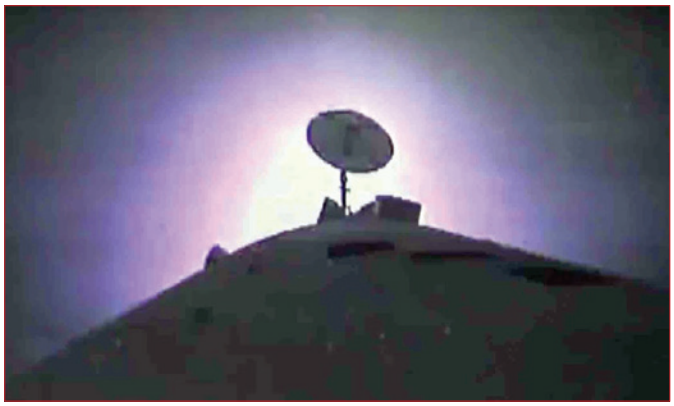
Tiangong 2 (TG-2) was deorbited on 19 July. A small amount of debris fell at 21:06 BJT into the pre-determined area in the South Pacific between 160-90°W and 30-45°S. An outside camera delivered video footage during the process to the control centre.

Tiangong 2: Life cycle of a space lab
The Tiangong 2 space lab made a controlled re-entry into the Earth's atmosphere at 21:06 BJT on 19 July 2019. The infographic summarises some of the most memorable moments from the mission.

In preparation of the re-entry, the TG-2 flight control team at CAST run numerous simulations and wrote a detailed flight control plan. During the deorbit process, they constantly monitored and adjusted the spacecraft's speed and angle to maintain the best attitude for re-entry. In contrast to the one-step re-entry process of Tianzhou 1 in 2017, TG-2's re-entry followed a two-step-procedure: lowering the orbit to an elliptical trajectory with an perigee of 200 km and in a 2nd step to a 70 km perigee. That allowed to collect additional data and knowledge of deorbit technology, in particular to learn how to save fuel during deorbit manoeuvres. It also helped engineers to understand how the Earth's upper atmosphere exerts drag on such objects.

TG-2 was launched on 15 September 2016. Its design lifetime was 2 years but the lab operated for more than 1,000 days and remained fully functional until disintegration during re-entry. It had a length of 10.4 m, a maximum diameter of 3.35 m and a take-off weight of 8.6 t. The deployed solar panels had a wingspan of about 18.4 m. The main tasks have been rendezvous and docking with the crewed Shenzhou spaceship and the Tianzhou cargo craft, in-orbit propellant refuelling and conducting a series of scientific and technological experiments. Already during a press briefing on 26 September 2018 Lin Xiqiang, Deputy Director of CMSE (China Manned Space Engineering Office), announced that the Tiangong 2 Management Committee had decided on 20 September 2018 to manually deorbit the space lab after July 2019. On 13 July 2019 CMSE published a short note that the date for the controlled re-entry is set for the 19 July 2019.

On 16 July 2019 the Permanent Mission of China to the United Nations (Vienna) informed the Secretary-General of the UN about the controlled re-entry into the designated area of 160-90° West longitude and 30-45° South latitude, scheduled for 19 July.



Screen shot of the onboard footage from Tiangong-2 during re-entry. Credit: CCTV

left: Link to footage of the camera on the outside of Tiangong 2 during re-entry.

right: TG-2 - Note verbale Permanent Mission of China to the United Nations (Vienna) informed the Secretary-General of the UN.

LUNAR AND DEEP-SPACE EXPLORATION

CHANG'E 3

Chinese researchers have successfully conducted in-situ measurements of lunar dust at the landing site of Chang'e 3 (CE-3). Using a temperature-controlled sticky Quartz Crystal Microbalance (QCM) on board the CE-3 lander as particle monitor, researchers from the Lanzhou Institute of Physics determined that the total lunar dust deposition rate caused by natural factors at a height of 190 cm above the lunar surface during 12 lunar days in the northern Mare Imbrium was about 0.0065 mg/cm², corresponding to an annual deposition rate of ~21.4 µg/cm². Knowing the exact characteristics of lunar dust is crucial for manned lunar exploration and the establishment of lunar bases.

A paper on the research results has been published in the *Journal of Geophysical Research: Planets: Li, D., Wang, Y., Zhang, H., Zhuang, J., Wang, X., Wang, Y., et al. (2019). In situ measurements of lunar dust at the Chang'E-3 landing site in the northern Mare Imbrium, 124, 8, 2168-2177. DOI: 10.1029/2019JE006054*

CHANG'E 4

Using high-resolution topographic data obtained by Chang'e 2 and images taken by Chang'e 4 (CE-4) during its descent and exploration, a research team of the National Astronomical Observatories of the Chinese Academy of Science (CAS) has reconstructed the descent trajectory of the CE-4 lunar probe including how it avoided obstacles autonomously. CE-4 landed on a slight slope of a degraded impact crater and is surrounded by five impact craters. It is located 8.35 m from the rim of a 25 m-crater to the North. The researchers calculated the precise location on the far side of the Moon at 177.5991°East longitude and 45.4446°South latitude with an elevation of -5,935 m.

The findings were published by the research team of the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) in *Nature Communications*.

compare for the full details: *GoTaikonauts! issue 27, page 17/18*
for CE-4 lunar day 7-9 activities: *see special report on page 20-23*

ESA microchip on CE-4

The CE-4 lander is running on a LEON2-FT microprocessor core, especially designed for space missions by European industry with close ESA support and sold commercially by the Microchip company, marketed as the AT697.

CE-4 - ON A SIDE NOTE

Geoff Brumfiel of the US-American National Public Radio, reflected on international efforts for lunar exploration. Among others, he interviewed Robert Wimmer-Schweingruber from the University of Kiel, who is the Project Scientist of the radiation detector on CE-4. Wimmer-Schweingruber told Brumfiel that "the speed at which the Chinese work is astonishing. "European missions are extremely slow, Americans are twice as fast, and the Chinese are another two to five times as fast as the Americans," he said. "It's just incredibly intense." From the moment he got funding to the moment his experiment launched was just over a year, which is nothing for a space mission. Wimmer described it as "absolutely crazy," but he adds that he would work with the Chinese again."

4th LDSE - Focus on CE-4

4th International Conference on Lunar and Deep-Space Exploration (LDSE) was held at the Zhuhai International Convention and Exhibition Centre from 22-24 July.

400 representatives from the Ministry of Finance, the Guangdong Provincial Department of Science and Technology, APSCO, domestic and foreign space agencies, research institutes, and universities attended the conference, including 60 foreign experts from Australia, Belgium, the Czech Republic, France, Germany, Israel, Italy, Japan, the Netherlands, Norway, Russia, South Korea, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

In total, 176 papers were presented on the future lunar and deep-space exploration plans of China, ESA and Russia along with papers on a wide range of lunar science topics, including the CE-4 mission as well as planetary research and interstellar and asteroid exploration.

Wu Yanhua, Deputy Director of CNSA called for international cooperation for China's future lunar and deep-space missions as well as for the planned International Lunar Research Base.

The Lunar Lander Dosimetry and Neutron (LND) instrument aboard CE-4 was presented by Yu Jia, China Project Manager of the Germany-developed LND instrument and Zhang Shenyi, the LND Principal Investigator on the Chinese side. Zhang said that the LND's main task is to study the two radioactive elements most harmful to humans and the data will support the assessment and preparation of future crewed activities on the Moon. Zhang confirmed that the payload has been successfully transmitting data back to the Earth and that the data analysis has been carried out by the Chinese and German scientists.

He also spoke about the challenges of the cooperation and delivering a payload under high time pressure: The two sides agreed to cooperate in August 2016 and the payload was ready and delivered by March 2017 to meet the scheduled launch time by the end of 2018. These 8 months set a speed record in German payload development. For the flight qualification, the German engineers of the University of Kiel would apply 8 space environment tests whereas 42 tests were needed according to Chinese standards. After negotiations, the two sides agreed on 24 tests, what was for the Chinese side the minimum requirement. China also carried out all the connector design among many other efforts to make the German payload fit and function perfectly on the CE-4 lander.

Learning from challenges and difficulties caused by different national standards China's space authorities are discussing applicable international standards. This will become important for the upcoming CE-6 mission on which 20 kg of payload capacity is available for international partners. The University of Kiel, developer of LND, has already filed a written payload cooperation proposal to Zhang. Depending on funds of the German Aerospace Agency DLR and the research goals of the Chinese National Space Agency, maybe more payloads from Germany would be hosted on CE-6.

4th LDSE - Manned Lunar Mission

Wu Weiren, CLEP's Chief Designer confirmed during a press conference for the 4th LDSE held in Zhuhai on 22 July that China is studying a manned lunar landing. He pointed out that a manned mission would not be "too much of a problem" for China but did not give a schedule. Wu Weiren, also told media that he wishes India's Chandrayaan 2 landing on the Moon success. At the same time he stressed that the international trend for more lunar missions, while motivating, is no reason to push China's lunar exploration. China is following its independent plans and makes sure the goals per each step will be achieved. "China is not going to compete with anyone over the matter."

Pei Zhaoyu, Deputy Director of the Lunar Exploration and Space Engineering Centre under the CNSA said that "China's future lunar exploration, including Chang'e 6 and those that follow, will be determined by the country's own technology capability and overall economic strength. China will not race against other countries, but will follow its own schedule."

CHANG'E 5

CLEP's Chief Scientist Ouyang Ziyuan said on 5 July at the Software-Defined Satellite Forum in Rizhao, Shandong province, that Chinese scientists have achieved technological breakthroughs, needed in all phases of the CE-5 mission. Those breakthroughs include launch, Earth-Moon transfer, deceleration, orbiting, descending, sampling, ascending, docking, orbiting, Moon-Earth transfer, separating, Earth re-entry and recovery. Artificial Intelligence technologies will enable autonomous hazard avoidance, landing site selection, soft landing, sample selection, drilling, and storage. The CE-5 lunar probe is expected to be launched by a CZ-5 from Wenchang.

CHANG'E-7 / Luna Resurs 1

Data Centre for Lunar and Deep-Space Research

During the 24th Meeting of the Russian and Chinese Heads of

Government from 16-18 September 2019 in Saint Petersburg, two Sino-Russian agreements on lunar research cooperation were signed on 17 September by Roscosmos' Director General Dmitry Rogozin and the Head of CNSA (China National Space Administration) Zhang Kejian. One agreement foresees the construction and operation of a joint Data Centre for Lunar and Deep-Space Research, with one main location in Russia and one in China. The agreement also calls for enhancing information capabilities and improving lunar research results, as well as engaging relevant national organisations and institutions (e.g. National Academy of Sciences institutions) for further data centre improvement.
The 2nd document deals with the coordination of the Russian Luna Resurs 1 (Luna 26) orbiter and the Chinese Chang'e 7 polar research mission.
Luna 26 will ensure a detailed exploration of possible landing areas for CE-7. Additionally, data transmission tests will be performed between both lunar craft. The parties will also analyse the possibility of mutual scientific payloads, as well as joint space experiments.

Economic Development is at the Heart of China's Lunar Programme
Marsha Freeman analyses in her article for the "Executive Intelligence Review" the history and development of China's Lunar Exploration Programme - CLEP. She explains the motivations and ambitions which drove China to take on lunar exploration and she gives an outlook what the country will gain from science and technology conducted on the Moon.

From Moon to Mars, Chinese space engineers rise to new challenges
A portrait of Sun Zezhou, Chief Designer of the CE-4 lunar probe and Li Fei, senior team member of the CE-3 and CE-4 projects, gives a glimpse of the challenges the lunar exploration experts encountered. Since the average age of the scientists and engineers is in their mid-30s, many of them will go on to contribute to China's Mars Exploration programme.

Future Lunar Exploration

• Plans

The *Science* journal published on 19 July 2019 an overview article on China's Lunar Exploration Programme CLEP. The authors Chunlai Li, Chi Wang, Yong Wei, and Yangting Lin, researchers with the Chinese Academy of Sciences, describe the past achievements of Chinese lunar missions and give an outlook on the near-term missions.
Regarding future plans of China's lunar exploration: the upcoming lunar missions CE-6, CE-7, and CE-8 are preparing the technological foundations for a robotic scientific research station - a prototype of the later manned lunar base. The exploration targets will shift from development of space technology, to space science and space applications. This first experimental lunar outpost is intended for the "technical verification and validation of resource development and utilization technology, explore prospects for applications, enhance the ability of lunar science and resource application, and lay the foundation for the construction and operation of future Lunar Research Stations, as well as exploration of the Moon by humans. After 2030, China's lunar exploration program will continue to develop capabilities in both robotic and human exploration." By further improving the capability of in-situ utilisation of lunar resources, "the Lunar Research Station could be built into a long-duration lunar base that astronauts can visit for a short time, with the eventual goal of long-term stay of astronauts on the Moon. International cooperation is an important element in China's strategy of lunar and deep space exploration. ... China has made policy adjustments to the sources of funding for future lunar and deep-space exploration missions and has widely encouraged the participation of commercial and private enterprises in addition to governments. The CNSA is setting up general procedures for international collaboration and the mechanism to organize international teams. Extensive international cooperation and diverse sources of funding will inject additional vitality into the ongoing planning and development of lunar and deep space exploration."
China's present and future lunar exploration program, Chunlai Li, Chi Wang, Yong Wei, Yangting Lin, Science, 19 Jul 2019, Vol. 365, Issue 6450, pp. 238-239; DOI: 10.1126/science.aax9908

• U.S.-China lunar cooperation option

During a panel discussion at the World Conference of Science Journalists on 2 July in Lausanne, Switzerland, under the topic: "The Moon in 2069: Top space scientists share their visions" former Head of National Space Science Centre (NSSC), Wu Ji said that he would like to see the U.S. supporting lunar exploration by sending a nuclear power station to the Moon to provide an energy source during the lunar night. As a return for this contribution, China could make its Queqiao communications relay satellite available to other nations' lunar far-side missions. He also thinks that the U.S. will be back on the Moon before China can land taikonauts. He pointed out that the current priority for China is the assembly of the CSS. A Chinese lunar landing is not out of reach and it would be in parallel with the CSS project.

• National Space Science Lab/commercial involvement

Wu Ji is a proponent of China setting up a National Space Science Lab, and open up deep-space exploration to private enterprises to increase investments and activities in this area. He predicts that in the next 20-30 years, the development and utilisation of the resources of the Solar System will become the most active field for the civil space economy. The function of the National Lab would be the strategic preparation and management of space activities in LEO and deep-space.
After Wu Ji retired as the Head of NSSC, he is now the President of the Chinese Society of Space Research (CSSR).

• Technology

Academician Wu Weiren, Chief Designer of the lunar exploration project, and his team proposed the development of space nuclear power for future space exploration. Based on the utilisation of the Chang'e 4 nuclear source a study was published in "China Science: Technical Science", Issue 1, 2019. The study emphasises the importance of nuclear power resource in situations where conventional solar power is not sufficient, e.g. for deep-space exploration beyond Jupiter, lunar and/or Mars research stations and planetary resource development. Also, for power demands of more than 50 kWe, nuclear power has better technical and economic competitiveness, for example for high orbit high-resolution SAR satellite, GEO service platforms, manned Mars exploration.

MARS

Mars Mission

Ouyang Ziyuan, Chief Scientist of China's lunar exploration programme, confirmed at the Software-defined Satellite Forum beginning of July in Rizhao, Shandong province that China's first Mars mission will launch in 2020 and that the assembly of the accompanying rover has been completed. The mission's primary objective is to detect signs of life on Mars.

Mars Science Team

In order to encourage more scientists from national institutes and universities, especially young scientists, to join China's deep-space exploration and to promote the development of domestic planetary science and overlapping disciplines, the Lunar Exploration and Aerospace Engineering Centre issued a call for the recruitment of the scientific team for the upcoming Mars mission. Based on the data from the Mars mission, the team would be responsible to propose and define science projects. Also, the team members would support the verification

and calibration tests of the scientific payloads, recommend relevant payload data and operations requirements, propose and contact peer experts to participate in the research, and organise exchanges for key technology and personnel for the follow-up scientific research.

Chinese names will fly to Mars with NASA

292,071 Chinese people have signed up for having their name sent on the 2020 NASA mission to Mars. In total, almost 11 million submissions (exactly: 10,932,295) from around the world were received between May and September 2019. The number of Chinese participants was the 4th highest on a list of countries and regions, behind Turkey, India, and the U.S.

SCIENCE

FAST - Five-hundred-meter Aperture Spherical Radio Telescope

• Start of Operation

FAST has passed a series of technical and performance assessments, preparing for full operations after a review meeting in October. From then onward, observation time will also be accessible for international researchers.

• Pulsar Detection

The FAST research team announced on 30 August that it has identified 93 new pulsars since October 2017. Pulsar observation is an important task for FAST, which can be used to confirm the existence of gravitational radiation and black holes, and help solve major questions in physics. FAST is also used for the exploration of interstellar molecules such as hydrogen and interstellar communication signals.

• Fast Radio Burst back-end

Chinese scientists have installed a highly sensitive FRB (fast radio burst) back-end on a 19-beam receiver on the telescope, and used it to observe the radio source FRB121102, which was first discovered by the Arecibo Observatory in 2015. FAST first detected the pulse on the morning of 30 August after a month-long search. In the following days it repeatedly detected pulses. There have been less than 100 fast radio burst sources discovered, and FRB121102 is the only one that has been detected erupting more than once. Repetition is considered important to understand the nature of these objects.

• Funds

The Ministry of Science and Technology (MST) has set aside a special fund of 50 million RMB (7.2 million USD) for intelligent robots supporting FAST's smooth operation, the maintenance of its laser targets and its overall monitoring system.

China from space: Satellite images of Guizhou

High-res video imagery from space - including from Guiyang Big Data Plaza, the FAST telescope and the "heart beat" of the universe as captured by FAST.

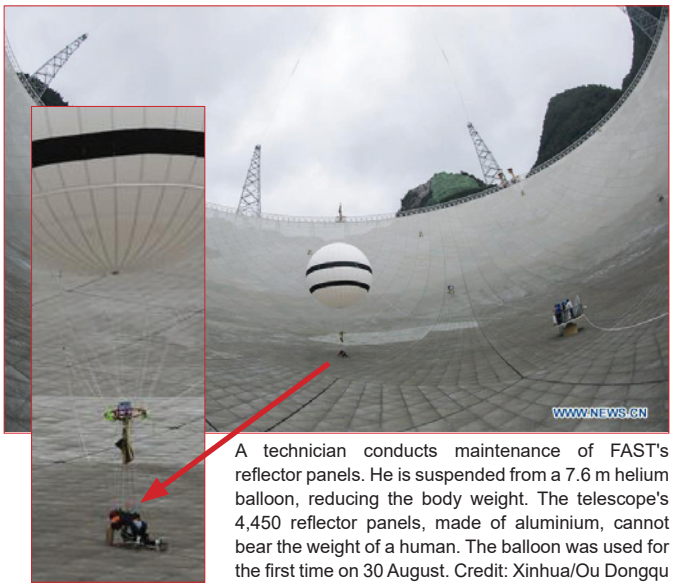
FAST photo gallery

FAST control room Credit: Xinhua/Ou Dongqu

Photo gallery on the occasion of FAST's 3rd anniversary of operation

On the occasion of FAST's 3rd anniversary of operation in September, photos taken on 27 August 2019 show the telescope from different perspectives and under changing light conditions. Since October 2017, FAST has identified out of 132 promising pulsar candidates 93 confirmed new pulsars.

Credit: Xinhua/Ou Dongqu



A technician conducts maintenance of FAST's reflector panels. He is suspended from a 7.6 m helium balloon, reducing the body weight. The telescope's 4,450 reflector panels, made of aluminium, cannot bear the weight of a human. The balloon was used for the first time on 30 August. Credit: Xinhua/Ou Dongqu

• Technical Extension for search for Exoplanets

Within the next 3 to 4 years it is planned to extend FAST's capability for searching for planets with Earth-like magnetic fields in a distance of up to 100 light years. The existence of a magnetic field around a planet is not a proof of the existence of life but considered to be an essential condition for protecting organic life from the hostile cosmic environment and enabling its existence. The plan is to add 35 smaller 5-m dishes to the main antenna and a simplified receiving unit, to extend the effective baseline from the present 300 m to several km. Astronomers from China and France published in the journal Research in Astronomy and Astrophysics their observation plan using FAST. Additionally, a data processing centre will be built in the nearby town of Guiyang.

DAMPE-Wukong

The international DAMPE (Dark Matter Particle Explorer) research team used data from the satellite to conduct a precise measurement of the spectrum of protons in an energy range from 40 GeV to 100 TeV (one TeV is one trillion electron volts, corresponding to one trillion times the energy of visible light). The experiment directly measured with high precision the cosmic ray protons up to the energy of 100 TeV. The resulting spectrum shows that the proton flux increases at hundreds of billions electron volts and then drops at around 14 TeV, indicating the existence of a new spectral feature of cosmic rays. The finding can help scientists understand the source and acceleration of cosmic rays in the Milky Way.

An earlier study by the international DAMPE team reported the precise cosmic electron and positron spectrum up to about 5 TeV in the academic journal *Nature* in 2017.

HXMT

From 31 August to 5 September 2017 scientists observed with the Insight - Hard X-ray Modulation Telescope (HXMT) the Crab

pulsar for experiments in pulsar navigation. The research team had also proposed an algorithm for X-ray pulsar navigation which they applied to the processing of the observation data of the 3 Insight detectors. The new navigation method is called SEPO (Significance-2-Enhancement of Pulse-profile with Orbit-dynamics). The positioning accuracy in the experiments reached 10 km and a velocity accuracy of 10 m/s. It verified the feasibility of autonomous deep-space navigation of spacecraft by using just one pulsar, laying the foundation for future practical application in deep-space exploration. The results also showed that the method works for different pulsars.
Pulsar navigation uses the periodic pulse signals from pulsars with which a spacecraft can autonomously determine its orbital parameters, position and velocity.
The results were published on 21 August 2019 in *The Astrophysical Journal - Supplement Series*: *Zheng, S., et. al. (2019) In-orbit Demonstration of X-Ray Pulsar Navigation with the Insight - HXMT Satellite, 244, DOI: 10.3847/1538-4365/ab3718*

China has also conducted a pulsar navigation test on the Tiangong 2 space lab and launched the pulsar navigation experiment satellite XPNAV-1 in November 2016.

MERIDIAN programme

As part of the Meridian Space Weather Monitoring Project, the Chinese Academy of Sciences has started building a high-energy laser radar with a reach of 1,000 km beyond the Earth's atmosphere into space. After completion in 4 years, it will be used for studying the physics of the upper atmosphere. The laser beam would be reflected by high-altitude atoms. Telescopes on Earth would receive these reflected signals allowing scientists to make conclusion about the solar activity. By 2025, the Meridian Project's global network of ground stations will comprise facilities at both Poles, the South China Sea, Gobi Desert, in the Middle East, Central Asia and South America. The announcement was met with scepticism among scientists, doubting that such heights can be reached by laser. Also, the location of the laser installation seems to be classified.

Near-Space experiment on atmospheric turbulence

In August, researchers completed an 13 h, 8 min-long in-situ detection experiment at an altitude of 21.625 km to investigate the influence of near-space atmospheric turbulences on energy and mass exchange, including the transport and diffusion of pollutants in Northwest China's Qinghai Province and Southwest China's Tibet Autonomous Region. The Anhui Institute of Optics and Fine Mechanics of the Chinese Academy of Sciences developed the detection device.

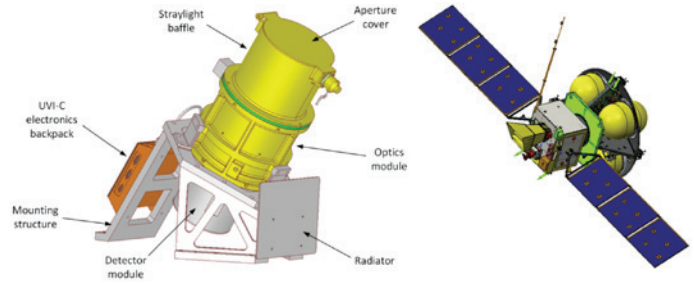
SKA - Square Kilometre Array

The construction of the SKA astronomical ground-based network of radio telescopes, spread over 3,000 km in the southern hemisphere is expected to start next year. China, as one of the founding members, is developing the reflector antennas for the project. The Shanghai Astronomical Observatory (SHAO) of the Chinese Academy of Sciences (CAS) are preparing to build a SKA big data regional data centre for the transportation, storage, reading, writing, computing, management and archiving and release of the SKA data. With financial support from the Ministry of Science and Technology and the CAS, SHAO recently led the construction and integration test of the prototype of the China SKA data centre. The SHAO team had completed a large-scale integration test of the SKA core software on the Tianhe 2 supercomputer platform in 2016.

SMILE - Solar wind Magnetosphere Ionosphere Link Explorer

• Canadian Participation

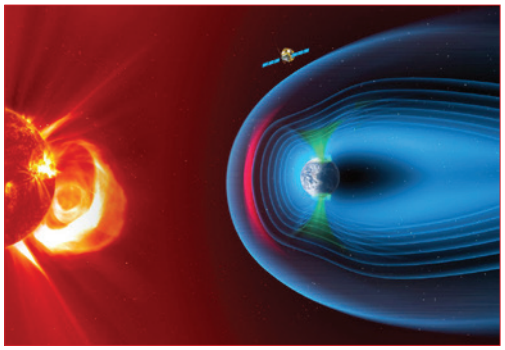
The Canadian Space Agency (CSA) announced on 22 July that it had formally agreed to join the SMILE satellite project. It will be the first joint satellite mission between the European Space Agency (ESA) and the Chinese Academy of Sciences (CAS), following on from the success of the Double Star/Tan Ce mission which flew between 2003 and 2008.
SMILE is the first occasion Canada cooperates with CAS in a space science project.
The Canadian Ultra-Violet Imager (UVI) will study the global distribution of the Northern Lights. Canada is the country with the largest landmass under the aurora borealis - the most visible manifestation of space weather. The instrument was proposed by researchers from the University of Calgary and it was selected by ESA and CAS from a pool of 13 scientific proposals.
The UVI is funded through an innovative business model that brings together funding from CSA, the Canada Foundation for Innovation, and Alberta's Ministry of Economic Development, Trade and Tourism. CSA has awarded two contracts: one over almost 11 million USD to Honeywell to design the UVI, and the second worth 1.5 million USD to the University of Calgary to design the UVI Science Operations and Data Centre.



left: CAD model of the Ultraviolet Imager (UVI). right: SMILE satellite concept. Credit: ESA.

• European Payload Module

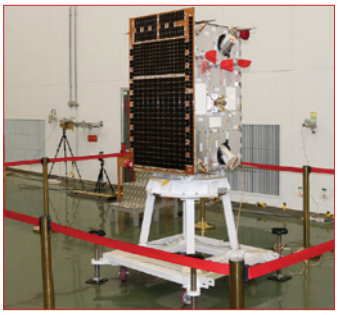
By the end of July, Airbus has been selected by ESA to build the European component of the 2,200 kg SMILE satellite.
The mission is now entering a 4 year period of manufacturing, testing, and integration of the payload module and the platform. In launch configuration, these two components will form a 3.15 m-high stack.
The spacecraft will travel in a highly elliptical orbit around the Earth. Its perigee will be at a distance of 5,000 km (from where it will download data to the Norwegian Troll ground station in Jutulsessen, Antarctica and the CAS ground station in Sanya, Hainan Island, China), while the apogee will be as far as 121,000 km. At this vantage point the satellite will have a prolonged view of the Earth's northern polar regions, to image the boundary of the Earth's magnetic field and the Northern Lights, or aurora borealis.
The payload module will be built at Airbus Madrid, where the instruments will be integrated. The satellite bus will be built in Shanghai. Both, the payload module and the platform will be integrated and tested at ESA's European Space Research and Technology Centre (ESTEC) facilities by a multi-national team.
The science payload consists of 4 instruments - 2 contributed by China, and one each from Europe-UK and Canada. An innovative wide-field Soft X-ray Imager (SXI), provided by the United Kingdom Space Agency (UKSA) and other European institutions, will obtain unique measurements of the regions


Mission concept: SMILE will study and understand space weather. especially the physics behind continuous interaction between particles in the solar wind and Earth's magnetosphere. Credit: ESA

where the solar wind impacts the magnetosphere. The Canadian Ultra-Violet Imager (UVI) will study global distribution of the auroras. (*see paragraph above*)
The Chinese Light Ion Analyser (LIA) will measure the energetic particles in the solar wind while the Chinese Magnetometer (MAG) will measure the energetic particles in the solar wind and changes in the local magnetic field.
Under the current plans, the spacecraft will be launched by a European Vega-C or Ariane 62 rocket in 2023. The estimated lifespan is 3-5 years.
Airbus has been responsible for the earlier space weather-related satellites Cluster and SOHO.

TAIJI 1

The Taiji 1 satellite, launched on 31 August, has completed the first phase of in-orbit tests and conducted technology experiments, laying the foundation for future gravitational wave observation in space. The name Taiji means "supreme ultimate" and is the black and white circular symbol representing yin and yang. The pattern of Taiji also resembles a binary star system composed by objects like neutron stars or black holes.
The 3-step Taiji project for studying gravitational waves from the merging of binary black holes and other celestial bodies was initiated by CAS in 2016. Unlike the LIGO research conducted from a ground-based observatory, Taiji will conduct space-based detection on the gravitational waves with lower frequencies to observe celestial bodies with greater mass or located farther away in the universe. Taiji 1 aims at testing key technologies such as high-precision and ultra-stable laser interferometer, gravitational reference sensor, ultra-high precision drag-free control and ultra-stable and ultra-static satellite platform. The in-orbit tests showed that the accuracy of displacement measurement of the laser interferometer on Taiji 1 could reach a 100 picometer-order of magnitude, equivalent to the size of an atom.
Taiji 1, is the first satellite of the satellite-based gravitational-wave observatory programme. In 2018 CAS decided to support the Taiji space science project by initiating two phases, the “Taiji technology development” and the “Taiji pathfinder”. The goal of the “Taiji technology development” phase is to study and develop the key technologies to meet the requirement of Taiji. The 2 “Taiji pathfinder” satellites will be launched after 2023 to verify long baseline interferometry in space. They will fly in the same orbit as the final Taiji constellation only with a shorter distance between the satellites. The satellite and payload design are also the same as Taiji, however one satellite only contains one laser ranging interferometer and one drag free control system, with the other slot installed by a dummy mass.
The final Taiji configuration of 3 satellites is the 3rd step around 2033. Each of the 3 satellites follows a heliocentric orbit. Together, they form a giant equilateral triangle with the side length being approximately 3 million km. The mass centre of the 3-satellite-constellation falls on Earth orbit and trails Earth for 20° or -20°. It is planned to detect with Taiji the low frequency


Taiji-1 satellite. Credit: Xinhua

(0.1 mHz-1 Hz) GW sources by using inter-satellite laser ranging interferometer and drag-free control technology. The expected operational life of the Taiji constellation is about 5 years.
(Note: Next to the Taiji Project, the Sun Yat-Sen University is leading the Tianqin Project with similar objectives.)

QUESS - Quantum Experiments at Space Scale - Micius

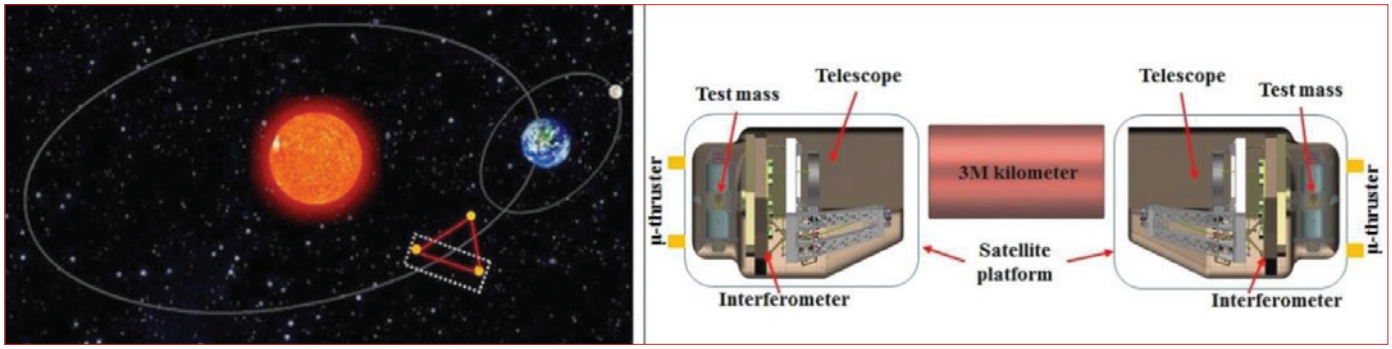
An international team led by Chinese scientists used the Micius quantum satellite to test why quantum mechanics and the general theory of relativity don't work together. The study, published on 19 September online in *Science* journal, partially ruled out a hypothesis that the entangled particles would de-correlate from one another as they passed through separate gravitational regions of Earth. The researchers used the satellite to produce and measure two entangled particles: one particle transmitted on the surface while the other passed through the planet's gravity field toward the satellite in a 500 km orbit. With the experiment, the researchers ruled out the strong version of the hypothesis as they did not see the obvious de-coherence rendered by gravity.

A Twenty-First-Century Sputnik Moment: China’s Micius Satellite
Aoki Setsuko, Professor of Law at Keio University Law School, explains in an interview with nippon.com the rapid development of China's space activities in the recent decades. She thinks of the launch of the quantum communications satellite QUESS-Mozi as the “Sputnik moment” of the twenty-first century. She also looks into the strategic moves China is making with respect to partnership programmes and reflects on the long-term perspectives of space competition in which China will play a leading role.

SATELLITES

Communication Satellites

On 23 August 2019, China Great Wall Industry Corporation (CGWIC), and Indonesia PT. Satelit Nusantara Tiga (SNT) signed a contract for a 13M RF front-end system for Ka-band Gateway to serve a new high-throughput satellite over Indonesia. A consortium led by the Indonesian satellite operator Pasifik Satelit Nusantara (PSN) was tasked by its national Ministry of Communication and Information Technology to take over the project. The PSN consortium formed SNT for the purpose of implementing the satellite project. The shareholders of SNT are PSN, PT Pintar Nusantara Sejahtera (Pintar), PT Nusantara Satelit Sejahtera, and PT Dian Semesta Sentosa (subsidiary of PT Dian Swastatika Sentosa Tbk). CGWIC together with North West China Research Institute of Electronics Equipment (NWIEE) are responsible for the 13M RF front-end system.
Prior to this contract, on 27 June 2019, CGWIC signed the contract to provide 9M RF front-end system for C- and Ku-band gateways with PSN for Nusantara Dua Satellite (formerly PALAPA-N).



The Taiji final configuration consists of three satellites. The schematic diagram of Taiji’s orbit (left) and payload (right). Credit: *Ziren Luo, et. al, (2020), A brief analysis to Taiji: Science and technology, Results in Physics, 16, 102918, DOI: 10.1016/j.rinp.2019.102918.*

International Charter on Space and Major Disasters

By activating the mechanism of the International Charter on Space and Major Disasters, CNSA launched on 25 July the satellite emergency response plan, following a request for international disaster relief support by the Indian Space Research Organization's (ISRO). The China Centre for Resources Satellite Data and Application (CRESDA) scheduled the 3 EO satellites Gaofen 1, 2 and 3, to capture images of flooded regions in India. CRESDA also made a query for archived data and sent a total of 14 pre- and post-disaster satellite images to ISRO.

Since the beginning of 2018, China has deployed its satellites to monitor more than 30 major natural disasters around the world and provided remote sensing imagery and data to affected nations and regions. Currently, the Gaofen 1, 2, 3, 4 high-resolution Earth-observation satellites as well as the Fengyun 3C weather satellite are available for duties under the charter.

China signed the Charter in May 2007 and made a first request for assistance under the charter in July the same year. So far China had made 24 requests for satellite data assistance through the mechanism of the Charter.

Tianzhi 1

China's first software-defined satellite Tianzhi 1 passed multiple in-orbit tests and verified several new technologies during its first 6 months of orbital operation.

The tests included satellite-and-rocket separation imaging, auto request-based measurement and control, and space target imaging, covering the fields of intelligent measurement, operation and control, and intelligent information processing

Tianzhi 1, meaning in Chinese "sky-based intelligence", is a software satellite, carrying a small cloud computing platform and 4 domestically made smartphones.

The satellite hardware is capable of developing flight software for other satellites and has an app store for various applications. The aim is to have satellites able to complete orbit determination and extrapolation independently from control centres on Earth or select the ground stations to communicate with, based on the mission requirements. The Chinese Software-defined Satellite Technology Alliance will continue to develop and launch a series of Tianzhi satellites and make breakthroughs in key technologies of software-defined satellites including space-based supercomputing, intelligent control and inter-satellite communication within constellations.

Currently, a Tianzhi 2 satellite is being developed with an 13 sensors camera array, allowing to collect data from different targets and improved data processing.

NAVIGATION

Beidou

• Cooperation

The 6th Meeting of the Russia-China Project Committee on Important Strategic Cooperation in Satellite Navigation (RCPCISCSN) took place from 28-30 August in Kazan, Russia. It was co-chaired by Wang Zhaoyao, Chairman of the China Satellite Navigation Committee, and Sergeij Saveliev, Deputy Director General of the State Space Corporation Roscosmos. 20 key representatives of the Beidou and GLONASS programmes and their related satellite navigation organisations and industries were part of the delegations. They confirmed that the “Agreement on Cooperation between the Government of the People’s Republic of China and the Government of the Russian Federation on the Peaceful Use of Global Satellite Navigation Systems BDS and GLONASS”, signed in November 2018 takes effect, providing legal and organisational guarantees for satellite navigation cooperation between the two countries as well as in the development and manufacturing of civil navigation equipment that supports both the Beidou (BDS) and GLONASS systems.

The 4 thematic working groups on compatibility and interoperability, augmentation and station construction, monitoring and assessment, and joint applications delivered their reports, concluding on joint ground station construction, cross-border transportation, precision agriculture and other cooperative projects including joint research and development of chips and other applications. Consensus was reached on the “Agreement on Time Interoperability Cooperation between BDS and Glonass”.

The feasibility study report of the precision agriculture project was discussed and adopted. Furthermore, a multi-mode and multi-radio frequency chip for global signals of the Chinese and Russian navigation satellite systems was released.

A site survey of potential joint satellite monitoring ground stations was concluded and the survey certificate signed. Under the agreement each country will deploy 3 monitoring stations within their own territories for the other country enabling the correction of navigation signals.

• Innovation

The Xi’an Satellite Control Centre has improved its capacity in managing the BDS satellites as well as in detecting and handling satellite faults.

It has developed a software for automatic remote control to make satellite management more convenient, scientific and efficient. It has conducted the health check and orbit control of 10 BDS-2 satellites to ensure the orbital positions of the BDS-3 satellites, without affecting BDS users. The new system reduced the test time from 10 h to 5 min, improving significantly the efficiency of data analysis as well as the maintenance of the constellation.

• Deployment

At the 8th CSA-IAA Conference on Space Technology Innovation on 4 and 5 September in Shanghai, China, Yang Jun, Deputy Director of China's Satellite Navigation System Management Office told the audience that China plans to send 5 to 7 Beidou satellites into space this year and 2 to 4 in 2020, which will help to fully complete the Beidou Navigation Satellite System global network. Currently, 39 satellites are in-orbit. In the future, BDS will also be further integrated with the internet, the Internet of Things, 5G and big data.

• Smart Manufacturing Plan

On 7 August, the "Beidou Smart Manufacturing Plan" aiming at Beidou application development was introduced. A total fund of 1 billion RMB (142 million USD) and technological support is available for software developers to help them create products in new application scenarios engaging more sectors and building a developer ecosystem. The plan provides developers with the Application Programming Interface (API), allowing easier access to Beidou data. The service provider Qianxun Spatial Intelligence (Qianxun SI), which hosts the new programme, will produce hardware that allows developers to test their products on mobile phones and computers. The intention is to establish cooperation with a range of companies, including Alibaba Cloud, Qualcomm, Broadcom and u-blox, to help developers to expand application in industry and services sectors.

• Beidou for navigation

The Civil Aviation Administration of China (CAAC) on 8 August held a conference to accelerate BDS' application in general and transport aviation and domestic commercial aircraft. The conference was used to revise the roadmap for BDS' application in aviation.

China from space: Satellite images of Guangdong

Researcher working on Beidou system seeks to inspire talent

TELECOMMUNICATION

ChinaSat on the International Stage - A Sleeping Dragon?
China Satellite Communications Company Limited - better known as ChinaSat - is by far the largest satellite operator in China. As the primary operator in what has been an effectively closed, monopolistic Chinese satcom market, ChinaSat can have a tendency to fly under the radar in the West, though this has started to change. With new satellites being launched in late 2019 and into the early 2020s, and with an increasing amount of capacity outside of China, ChinaSat is likely to start having a bigger impact on international markets in the coming years, for several reasons. An analysis by Blaine Curcio of Orbital Gateway Consulting.

AsiaSat's Privatization Marks the End of an Era for Hong Kong
Hong Kong is one of the world's truly global cities. Long an entrepot focusing on trade, starting in the 1970s and 1980s, Hong Kong became a centre for regional broadcast, and in the 1990s, a centre for satellite communications. Indeed, this city of under 8 million people is home to no less than 3 satellite operators (arguably 4), as well as the largest satellite service provider in the world (ABS, APT Satellite, AsiaSat, and arguably GapSat, and SpeedCast, respectively). Although many of the broadcasters have left Hong Kong for places such as Singapore, the satellite operators remain, and while they are putting less emphasis on the small, terrestrially-connected Hong Kong market, they are beginning to evolve in a satellite market that increasingly demands rapid evolution. Blaine Curcio of Orbital Gateway Consulting reflects on the past and future of Hong Kong's satellite industry.

TECHNOLOGY

The 206th Institute under CASIC (China Aerospace Science and Industry Corporation) developed a miniaturised ion liquid electric thruster that can extend the operational life of small satellites and prevent them from becoming space debris. The thruster has a mass of 300 g. It completed in-orbit tests on an experimental satellite launched earlier this year.
The new ion thrusters generate propulsion using liquid metals - usually Caesium, Indium or Mercury. They do not need big fuel tanks, pumps or valves. They are portable and capable of high-precision orbital manoeuvres. Because of the modest requirements, ion thrusters can spare the small amount of fuel needed for manoeuvring the space craft out of its operational orbit at the end of service life.

SPACE APPLICATIONS

Land Survey
After 1996 and 2007-2009, China is conducting between October 2017 and 2020 a 3rd national land survey with high resolution satellite imagery to undertake the most comprehensive and accurate record of China's land resources and utilisation status.

Atomic Clocks
At the beginning of August, China started the mass production of a new generation of atomic clocks that are just 17 mm thick, 76 mm long and 76 mm wide. Previous rubidium clocks were 40 mm thick. The new clock has a plug-in design, enabling easy integration into circuit boards and it shows improved performance with a higher temperature resistance up to 70°C. In addition, it has a taming function, enabling the clock to be automatically recognised and tamed by the pulse per second (PPS) signal provided by navigation satellite systems, improving the accuracy of local frequency. The clock was developed in 2018 by a research institute under CASIC.

Robotic Applications for:

- **Safety and Security**

At the 2019 World Robot Conference robots developed by the China Academy of Launch Vehicle Technology (CALT) were exhibited. They are the result of space technology transfer involving navigation, infrared sensors, radiation hardening, software, algorithms, 3D modelling, and drone technology. All those technologies were applied to patrol and security robots, to dog-like robots that can perform tasks in complex, harsh and dangerous environments, to intelligent searching and environment perception robotic systems, and to collaborative high-precision robotic arms for industrial use.

- **Waste Treatment**

A robotic arm, designed and built by CALT was launched in 2016 on a CZ-7 rocket, to test the removal of space debris, including rocket emissions and fragments from disintegration, erosion and collision. CALT's engineers have used space and artificial intelligence technologies, to upgrade this arm into a high-efficient garbage sorting tool. The robot sorts garbage by scanning waste items with a visual identification system. In experiments, it achieved an accuracy of more than 94 %, which is comparable to manual sorting. Even if a target is covered by as much as 30 % by other items, the robot can still identify and sort it accurately. The robot can be equipped with up to 30 arms working at the same time. With one camera and four robots, the technology could sort 300 tonnes of garbage a day. The robotic arms can also be used to sort packages for delivery, food, drug and agricultural products.

- **Energy Grid Maintenance**

In Chengdu, a robot powered by technology developed for space exploration, supports the workers in the maintenance unit of the State Grid Sichuan Electric Power Company and was used for the first time. Remotely controlled, the robot opened a power box and flicked an air switch inside. It was capable of replacing over half of the manual operations. The robot was jointly developed by an institution under China Aerospace Science and Technology Corporation and the State Grid Sichuan Electric Power Company. Sichuan is a major province in generating electricity with one of the most expansive grids in China with countless sub-stations and switch stations across Sichuan, some in remote mountainous areas.

COMMERCIAL SPACE

Investment in China Commercial Space
According to the Commercial Space Investment Race Report by FutureAerospace, 161 rounds of investment in China's commercial space sector have taken place between 2015 and July 2019. Investment has come from 218 different sources, among them the most active players are Matrix Capital China, Shunwei Capital and Shenzhen Capital. The report also showed that the investment in the commercial space sector is increasing. Most funds go into satellite manufacturing, satellite applications and launch services. Estimations give as the total amount of capital raised between 2015 and July 2019 at least 10 billion RMB (1.42 billion USD).

LAUNCHERS
China Great Wall Industry
Xing He, Executive Vice President of China Great Wall Industry Corporation said in a panel discussion at the World Satellite Business Week in Paris that he is optimistic about the return to flight for the CZ-5 still this year because the exact cause of the failure of the launch in July 2017 has been found out. He was also optimistic about launch services for small satellites which CGWI can accommodate as secondary payload on large rockets or on small commercial rockets. The small satellite business makes it easier to avoid ITAR regulations and opens up new opportunities within the planned constellations projects. Those constellations will drive the emergence of approx. 10 small launcher services worldwide of which 5 will be Chinese.

Deep Blue Aerospace
Beijing Deep Blue Aerospace Technology Co., Ltd., reported end of September a successful thrust chamber hot test fire of the kerosene-LOX engine for its Nebula rocket.

Galactic Energy

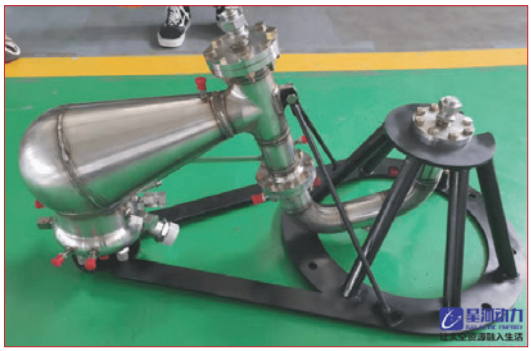
• Pallas

On 6 July, Galactic Energy Aerospace Technology Co (Beijing Xinghe Dongli Space Technology Co. Ltd.) has successfully completed its first series of test firing of its independently developed 40 t LOX-kerosine engine for its medium-sized Pallas 1 rocket. A total of 7 ignition tests were carried out, accumulating a total test time of 380 s and a maximum single operation time of 100 s. The analysis of test data showed that all parameters reached the advanced level. The gas generator will become the main power source for the Pallas 1 rocket, a reusable medium liquid propellant launcher.

Galactic Energy started the engine development in December 2018. Next tests will be the turbo-pump half system test and the engine full system test. A demonstration launch of the reusable, two-staged Pallas rocket (4 t to LEO) is planned for 2022.

• Ceres

Galactic Energy is also working on the small solid-fuel rocket Ceres 1, scheduled for a first launch in 2020 from the Jiuquan Satellite Launch Centre. A main satellite and two smaller payloads are already on the manifest for that flight. On 9 September, the company successfully carried out a 74 s hot fire test of the 2nd stage engine for its Ceres 1 launch vehicle including a stage separation test of the first two solid-fuel stages. Ceres 1 will consist of three solid stages and a liquid-propellant fourth stage. It has a payload capacity of 79 kg, available to global customers. Until the end of the year, the rocket will undergo 20 ground tests, including assembly.



Galactic Energy's Multiple Counterflow Vortex Unique Configuration Gas Generator – the key component for the Pallas 1 rocket engine. Credit: Galactic Energy

Thoughts on the "Hype" about China's NewSpace Launcher Startups

Part 1 Part 2

When discussing the rapid development of China's private space sector and notably launch vehicles, many observers hint at a bubble: an unhealthy number of start-ups all pursuing the same scope of activities with similar technical solutions, and unsustainable growth not correlated with market demand. Is this justified? In this blogpost, space analyst Jean Deville, offers some thoughts and engage in a comparison between Chinese and U.S. NewSpace, discussing market size and Sino-foreign space "ecosystem decoupling".

iSpace

Initially planned for launch in May 2019, the Hyperbola 1 rocket was finally delivered to Jiuquan on 6 July to get readied for launch. After LandSpace and OneSpace failed to reach orbit, iSpace succeeded with the first commercial space launch for and from China on 25 July.

iSpace plans several commercial launches in 2020 and aims for the debut of its reusable Hyperbola 2 in 2021. The reusable design of Hyperbola 2 is supposed to cut costs by 70%.

Landspace

At the Russian airshow MAKS-2019 in Shukovsky, near Moscow, Landspace Technology Corporation Ltd. announced that the company is accepting payloads from around the world for the maiden launch of its Zhuque 2 (ZQ-2) launcher powered by the TQ-12 LOX/LCH4 liquid-propellant rocket engine. ZQ-2 has been designed as a low-cost "universal" solution for commercial launch needs for global customers, able to deliver 2 t-payloads (with upper-stage 4 t-payloads) into a sun-synchronous orbit (SSO) at an orbit height of 500 km. Landspace was the only Chinese private space company participating in the MAKS-2019. (*also see below: MAKS-2019*)

Landspace's TQ-12 engine has completed a full-thrust test run of 100 s duration at its test range near Huzhou. Key technical parameters have reached the design requirements and further verified the product's quality and structural reliability. TQ-12 will undergo further tests including a test under extreme working conditions and a long-run test.

In early July, Landspace carried out lengthy tests of the TQ-11, the 10 t-thrust methalox engine for the ZQ-2 2nd stage.

Linkspace

On 10 August, Linkspace successfully completed the 3rd untethered vertical take-off, vertical landing (VTVL) test of its RLV-T5 (NewLine Baby) rocket. The 8.1 m tall rocket, took off at 10:35 BJT at Linkspace's launch base in Lenghu Town, Yuya City, northwest China's Qinghai Province. It reached a height of 300.2 m before landing at the designated area with little deviation. The whole flight lasted 50 sec.

The 1st test flight was on 27 March reaching 20 m and the 2nd on 19 April reaching 40 m. During the next test flight it is planned to reach a height of 1 km before the RLV-T6 version, equipped with methane/LOX engines, will be tested which is intended for flights up to 100 km. A flight of the NewLine-1 orbital rocket is planned for 2021.

Linkspace's RLV-T5 rocket during the test on 10 August 2019. Credit: CGTN Photo

MAKS2019

The International Aviation and Space Salon MAKS-2019 was held in Zhukovsky, Moscow Region, Russia, between the 27 August and 1 September 2019.

For the 1st time, China has been the partner country for the airshow. The official site of the XIV International Aviation and Space Salon MAKS-2019 has been translated into Chinese language.

• China Pavillion

China's leading aerospace companies participated in the exhibition programme showcasing across 3,000 m^2. There was a number of business programme events, focused on international cooperation and the implementation of Chinese-Russian programmes.

The China Pavilion opened on 27 August. While the China Pavilion features mainly weapons, aircraft, and equipment from nearly 20 companies, only a few space achievements were exhibited. CASC showed the CZ-7 and CZ-11 carrier rockets and Mars probe. CASIC/Expace featured its Kuaizhou 11.

Landspace brought scale models of its carrier rockets to MAKS 2019 and announced during an event that it has begun inviting customers from around the globe to consider using its ZQ-2 liquid-propellant, medium-lift rocket. ZQ-2's debut mission in

2021 will take several small satellites to a 500 km SSO. Some domestic and foreign firms have expressed interest.

• 3rd Eurasian Aerospace Congress

The Eurasian Aerospace Congress, organised by the Eurasian Aerospace Cluster Partnership and the Samara Region Government, has opened the MAKS-2019 business programme. One of the key topics of the event in 2019 was building a dialogue between industry and science in the Eurasian region.

• Cooperation with China

At the MAKS 2019, Dmitry Rogozin, President of the State Space Corporation Roscosmos, told media that Russia could launch satellites for China's planned orbital constellation, as well as in delivering rocket engines to China. In return, Russia would be interested in Chinese microelectronics. Rogozin also mentioned that Russia and China are open to cooperation in near-space infrastructure without elaborating on details in this regard.

Space Trek

Space Trek (Beijing Xingtu Exploration Technology Co., Ltd.) announced that it is preparing for a technology test flight of its suborbital test rocket in October. The company could secure seed funding from Tongfang Venture Capital and Guosen H&S Investments for the development of its orbital launcher Xingtu 1.

SATELLITES

AsiaSat

Satellite operator AsiaSat, headquartered in Hong Kong, but legally based on Bermuda, was taken over by the major shareholders CITIC and Carlyle as of 1 September. The buyout makes AsiaSat a subsidiary of Bowenvale Ltd. On this occasion, AsiaSat relocated within Hong Kong - from Wan Chai District to Tai Po Industrial Estate, where its antenna park is already based.

Chang Guang Satellite

The Changchun Aerospace Information Industrial Park funded by Chang Guang Satellite was put into operation in September. The facilities in this park are utilised for satellite research and development, production of annually 30 satellites and 200 unmanned aerial vehicles, including testing, and space education. The park will gradually form an industrial cluster of satellite and unmanned aerial vehicle research and development, production, remote sensing information processing and application.

CAST - Commercial Recoverable Satellite

CAST is developing a new generation recoverable satellite for commercial use, which is expected to make its maiden flight in 2020, Zhao Huiguang, Chief Designer of the recoverable satellite project at CAST reported during a public event mid-July. The new re-entry capsule would be able to return 500 kg to 600 kg payloads back to Earth. The currently used Shijian satellite is capable of returning 250 kg. Zhao confirmed that the parameters of the new generation re-entry capsule regarding payload capacity, microgravity level, data service, power supply and duration of stay in orbit will be further improved. Considering the high demand for free-flyers from material sciences, electronic technology and biological pharmacy, the coming 10 years will see 10-15 launches of recoverable satellites for domestic and international customers.

GalaxySpace Financing

On 16 September, GalaxySpace secured a series B round funding, by JIC Technology Investment, Shunwei Capital, IDG Capital, Legend Capital and Morningside Venture Capital. The amount of financing was not revealed but the company is now valued at 5 billion RMB (703 million USD). GalaxySpace is working on a low-cost, high-performance 5G satellite constellation.

Hong Kong Aerospace Technology Group

In September 2019, Hong Kong Aerospace Technology Group Limited (HKATG) was co-founded by 10 aerospace engineers with international expertise and Hong Kong Financial Asset Management Holdings Limited (HKFAM). After more than 3 years of preparation and resource integration, it was established in The Hong Kong Special Administrative Region of the People's Republic of China in 2019.

The core business of HKATG are: the “Golden Bauhinia” Constellation and international commercial satellite ground receiving station, embracing satellite manufacturing, satellite remote sensing, satellite navigation, satellite communication, aerospace industry services. HKATG is the first and so far the only Hong Kong member of the International Astronautical Federation (IAF).

Golden Bauhinia Constellation

The "Golden Bauhinia" constellation is an active-passive hybrid low-orbit high-frequency satellite constellation that combines optical remote sensing and synthetic aperture radar to form an all-weather and near-real-time dynamic monitoring service system that is not affected by weather conditions such as cloud and rain. The "Golden Bauhinia" constellation will establish special applications and services for regional dynamic monitoring under the real-time satellite communication and navigation requirements, provide users with integrated solutions for smart cities, and help cities achieve full-cycle monitoring of refined management and ecological environment construction.

MinoSpace Financing

By the end of September, MinoSpace secured a series A+ funding from Shenzhen Capital Group, Kexin Capital, Yonghua Capital, CASSTAR and NXROBO. The financing was announced on 18 September. Prior to it, it had also collected money from China Aerospace Science and Industry Corporation’s subsidiary, Essential Capital, Amphora Capital, Feng Yang Capital, and CPG Capital Partners.

Remote Sensing

Argentinian geospatial analytics company Satellogic has partnered with science data company ABDAS in China's Henan Province, to provide exclusive monthly access to multispectral EO imagery from a satellite constellation over a specific area. Satellogic is marketing this service concept as a “dedicated satellite constellation”. The advantage for the customer is that it can use the satellite as its own without developing, launching and operating the satellites or the constellation. The agreement is valued at 38 million USD.

Satellogic, founded in 2010, is financially backed by Tencent giving the company advantage on the entry to the Chinese market and makes it one of the first international providers of space imaging in China. The contract provides ABDAS with access to a platform with operational control of the satellites and a private cloud for processing, cataloguing, and storing images. Satellogic operates currently 8 EO satellites, with 2 more NewSat Mark IV satellites planned for launch in January on board a CZ-2D and 80 more over the next two years on the European Vega rocket and the Chinese Long March.

The imaging sensors on the satellites provide 1 m resolution via the multispectral channel and 30 m resolution on the hyperspectral imager.

INTERNATIONAL COOPERATION

ANGOLA

On 3 September, two representatives from China Great Wall Industry Corporation (CGWIC) discussed with experts from the Department of Space Sciences and Applied Research (DCEPA) of the Angola National Space Program Management Office (GGPEN) possibilities for space project partnerships.

ARABIC STATES

On 5 September, the 4th China-Arab States Expo was opened in Yinchuan, Ningxia Hui Autonomous Region. Meteorological scientific achievements like the Fengyun meteorological satellites, meteorological sounding facilities, and weather modification technical facilities have been exhibited. Also, remote sensing monitoring capacities of meteorological satellites for typhoon, sand and dust, water and fire conditions were demonstrated, as well as the Emergency Support Mechanism for International Users of Fengyun Meteorological Satellites in Disaster Prevention and Mitigation (FYESM). The FY-2H can provide meteorological monitoring and data services for Arab states and provides scientific support for disaster preparedness and ecological conservation in those areas. 6 meteorological experts from China were invited to become members of the Expert Consultation Committee of China-Arab States Technology Transfer Project.

EGYPT

• Satellite Manufacturing Facility

Egypt's Minister of Higher Education Khaled Abdel Ghafar and Ambassador of China to Egypt Liao Liqiang inspected on 29 September the Satellite Assembly, Integration and Test Centre in the New Administrative Capital, discussing strategic Egyptian-Chinese relations in space technology and remote sensing. Abdel Ghafar clarified that the centre will help Egypt host the African Space Agency and design joint programmes between the African Space Agency and other space agencies. The bilateral agreement on the Chinese support for the establishment of the 1st Satellite Assembly, Integration and Test Centre in the Arab region was signed in January.

Egypt and China have concluded several funding agreements for Egypt's space programme since 2017: In 2016 a grant of 23 million USD, in August 2018 a second grant worth 45 million USD, dedicated to the Egyptian satellite "EgyptSat2" including training of Egyptian specialists in China on remote sensing and on 21 January 2019 a grant of 72 million USD, mainly for Egypt's MisrSat-2 satellite and the New Administrative Capital facility. (*compare GT! no 27, section: International Cooperation*)

Photo taken on 8 September 2019 shows the Egyptian Satellite Assembly, Integration and Test Centre in the Egyptian Space City near Egypt's New Administrative Capital. Credit: Xinhua/Li Binian

• MisrSat-2 kick-off meeting

Egyptian and Chinese teams announced on 8 September the start of the implementation phase of the China-funded MisrSat-2 satellite project. MisrSat-2 is a small high-resolution remote sensing satellite. During the kick-off meeting, which was held at the Egyptian Space City near Egypt's New Administrative Capital, both sides signed the project documents.

Already on 7 September, a ceremony to launch the satellite project was held during the 4th China-Arab States Expo, in Yinchuan, China's Ningxia Hui Autonomous Region.

The satellite will be developed cooperatively by Chinese and Egyptian teams working in parallel, noting that there will be Chinese guidance throughout the project phases which will be carried out in Egypt as well as in China, but the assembly and integration of the satellite will be done in Egypt at the new Satellite Assembly, Integration and Test Centre. The development phase of the satellite is expected to last 35 months.

In addition to the satellite, a ground station and a ground application system to support the operation of the satellite will be supplied. The lifetime of the satellite is 5 years, while the lifetime of the ground station is 15 years.

The satellite cooperation is within the framework of the Belt-and-Road Initiative.

After the project is completed, Egypt will be the 1st African country to have a complete satellite assembly integration and testing capability.

In 2017, Egypt's Council of Ministers approved a law allowing the President to establish an Egyptian Space Agency with the mandate to coordinate Egypt's national space programme. The Agency is expected to help build Egypt's capabilities in areas of satellite design and fabrication, space science and application, and launch systems. In February, Egypt won the bid to host the proposed African Space Agency.

KIRIBATI

From 1997 until 2003, South Tarawa Atoll, capital of Equatorial island nation Kiribati, was home to China's first overseas Space Tracking, Telemetry and Control Station, which played an important role in the manned Shenzhou missions and the launches for the Beidou navigation system. When Kiribati established diplomatic relations with Taiwan in 2003, China left its ground station on South Tarawa.

On 20 September Kiribati announced the re-establishment of its diplomatic relations with China. This move sparked questions on whether the space tracking station might become revived. That could ease the use of space tracking ships which need to be deployed to the Pacific to track and control the early launch and operations phase of space missions, a procedure that is three times more expensive than using a station on land, Wang Shaohua, former Chinese ambassador to Kiribati told SCMP (South China Morning Post).

LAOS

On 10 September China Meteorological Administration (CMA) and the Ministry of Natural Resources and Environment (MONRE) of the Lao People's Democratic Republic signed a Memorandum of Understanding on cooperation in the field of meteorological disaster prevention, tropical meteorology and agrometeorology, weather forecast and meteorological information exchange, meteorological telecommunication and technical exchange, climate monitoring and prediction, climate change research, meteorological observation system and instrumentation, meteorological services, operational organisation and management as well as personnel training. The Laotian delegation visited the National Meteorological Centre (NMC) and National Meteorological Information Centre (NMIC).

MONGOLIA

From 16 to 20 September staff of the China National Satellite Meteorological Centre (NSMC) and China National Meteorological Information Centre (NMIC) supported the National Agency for Meteorology and Environment Monitoring of Mongolia (NAMEM) to complete the maintenance of CMACast and the local configuration of FY satellite data reception, ensured the stable CMACast broadcast of FY satellite data, carried out training on CMACast reception procedures and data for FY-4A and FY-2G cloud images and products, and conducted remote video consultation with 21 provinces of the country. During the demonstration on 19 September, for the first time FY-4A cloud images were included in the national weather consultation of Mongolia.

PAKISTAN

Pakistan plans to send its first astronaut to space by 2022 with the support of China, the Minister for Science and Technology, Chaudhry Fawad Hussain, said on 15 September. The selection process would start in February 2020 under the lead of the Pakistan Air Force involving mainly air force pilots. 50 candidates will be shortlisted. Those will be further screened to reduce them to 25 and finally to 10 which will undergo astronaut training. And out of them only one would be sent to space.

A report in Pakistan media outlet DAWN quoted Chaudhry as saying "that there is an agreement between Pakistan and China since 2015 and as the country does not have its own satellite launch site, a Chinese facility will be used, as done previously." Once the Pakistan Air Force has selected the potential astronauts, Space and Upper Atmosphere Research Commission (SUPARCO) would contribute science projects for the 2022 mission.

RUSSIA

At the invitation of Russian Prime Minister Dmitry Medvedev, Chinese Premier Li Keqiang visited Russia from 16-18 September and co-chaired the 24th Regular Meeting between the Chinese and Russian Heads of Governments. Both sides decided to hold the China-Russia year of scientific and technological innovation from 2020 to 2021 alternating in China and Russia. The move is intended to strengthen traditional cooperation on energy, space, aviation and the military industry. The leaders had a detailed discussion on cooperation in key areas and improving the level of scientific and technological innovation.

Also see section: CHANG'E-7

THAILAND - Fengyun satellite

APSCO and CMA jointly organised a Field Trip and Training for FY-2 Meteorological Satellite Medium Scale Data Utilisation Station for the Thailand Meteorological Department (TMD) from 17-19 September 2019 in Bangkok, Thailand. Experts from CMA introduced the FY series satellites and its applications, gave an introductory training on the FY-2 system and three possible locations for the ground station were identified. CMA experts also helped TMD to update the software and trouble-shot the CMAcast system which was installed more than a decade ago. Because of Thailand's rough terrain, meteorological satellites data play an irreplaceable role in weather forecast as well as disaster management.

CMA experts show their colleagues of TMD to install a satellite receiver. Credit: APSCO/CMA

UK

On 17 July, the China-UK Joint Centre for Earth and Planetary Sciences, a cooperation between the Institute of Geology and Geophysics of Chinese Academy of Sciences (IGGCAS) and the University of Leeds, was inaugurated in China.

UN

Chinese State Councillor and Foreign Minister Wang Yi submitted to the UN the report "Big Earth Data in Support of the Sustainable Development Goals". The report outlined that China will continue to support the United Nations' Sustainable Development Goals 2030 (UN SDG 2030) by providing open, high-quality Earth science data, research methods and Chinese solutions on major issues that may serve as a reference or inspiration for other countries. To achieve the SDG, insufficient data, imperfect research methods and diverse local concerns are some of the biggest obstacles. With the 5-year Big Earth Data Science Engineering Project by the Aerospace Information Research Institute of the Chinese Academy of Sciences launched last year those obstacles can be tackled. The report focuses on 5 of the 17 SDGs: zero hunger, clean water and sanitation, sustainable cities and communities, life below water and life on land. In the report could be shown that the environmental impact per unit of production in China has decreased since 2000 due to better farm management, but rapid urbanisation is challenging this trend. Therefore, farm management and land-use planning must be better coordinated to ensure sustainable food supply in China, especially in urbanising regions. The data also provided evidence that the water quality in western China is generally better than that of the more populous eastern regions, hence future policy should focus on pollution source control and encourage scientists to collect standardized, unified and timely data tailored to local government needs.

U.S.

From 10 to 12 July, the 8th Conference of the Chinese-American Oceanic and Atmospheric Association (COAA) was held at the Nanjing University of Information Science & Technology (NUIST). The topics of the conference focused on climate change science and accurate weather prediction, and conducts in-depth discussions over topics like climate change, ocean science, Earth model, and air pollution.

EDUCATION

Beijing Museum Exhibition

At the China Science and Technology Museum in Beijing an interactive exhibition showcased major scientific and technological achievements in space exploration, maritime research, nuclear energy, manufacturing, information and health industries since the founding of the PRC 70 years ago. A model of the interior of the Tiangong space lab and the Queqiao relay satellite were included in the space section. The exhibition was one of 24,000 activities held across the country from 14 to 20 September to mark National Science Day, an initiative that aimes at improving public scientific literacy since 2004.

Space Camp in Beijing

The award ceremony for the essay competition "Looking for Young Astronauts - My Moon Home" and the opening ceremony of the "Junior Astronaut Training Camp" were held at the National Astronomical Observatory on 29 August. The first prize winner of the essay activity was invited to participate in the "Junior Astronaut Training Camp". Since the launch of the event in early March, the essay competition has set off a sci-fi boom among young people across the country, attracting teachers and students from schools in 32 provinces, municipalities and autonomous regions, and collecting more than 20,000 works.

The 5-day "Junior Astronaut Training Camp" activities included training sessions "Beijing Aerospace City", "Junior Astronauts' Extended Training", "Long March Rocket Factory" and "Aerospace Science Experience".

The event was co-sponsored by the China Science and Technology Association Youth Science and Technology Centre and the Lunar Exploration and Space Engineering Centre. It was supported by the China Aerospace Foundation and hosted by the Beijing Aerospace Information Institute.

MISCELLANEOUS

Space Science Heroes of 70 years of the PRC

The Chinese government has released names of individuals who will be recognised for the first time in commemoration of the 70th anniversary of the founding of the People's Republic


left: A file photo of Nan Rendong. Credit: National Astronomical Observatory
right: During the event. Ye Peijian sits at the far right. Credit: ChinaDaily

of China. Among them are 3 space experts: Sun Jiadong, Ye Peijian, (*see: page 21*) and Nan Rendong.
Scientist Nan Rendong, born in February 1945, died in September 2017. Nan was the founder of and driving figure behind the Five-hundred-metre Aperture Spherical Telescope (FAST) project. With approval from the International Astronomical Union, an asteroid has been named after him.

Nike's Chinese Space Sportshoes
Nike dedicated 5 sport shoe models of its Nike Sportswear Space Capsule Collection to the 20th anniversary of the Shenzhou 1 launch in November. The shoes, only for sale in China were decorated with details resembling spaceflight aesthetic such as silver foil accents and insoles made with spacesuit insulation.

Early Space Pioneers
Five leading scientists shared their stories and passion about China's development at a forum held on 16 August to mark the 70th anniversary of the People's Republic of China. Among them were Ouyang Ziyuan, Academician of the Chinese Academy of Sciences (CAS) and 1st Chief Scientist of China's lunar probe project and Zhou Jianping, Chief Designer of China's manned space programme and Academician of the Chinese Academy of Engineering.

The US public and Chinese space activities
Justin Key Canfil, a PhD Candidate in Columbia University's Department of Political Science was conducting research on how media and the public in the U.S. are reflecting on China's space activities. He analysed articles by the New York Times on the space achievements of the Soviet Union's Luna and China's Chang'e missions. The text was first analysed computer-based and then read by humans who had to give their evaluation of the authors attitude towards the subject. His findings show that the reflections are not in line with the current "hawkish discourse on space competition" in political or institutional language in the US. His data suggest that the public attitudes toward Chinese space activities is driven by "space enthusiasm," rather than space nationalism. He also concludes that "other states' successes have the potential to bridge divides by building mutual respect, even when tensions run hot."

ON A SIDENOTE
NASA Administrator Jim Bridenstine on CBS's "Face the Nation" on 14 July 2019: "So, quite frankly, ... We're so far ahead of China right now, it's not even a comparison."

American kids today dream of being vloggers, not astronauts - and Chinese?
On the occasion of the 50th anniversary of NASA successful landing on the Moon, LEGO and The Harris Poll asked children in the US, UK and in China what their aspirations for the future are. While in the US and the UK 11% said they would like to become an astronaut, in China 56% of the children found this an interesting occupation. To the question whether future humans would live in space, 96 % of Chinese children said yes, compared to 68 % in the US and 63 % in the UK. Also, 95 % of Chinese youngsters between the age of 8 and 12 would like to travel into space, while in the US only 70 % found this a good idea and 63 % in the UK.

Regulatory Framework for Commercial Rocket Manufacturing

In order to thoroughly implement the national innovation-driven development strategy and the military-civilian integration development strategy, on 10 June 2019, the Central Military Commission's Equipment Development Department of the Ministry of National Defense, Science and Technology Industry, published a 6-point regulatory framework to guide and promote the orderly development of commercial launch vehicles, its research, production, launch, safety and technical control.

GENERAL REMARKS
The Chinese government actively promotes the development of private rocket companies with the aim in mind to reduce launch cost, complement the efforts of state-owned rocket companies, support industrial innovation and strengthen China's position on the international launch market.

Commercial companies are those who operate with private funds aimed at making profit through their launch activities.

Commercial space activities are those which launch privately-developed launchers into space and undergo activities in outer space.

A commercial launcher can be an expendable launcher, sounding rocket, re-usable launcher or re-entry vehicle, including all materials, technologies and sub-systems used.

Commercial companies have to obey the rules and regulations as set by the Chinese government and have to get licenced before starting the business operation.

LICENCING
Commercial rocket companies apply for the required licences in two steps: for the development, production and testing, a production license needs to be obtained, and for the actual launch, a launch permit is required.

The responsible authority for granting permission is the National Defense Science and Technology Bureau and the Equipment Development Department of the Military Commission.

Commercial companies have to follow all regulations regarding safety, security and confidentiality. Furthermore, the launch activities have to comply with international law regarding orbit registration, space debris mitigation, airspace closures, drop zone safety, etc.

LAUNCH SITE OPERATIONS
Space launches are only permitted from nationally recognised space launch sites.

National Space Launch Sites should actively provide service and support for commercial entities. Private companies have to comply with the existing rules and regulations of the launch site and have to coordinate its intended rocket launch with the authorities of the launch site.

For sub-orbital testing, a designated launch or test site can be used. Also, for this purpose, the commercial company is required to follow the existing regulations at the site.

SAFETY AND EXPORT CONTROL
Commercial rocket companies have to follow the State's export control rules. In case, the commercial company intends to export rockets or parts of it, permission has to be obtained from the national export control department.

OUTLOOK
State authorities will establish synergies for promoting and supporting the innovation and development of commercial launch vehicles, improve the legal environment for commercial aerospace activities and safety policies, and promote the healthy and orderly development of commercial space in China.

LAUNCHES

2019-043A
2019-043B
25 July 2019 - 05:00 UTC (13:00 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC
launcher: Shuāng Qūxiàn 1 - SQX-1 (Hyperbola 1)
payloads: CAS 7B/BP-1B (Beiligong 1)
Hangtian KKG Fazhang

For the 1st time, a commercial company in China successfully launched a self-developed rocket, writing national space history. iSpace (Beijing Interstellar Glory Space Technology Ltd.) sent its Shuāng Qūxiàn 1 (SQX-1 Y1 - Hyperbola 1) into space on 25 July. The 20.8-m tall rocket took-off from a purposely installed supporting platform. The Hyperbola 1 has 3 solid-fuelled stages and a liquid-propelled upper stage where the attitude and orbit control system is integrated. The take-off weight is 31 t and the payload capacity into LEO is 300 kg and 260 kg into a 500 km SSO (150 kg to 700 km SSO). The 1st stage is equipped with grid fins. The low cost (approx. 5 million USD) and fast response rocket is capable of versatile launch services.

Nearly 15 min after launch, Hyperbola 1 deployed 2 satellites into a 300 km LEO. One was the CAS-7B (BP-1B) amateur radio satellite. The 3 kg, 1.5 U cubesat was developed by the Chinese Amateur Satellite Group (CAMSAT) in cooperation with the Beijing Institute of Technology (BIT). CAMSAT was responsible for the project planning, design, building, and testing, and on-orbit operation. BIT managed the space environmental testing, launch support, and financial support. BIT students were involved in the project. Within the OSCAR network, the satellite is coded BIT Progress OSCAR 102 (BO-102), the BIT amateur radio club call sign is BI1LG. The 263 x 140 x 105 mm sized satellite carried a CW telemetry beacon and FM repeater and was equipped with a solar cell. Attached was a 500 mm diameter flexible film ball for passive stabilisation. Based on the orbit and the satellite structure, the lifetime of CAS-7B was expected to be between one week and one month. It re-entered on 6 August.

The other satellite was the technology test payload Hangtian KKG Fazhang for CASIC subsidiary satellites manufacturer.

3 smaller experimental payloads, the dummy satellite CubeX-1 for Xigua City, a Hangzhou-based education institute, Star Age 6 (Tiange 1 DSF, Xingshidai 2) of the PR-company Aerospace Science and Technology Development Co., Ltd. of Beijing and the Beijing Polytechnic University and HECATE 1 of Zero-g-Lab, were fixed to the 4th stage and re-entered within 24 hours. No COSPAR IDs were assigned to them.


Hyperbola-1 launch preparation.
Credit: Hu Junshe / 胡军 摄

Chinese automobile manufacturer Chang'an Automobile Co., Ltd. sponsored the launch by buying the naming rights for the rocket. Its name was written on the rocket and the company chose the colours of the rocket. Additionally, a small model of a red SUV from Oushang, a car brand under Chang'an, was mounted within the payload fairing. Chang'an Oushang was the 2nd Chinese carmaker sponsoring a private rocket launch in 2019. (*compare sponsoring of CZ-11 sea launch by WEY - GoTaikonauts!, issue 25, page 22*) Chang'an Oushang also announced to give out to customers 10 million RMB (1.5 million USD) through lucky draws via local dealers if the launch succeeds. The company intends to test the performance of its car technologies in the extreme conditions of space, and has been receiving launch-related data from iSpace.

The launch was the 3rd civil and commercial rocket launch organised by the Jiuquan Satellite Launch Centre.

2019-045A
2019-045B
2019-045C
26 July 2019 - 03:57 UTC (11:57 BJT)

launch site: Xichang Satellite Launch Centre - XSLC
launcher: Chang Zheng 2C - CZ-2C
payloads: Yaogan 30-05-01/Yaogan 30-05-02/Yaogan 30-05-03

A new triplet of Yaogan 30-05 remote sensing satellites was added to the existing Chuangxing constellation which will consist of 72 satellites when fully deployed. The new additions are also named Yaogan 30-13 to 30-15 or the 5th group of Chuangxing satellites. The 3 satellites have entered the planned orbits which are in a new orbital plane of the network which supports electromagnetic environment detection and related technological tests.

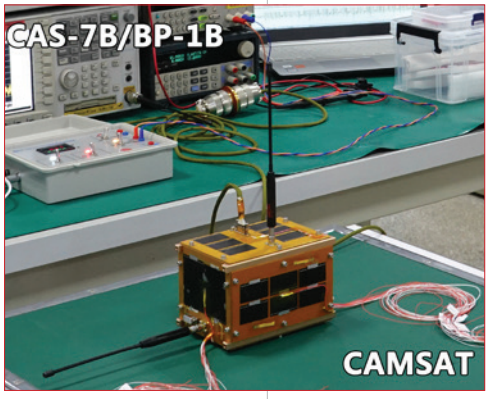
The Yaogan satellites were developed and built by Aerospace Dongfanghong Satellite Co. No other details became known.

The CZ-2C first stage was modified to accommodate grid fins, which helped to steer its trajectory after stage separation to a more precise impact location.

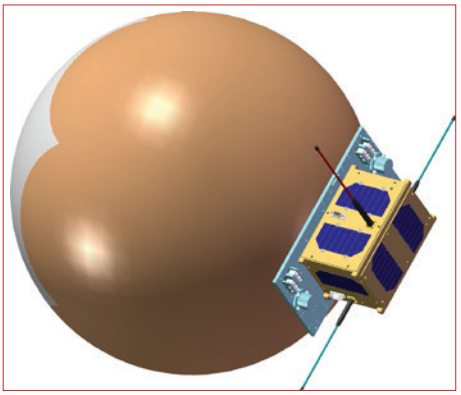
2019-052A
2019-052B
2019-052C
17 August 2019 - 04:11 UTC (12:11 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC, mobile truck to the East of LC 91
launcher: Jielong 1 (Smart Dragon 1, SD-1)
payloads: Qiancheng 1-01 / Xingshidai 5 / Tianqi 2

The new carrier rocket Jielong 1, designed for commercial use by China Rocket Co., Ltd. - a CALT subsidiary, launched on its



CAS-7B / BP-1B undergoing test. Credit: CAMSAT
https://amsat-uk.org/2019/06/02/cas7b-bp1b-satellite/


CAS-7B / BP-1B satellite schematic diagram.
Credit: CAMSAT

1st flight 3 satellites from 3 different customers into a 540 km SSO. The 3 satellites will be used for remote sensing services, communication and IoT.

The 4-staged Jielong 1 has a launch mass of 23 t, a length of 19.5 m and a diameter of 1.2 m. The first 3 stages are solid-fuel propelled and the 4th stage has a hydrazine engine. The payload capacity for a 500 km SSO is 200 kg. The rocket's design and development began in February 2018. By relying on optimised or streamlined designs and using COTS elements, it now takes 6 months to produce a Jielong rocket and 24 hours to prepare for launch. Jielong can accommodate multiple satellites. The next 6 launches are already booked by customers. CALT said the price per kg payload is around 30,000 USD.

Jielong was launched from an off-road mobile vehicle, showing a high operational flexibility. After OneSpace, Landspace, and iSpace, the Smart Dragon rocket was the 4th Chinese commercial launcher to make its debut within 10 months. All those launches were supported by JSLC.

The main payload was the 65-kg commercial Earth observation satellite Qiancheng 1-01, also named Haichuang Qiansheng. It is a box-shaped satellite with two solar panels and a 2 m resolution camera. The satellite was built over 14 months by Qiancheng Exploration Tech Co., Ltd. (QS-T) and has a dual function for remote sensing (soil moisture monitoring) and communications. The communication payload is a 20 kbps speed narrowband transmitter. Qiancheng 1-01 is one of the most sophisticated satellites made by a private company in China. The satellite is supposed to be the 1st of a series that will eventually form a 24-satellite network.

Xingshidai 5 is a test Earth observation satellite for Chengdu Guoxing Aerospace Technology Co. Ltd., using a box-shaped Weina MN10-02 bus. The 9.3 kg satellite, built by MinoSpace Technology (also: Weina Star Technology Co., Ltd.), is equipped with a 3-segment solar panels and a RGB imaging sensor with a 10 m resolution and a 25 km swath.

Tianqi 2 is a satellite for Guodian Gaokeji (Beijing) for IoT data relay. It is a prototype smallsat and follows Tianqi 1 and 3 launched in October 2018 and June 2019 as test satellites of a planned constellation.

The SD-1-Y1, the first in the solid-propellant Jielong series, was launched from a large launch vehicle. Credit: Wang Shen/chinadaily.com.cn

Jielong 1 in assembly hall. Credit: CALT

2019-053A
19 August 2019 - 12:03 UTC (20:03 BJT)

launch site: Xichang Satellite Launch Centre - XSLC, LC2
launcher: Chang Zheng 3B - CZ-3B (CZ-3B S/N)
payload: ChinaSat 18 (Zhongxing 18, ZX-18)

ChinaSat 18 was launched into geotransfer orbit. XSLC confirmed that launch and payload separation were normal but mission control could not establish contact with the comsat. It was not clear whether the solar panels deployed. Most likely the satellite remained in a highly elliptical transfer orbit.

Since 2013 CAST was working on ChinaSat 18. For the first time, the extended DFH-4E satellite bus, consisting of a service module and propulsion section, was used. This improved version has an 30 % increased capacity supported by two solar cells (10.5 kW at the end of life). The launch mass of the box-shaped satellite was 5.500 kg, the payload mass 900 kg. Its size is 2.36 x 2.10 x 3.60 m. The satellite is 3-axis stabilised. Its station-keeping precision is ±0.05° in West-East and North-South direction. ChinaSat 18 was equipped with 30 Ku-band, 9 Ka-band high-throughput and 2 Ka BSS-band transponders, delivered by Thales Alenia Space.

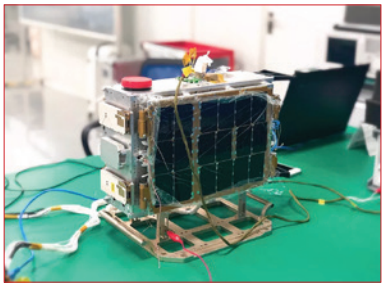
China Satellite Communications (China Satcom) would have become the operator and owner of the satellite, using it for improving the telecommunication, internet and broadcasting services for China and the southwest-Asian region. Together with ChinaSat 16, the satellite's capacities would have improved the in-flight connectivity to airline passengers over China through a partnership with U.S. operator Viasat. The comsat was expected to work in GEO at its position of 115,5° East for 15 years.

2019-058A
2019-058B
30 August 2019 - 23:41 UTC (31 August - 07:41 BJT)

launch site: Jiuquan Satellite Launch Centre-JSLC, mobile platform
launcher: Kuaizhou 1A
payloads: Xiaoxiang 1-07 (XX-1-07, Tianyi 1-07, TY-1-07)
KX-09 (Taiji 1)

It was the 3rd launch of Expace's Kuaizhou 1A rocket with two satellites. The main payload was the microgravity research satellite KX-09 (CAS-KX-09), built by Aerospace Dongfanghong Satellite Co. for CAS. It is a cube-shaped satellite with one solar cell unit. After launch, the satellite was renamed Taiji 1. Equipped with a novel Hall-effect thruster (HET), it will conduct on-orbit experiments on ultra-high precision altitude control and space laser interference measurements, laying the foundation for space-based gravitational wave detection and ultra-high precision inertial navigation. Taiji 1 will be joined in the coming years by two other satellites.

The 2nd payload which was added to the launch on short notice, was the 6U cubesat Xiaoxiang 1-07 from SpaceTY Co., Ltd. (Changsha). The technology satellite is also named Tianyi 1-07. It is a laser communications test satellite, to be operated by Laser Fleet. Also, integrated into the cubesat was a solar sail deployment mechanism (SIASAIL 1) which will be pushed out of the satellite platform later on. After that the mechanism will be turned 90 degrees. In a second step the sail masts will deploy and gradually spread the sail. The unfolded solar sail is about 0.6 square meters.



left: Testing of the Xiaoxiang 1-07 at Tianyi's workshop. Credit: Tianyi

2019-059A / 2019-059B / 2019-059C
12 September 2019 - 03:26 UTC (11:26 BJT)

launch site: Taiyuan Satellite Launch Centre - TSLC, LC9
launcher: Chang Zheng 4B, CZ-4B
payloads: Ziyuan 1-02D (ZY-1 02D)
Jingshi 1 (Ice Pathfinder, BNU-1)
Jinniuzuo 1 (Taurus 1)

2019-060A / 2019-060C / 2019-060D / 2019-060E / 2019-060F
19 September 2019 - 06:42 UTC (14:42 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC,
launcher: Chang Zheng 11, CZ-11
payloads: Zhuhai 1 OVS-3 - Chunlei Jihua Zhixing
Zhuhai 1 OHS-3A - Xiahaian 1
Zhuhai 1 OHS-3B - Feitian Maotai
Zhuhai 1 OHS-3C - Gaomi-1
Zhuhai 1 OHS-3D - GuoyuanV9

2019-061A
2019-061B
22 September 2019 - 21:10 UTC (23 September, 05:10 BJT)

launch site: Xichang Satellite Launch Centre - XSLC, LC2
launcher: Chang Zheng 3B CZ-3B/YZ-1 (with Yuanzheng upper stage)
payloads: Beidou-3M19 (DW 47) MEO23
Beidou-3M20 (DW 48) MEO24

The launch of Kuaizhou-1A on 30/31 August from Jiuquan Satellite Launch Centre. Credit: Xinhua

During the 3rd quarter 2019, four more launches took place. (see left and below) The details for these launches will be provided in GoTaikonauts! issue no 30.

2019-063A
25 September 2019 - 00:54 UTC (08:54 BJT)

launch site: Jiuquan Satellite Launch Centre, JSLC
launcher: Chang Zheng 2D, CZ-2D
payload: Yunhai 1-02

Ralf Hupertz *and* ***Arno Fellenberg*** *kindly contributed information to the section Chinese Space Launches. Other sources of informations are:*

http://news.xinhuanet.com
http://www.xinhuanet.com/english/list/china-science.htm
https://www.nasaspaceflight.com
http://www.spaceflightinsider.com
https://spaceflightnow.com
http://www.planet4589.org/space/jsr/jsr.html

ACC	Astronaut Centre of China
AIOFM	Anhui Institute of Optics and Fine Mechanics
AO	Announcement of Opportunity
APSCO	Asia-Pacific Space Cooperation Organisation
BACC	Beijing Aerospace Command and Control Centre
BDS	BeiDou satellite navigation System
BJT	Beijing Time
BRI	Belt-and-Road Initiative
CALT	China Academy of Launch Vehicle Technology, 1st Academy of China Aerospace Science and Technology Corporation CASC
CAS	Chinese Academy of Sciences
CASC	China Aerospace Science and Technology Corporation
CASIC	China Aerospace Science and Industry Corporation
CAST	China Academy of Space Technology
CCTV	China Central Television
CE	Chang'e
CGWIC	China Great Wall Industry Corporation
CLEP	China's Lunar Exploration Programme
CMA	China Meteorological Administration
CMSA	China Manned Space Agency
CMSEO	China Manned Space Engineering Office
CNSA	China National Space Administration
CRESDA	Centre for Resources Satellite Data and Applications
CSA	Canadian Space Agency
CSS	Chinese Space Station/China Space Station

CZ	Changzheng, Long March
DFH	Dong Fang Hong
ESA	European Space Agency
FAST	Five-Hundred Metre Aperture Spherical Radio Telescope
FY	Fengyun
FYESM	Fengyun Meteorological Satellites in Disaster Prevention and Mitigation
GEO	Geostationary Orbit
GNSS	Global Navigation Satellite System
HKATG	Hong Kong Aerospace Technology Group
IAA	International Academy of Astronautics
IGSO	Inclined Geosynchronous Orbit
ISRO	Indian Space Research Organisation
JSLC	Jiuquan Satellite Launch Centre
LDSE	International Conference on Lunar and Deep-Space Exploration
LEO	low Earth orbit
LEOP	launch and early orbit phase
LND	Lunar Lander Dosimetry and Neutron
LOX	liquid oxygen
LRO	Lunar Reconnaissance Orbiter
NSSC	National Space Science Center
P/L	payload
PSN	Pasifik Satelit Nusantara
QUESS	Quantum Experiments at Space Scale
RLV	reusable launch vehicle
Roscosmos	Russia's State Space Corporation

SAR	Synthetic-Aperture Radar
SAST	Shanghai Academy of Spaceflight Technology
SASTIND	State Administration of Science, Technology and Industry for National Defense
SCO	Space Climate Observatory
SHAO	Shanghai Astronomical Observatory
SJTU	Shanghai Jiao Tong University
SKA	Square Kilometre Array
SMILE	Solar wind Magnetosphere Ionosphere Link Explorer
SNT	Indonesia PT. Satelit Nusantara Tiga
SSO	Sun-Synchronous Orbit
SUPARCO	Space and Upper Atmosphere Research Commission
TG	Tiangong
TQ	Tianque
TT&C	Space Telemetry, Tracking and Command Station
TZ	Tianzhou
UKSA	United Kingdom Space Agency
UN	United Nations
UNOOSA	UN Office for Outer Space Affairs
UTC	Coordinated Universal Time
UVI	Ultra-Violet Imager
VC	Venture Capital
VTVL	vertical takeoff, vertical landing
WMO	World Meteorological Organisation
YW	Yuanwang
ZQ	Zhuque

Imprint

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Chang'e 4 – Behind the Moon (part 3)

Operations of lunar days 7 to 10 on the far side of the Moon

by Jacqueline Myrrhe

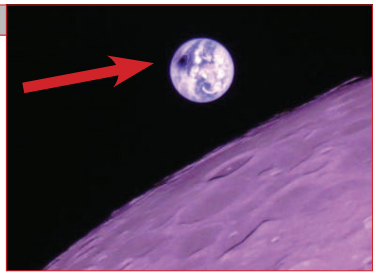
7th lunar day - from approx. 26 June to 09 July

3 July - Longjiang 2 photographs the solar eclipse

The Longjiang 2 (DSLWP-B - **D**iscovering the **S**ky at **L**ongest **W**avelengths **P**athfinder-B) microsatellite, built by the Harbin Institute of Technology (HIT) and launched together with Queqiao on 21 May 2018, photographed from lunar orbit a solar eclipse taking place in the early hours of the 3 July (around 19:00 UTC on 2 July 2019). On Earth, the eclipse was visible from the Southern Pacific Ocean, starting East of New Zealand to the Coquimbo Region in Chile and Argentina.

Wei Mingchuan from the HIT planned the commands for taking the photos with the student-built on-board mini CMOS camera. The German amateur radio astronomer Reinhard Kühn uploaded the commands to the spacecraft and the data were received by the team from the Dwingeloo Telescope in The Netherlands, led by Tammo Jan Dijkema. The radio amateurs could receive 4 photos of the eclipse and many more throughout the mission.

During the 7th lunar day, all scientific instruments worked well. By the end of the day, the 6th batch of scientific data with a total volume of 1.2 GB consisting of a total of 531 data files was sent to the Chang'e 4 (CE-4) science team for further processing and analysis.



The Moon's shadow on Earth (pointed) as seen with the Inory Eye camera on board the Longjiang 2 microsatellite during the total solar eclipse on 3 July 2019. Credit: Wei Mingchuan (Harbin Institute of Technology, BG2BHC/BY2HIT), CAMRAS Dwingeloo Radio Telescope, Reinhard Kühn DK5LA.

Gallery of photos taken with the Inory Eye camera on Longjiang 2 (DSLWP-B)

NASA's LROC team: Longjiang 2 Impact Site Found!

The full story on the localisation of the impact site

7th lunar night - from approx. 10 July to 24 July

Both the CE-4 lander and the Yutu 2 rover (YT-2) switched to dormant mode for the 7th lunar night in the morning of the 9 July (BJT) - CE-4 at 9:00 BJT and YT-2 at 9:10 BJT. Yutu 2 remained stationary from 9-25 July.

22-24 July – 4th LDSE

The 4th International Conference on Lunar and Deep-Space Exploration (LDSE) was held at the Zhuhai International Convention and Exhibition Centre from 22-24 July, discussing the latest results from China's lunar exploration programme, including the achievements of the Chang'e 4 mission. *See for more details: Quarterly Report on page 5*

8th lunar day - from approx. 25 July to 07 August

YT-2 was woken up at 3:59 BJT on 26 July and the CE-4 lander at 19:12 BJT the same day.

During the 8th lunar day, the scientific instruments on the lander and rover operated nominal. YT-2 lunar rover had accumulated 271 m of traversing the lunar surface.

At the end of the day, mission control released the 7th batch of scientific exploration data, sending it early August to the science team for analysis.

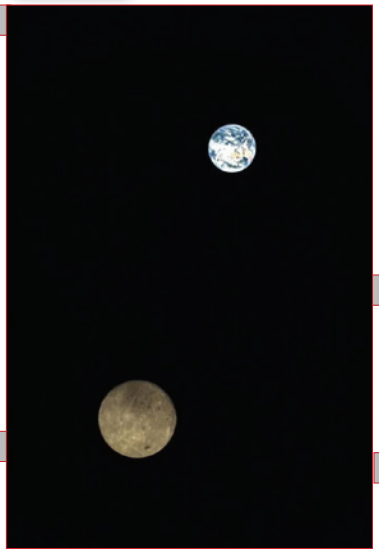
31 July - Longjiang 2

The Longjiang 2 micro satellite (DSLWP-B) was guided for a crash landing in a predetermined area on the far side of the Moon at 14:20 UTC (22:20 BJT) on 31 July.

Amateur Radio operator Daniel Estévez from Spain made a calculation in August to predict the impact site of Longjiang 2 somewhere within the Van Gent crater (16.69°N, 159.52°E). On his website, Daniel explains the efforts done by him together with other space enthusiasts from all over the world: "Wei Mingchuan BG2BHC from Harbin Institute of Technology was the first to take the orbital information from the Chinese Deep-Space Network, perform orbit propagation and compute the crash location assuming a spherical Moon, thus obtaining an approximate position in the Van Gent X crater. Cees Bassa from ASTRON refined Wei's calculations by including a digital elevation model. Phil Stooke from Western University first suggested to use a digital elevation model, helped us contact the LROC (Lunar Reconnaissance Orbiter Camera) team, and filled in an observation request for the camera. And of course, the LROC team and the Chinese DSN, since the quality of their ephemeris for DSLWP-B allowed us to make a rather precise estimate."

NASA's LROC team used these coordinates to image the area on 5 October 2019 from an altitude of 122 km (M1324916226L). Through a careful comparison of pre-existing NAC (Narrow Angle Camera) images, the LROC team was able to locate a new impact crater (16.6956°N, 159.5170°E, ±10 m), at a distance of only 328 m from the estimated site! The crater is 4 m x 5 m in diameter, with the long axis oriented southwest to northeast.

Longjiang 2 was operational for 437 days, exceeding its designed one year-lifespan. The overall mass was 47 kg, the size 50 x 50 x 40 cm. The microsatellite carried a low-frequency radio detector, developed by the National Space Science Centre of the Chinese Academy of Sciences, for radio astronomical observation and studying solar radiation. Longjiang 2 also hosted the optical high-definition camera built by the King Abdulaziz City for Science and Technology of Saudi Arabia (KACST). The camera had captured 30 high-definition images of the Moon. Last but not least, DSLWP-B's payloads which achieved remarkable outreach effect, were the radio amateur payload and a student-built camera, baptised by the HIT students the Inory Eye camera.



A single frame of the Earth and the Moon taken by the surveillance camera of Queqiao. (Credit: WeChat account of CLEP)

A routine day on the far side of the Moon

One full lunar day equals roughly 29 Earth days with approximately 2 weeks of daylight and 2 weeks of lunar night. During standard operations, Yutu 2 would wake up ~ 24 hour after sunrise. Usually the rover would work for 3 days before going into a 6 day hibernation during the hot hours of lunar noon. After that, the rover would be operational for another 3 days before switching to safe mode roughly 24 hour ahead of the lunar night. During the two weeks of the lunar night, lander and rover are in stand-by mode.

8th lunar night - from approximately 8 to 22 August

YT-2 entered sleeping mode for the 8th lunar night at around 17:50 BJT on 07 August. The lander entered dormant mode at 17:00 BJT after receiving signals from ground control.

Yutu 2 was stationary between 7-23 August.

9th lunar day - from ca. 23 August to 5 September

The CE-4 lander woke up on 25 August at 8:10 BJT. YT-2 already awoke at 8:42 BJT on 24 August. Rover and lander switched on the scientific payloads and continued with operations for the 9th lunar day. The scientific instruments on the lander and rover worked well. YT-2 had been busy investigating several locations. At the end of the 9th lunar day, Yutu 2 lunar rover had accumulated a driven distance of 284.66 m.

By the end of the day, a new and in the meanwhile 8th batch of 2.9 GB science data with a total of 380 data files was sent for further analysis to the research team.

During the noon of the 9th lunar day, a science team member discovered on a photo already taken by YT-2's main camera during the 8th lunar day, an unidentified, shiny substance in an impact crater close-by. The science team associated the material to a "gel-like" matter. Because of this finding, the initial driving route for the afternoon was put on hold and the ground controllers designed a new route for the rover to the West of

the landing site to allow for scientific detection of the depth of the impact crater and the distribution of the ejecta. Both the material and the crater itself were examined with the rover's Visible and Near-Infrared Spectrometer (VNIS) instrument.

9th lunar night - from approx. 7 to 21 September

Both the CE-4 lander and the YT-2 rover switched to dormant mode for the 9th lunar night on 6 September. The lander switched off at 5:50 BJT and YT-2 at 4:12 BJT. During the following days, the science team processed and analysed the downloaded data.

17 September – awards for leading lunar scientists

On 17 September, President Xi Jinping signed a Presidential Decree to award the Academician Sun Jiadong the "Order of the Republic" and Academician Ye Peijian the national honorary title of "People's Scientist".

10th lunar day – approx. 22 September to 6 October

The CE-4 lander woke up at 20:26 BJT on 23 September, and the rover awoke one day earlier at 20:30 BJT on 22 September. Both are in normal working condition, according to the Lunar Exploration and Space Programme Centre of the China National Space Administration.

During the 10th lunar day, the YT-2 moved according to the plan 5.1 m, and had accumulated a total route of 289.769 m.

The science team was processing and analysing the 9th batch of data obtained by the different scientific payloads, and carried out in-depth research based on the already gained scientific research results.

10th lunar night – from approx. 7 to 20 October

CE-4 lander and YT-2 rover switched to dormant mode on 5 October – the lander at 19:30 BJT and the rover at 15:43 h BJT.

to be continued in the next issue of GoTaikonauts!

Already on 14 June 2018, China and Saudi Arabia released photos taken by Longjiang 2's high-resolution optical camera, developed by the King Abdulaziz City for Science and Technology of Saudi Arabia (KACST). This view shows the Moon and the Earth. Credit: CNSA / KACST

The tiny white dots are the shiny substance, found on photos by Yutu 2. Credit: CLEP

Ye Peijian was the Chief Designer and Chief Commander of Chang'e 1, the Chief Scientist of Chang'e 3, the Chief Commander of Chang'e 2, Chang'e 4, and Chang'e 5-Test Mission, and is the Chief Designer's consultant. He has played an important role in technical research, large-scale test planning and verification, and Chang'e 4's first soft landing on the far side of the Moon. Credit: ChinaNews

The 2019 Physics World Special Report on China - Exploring the far side

In the 5th and latest Physics World special report on China - following previous reports in 2011, 2016, 2017 and 2018 - the magazine takes an in-depth look at China's Chang'e 4 mission to the far side. Ling Xin examines the consequences for our understanding of Earth's nearest neighbour.

Deep-Space Network for Chang'e 4

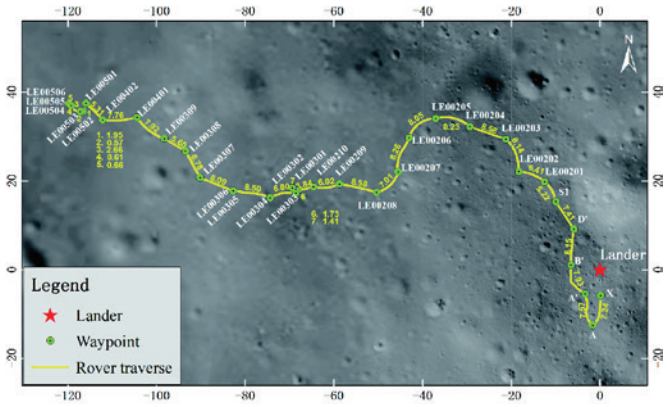
The new ground station in the Argentinian Province Neuquén of Patagonia, opened in October 2017, played a crucial role in the CE-4 mission. For the Chang'e 3 mission, operations for only 14 h a day were possible because just the antennas on Chinese territory in Jiamusi and Kashgar were available. For CE-4, the Argentinian dish allowed for seamless operations during the full length of the lunar day: 10 terrestrial days, all around the clock.

© Casa Rosada (Argentina Presidency of the Nation), CC BY 2.5 ar

Sun Jiadong is one of the pioneers of China's early satellite programme and deep-space exploration technology. He was the Head of the overall design team of the Dongfanghong 1 satellite. After that, he led the development of 34 satellites and served within CACS as the Chief Designer for the 1st phase of China's lunar exploration project. Credit: ChinaDaily

Chang'e 4 main payloads on the lander:

- Landing Camera - LCAM (FOV 45.4 degree, resolution 1024 x 1024 pixel)
- Panoramic Camera - PCAM
- Terrain Camera - TCAM
- Low Frequency Spectrometer - LFS (complemented by the Netherlands-China Low-Frequency Explorer (NCLE) on the Queqiao relay satellite
- Lunar Lander Neutrons and Dosimetry - LND, which was provided by University of Kiel, Germany),
- additionally: small ecosystem containing cottonseed, potato, rapeseed, Arabidopsis thaliana along with yeast and fruit fly eggs, to test photosynthesis and respiration in the 1/6 Earth gravity of the lunar environment. Designed and developed by a team from 28 Chinese universities.



payloads on the rover:

- Three pairs of stereo cameras: navigation camera NAVCAM, panoramic camera PANCAM, and hazard avoidance camera HAZCAM (NAVCAM and PANCAM are mounted on the same camera rack of the rover mast, while HAZCAM is fixed on the lower front of the rover body.)
- Topography camera and geology sensors
- Infrared Imaging Spectrometer
- Lunar Penetrating Radar - LPR
- Visible and Near-Infrared Imaging Spectrometer - VNIS
- Advanced Small Analyzer for Neutrals - ASAN contributed by Sweden

After announcing flight opportunities in April 2015, CNSA received 20 proposals from 10 countries for international payloads. Finally, four from Germany, Sweden, Netherlands, Saudi Arabia were selected to be integrated on the Chang'e 4 lander, rover, relay satellite and the Longjiang 2 microsatellite. China also intends to form an international team for science data research. CNSA set-up a website for access to the data from national payloads: http://moon.bao.ac.cn/

For tracking and data relay, the Argentinian Deep-Space Station and ESA's Deep-Space Network antennas are used.

left graphic: The yellow line traces Yutu 2 surface movements during the first five lunar days derived from cross-site visual localization (unit: m).
In a paper for the journal SCIENCE CHINA Information Sciences, Chinese scientists describe how they calculated the exact route of Yutu 2.
Liu, Z., Di, K., Li, J. et al. Landing site topographic mapping and rover localization for Chang'e-4 mission. Sci. China Inf. Sci. 63, 4, 140901 (2020). https://doi.org/10.1007/s11432-019-2796-1

"On the far side of the Moon, the Chinese did a good job."

Highlights from the Chang'e 4 Press Conference

On 14 January 2019, the State Council Information Office (SCIO) hold a press conference in Beijing to inform about Chang'e 4's landing on the far side of the Moon.

The questions by the journalists were answered by:

Wu Yanhua, Deputy Director of the China National Space Administration CNSA and Deputy Chief Commander of the Lunar Exploration Project CLEP
Li Guoping, Secretary General and Press Spokesperson of the China National Space Administration CNSA
Wu Weiren, CLEP Chief Designer
Sun Zezhou, Chang'e 4 Chief Designer

We are recalling some of the most interesting topics discussed during the event.

Li Guoping. Credit: CNSA/SCIO

Sun Zezhou. Credit: CNSA/SCIO

Wu Weiren. Credit: CNSA/SCIO

Wu Yanhua. Credit: CNSA/SCIO

China-Russia lunar cooperation

The representative of the **Russian International News Agency** wanted to know which projects are included into the Sino-Russian Space Cooperation Programme 2018-2022.

Li Guoping replied that Russia is one of China's important partners in the field of space. Under the mechanism of the Regular Meetings between the Chinese and the Russian Prime Minister, a special Russian-Chinese Sub-Commission for Cooperation in Space Exploration meets annually. The outcomes of this meetings will be integrated into the Space Cooperation Programme. Projects regarding lunar and deep-space exploration, Earth observation, satellite communications and space debris are envisaged. For lunar and deep-space cooperation the Moon and Deep-Space Exploration Working Group was established under the sub-committee. This working group defined a joint science plan for China's Lunar South Pole mission and Russia's Luna 26 (Luna-Resurs 1) mission. Currently, a detailed follow-up plan is worked out.

NOTE: As part of the 24th Meeting of the Russian and Chinese Head of Governments, Roscosmos Director General Dmitry Rogozin and the Head of China National Space Administration Zhang Kejian signed on 17 September 2019 in Saint Petersburg two agreements. One agreement aims at the establishment of a joint Data Centre for Lunar and Deep-Space Research with two physical locations in Russia and China.
The second document is about the coordination of the Russian Luna Resurs 1 (Luna 26) orbiter mission with the Chinese Chang'e 7 Moon polar research mission through the provision of instruments on each other's mission and by conducting joint space experiments. Luna 26 will probe the Moon's surface for a suitable landing site of CE-7. Apart from that, data transmission tests will be performed between Luna Resurs 1 and Chang'e 7.

How much does Chang'e 4 cost?

The correspondent of **Reuters** asked what the total cost of the Chang'e 4 mission is?

Wu Yanhua responded by saying that the costs for CE-4 are equivalent to building 1 km of subway in China.

NOTE: The cost-per-km of subway in China varies from 500 million RMB (about 72.6 million USD) to 1.2 billion RMB (about 172.4 million USD), based on the difficulty of construction.

Reddish images from the Far Side

The reporter from **CGTN** was wondering why the first images transmitted by CE-4 were reddish?

Sun Zezhou explained that the cameras have a higher colour saturation in the red channel. In order to have the first images quickly, the photos from the release mechanism and the transfer mechanism were unprocessed. It was important to see as quick as possible how the landscape around the lander looks like and to judge whether there are obstacles along the path the rover would drive on once it is unlocked from the lander and would roll down the ramp.

There are more than a dozen of different types of cameras mounted on CE-4.

NOTE: The surveillance camera for monitoring the release process of the rover had black/white and full-colour capacity. The navigation camera operates in full colour to obtain images of the landscape around the rover and has stereoscopic capabilities for three-dimensional imaging of the ground to feed the data back to the processor for path planning. The panoramic imaging, the topographical camera and the obstacle-avoidance camera on the rover also operate in colour mode.

U.S.-China lunar cooperation

The representative of **Global Times** had an interest in U.S.-China lunar cooperation. What is the situation on this?

Wu Yanhua told him that during the IAC2018 in Bremen, Germany, the Directors of NASA and CNSA held talks, hoping to explore more areas of cooperation, especially in the field of deep-space exploration. They discussed to use NASA's Lunar Reconnaissance Orbiter LRO to observe the lunar dust released during the CE-4 landing impact. After the IAC, the scientists from both sides kept in close contact through video conferencing. NASA gave CNSA the relevant information on LRO. The Chinese side provided the coordinates of CE-4's landing site. Due to the NASA and Government Shutdown in January 2019, NASA could not provide the necessary resources to manoeuvre LRO into the right position for monitoring the landing. Later, when the LRO passed the site, images were taken.

The next lunar missions

The journalist from the **China Review Society** asked what the plans for the next lunar missions and for a manned lunar landing are.

Wu Yanhua referred to the plans for the upcoming lunar missions CE-5, CE-6, CE-7 and CE-8 (compare GoTaikonauts! 27, p. 4). Those are the governmentally approved missions within the development plan 2030. With respect to a human lunar landing, he said, that there are scientists tasked to study such a scenario. But these are studies and there is nothing in the decision-making process.

Lunar Research Station

The representative of the **21st Century Business Herald** put forward the question about the cost of a research station on the Moon and how far China's plans for such a lunar habitat are evolved.

Wu Yanhua explained that a lunar research base is currently under discussion. So far, these ideas are conceptual blueprints with no specific plans. Not only China but also other countries have put forward relevant concepts. Such increased number of future lunar missions would mean it is advisable to have an infrastructure there to support routine exploration. This infrastructure should preferably be an international effort which would be welcomed by China.

Wu Weiren added that it makes sense to take advantage of the high number of days with sun illumination at the lunar South Pole. It would be advantageous to set-up a research station there.

Regarding the costs, the work could be done in steps, by applying modular construction. Also, international cooperation can help to share the costs.

Private Companies on the Moon?

The reporter from **Xinhua News Agency** asked whether the success of the CE-4 mission has any impact on China's commercial aerospace industry.

Wu Yanhua stressed that China's lunar and deep-space exploration is mainly a governmental activity. It is dedicated to scientific tasks and is done in the interest of the public.

There are however, some aspects of relevance for the commercial sector: 1. In general, the success of such firsts in space, no matter whether these achievements are domestic or foreign, institutional or private, they increase the awareness and enthusiasm about space, not only in the public but also among owners of private capital. The Chinese government has created a favourable policy environment for private space activities. In many fields social capital, including the participation of international capital, is welcome. 2. Lunar exploration is driven by high-tech and hardware developed in high-end industry. This high-technology can serve the people in many aspects. Private capital is welcome to transfer those technologies to develop numerous applications. 3. The United States and Luxembourg have laws in place to encourage private companies to explore the Moon and even mine the Moon. The Chinese government should also open its minds to explore the Moon, including Mars and deep-space resources. These can be best done by the involvement of private capital.

Why landing on the Far Side?

The **Zhejiang Daily** reporter asked why it was decided to land on the far side of the Moon?

One of the considerations was a scientific one, explained **Wu Yanhua**. The far side of the Moon, especially the CE-4 landing zone is one of the oldest crater. Its geological structure and composition of minerals might be more representative for the age of the Moon. On the other hand, the far side is a naturally radio-shielded location, favourable for low-frequency radio astronomical observations. From the engineering point of view, humans have been exploring the Moon for decades and have been more focussed on the near side. There is the hope to reach one day all regions of the Moon. The planned landing at the polar region is one step in that direction.

Wu Weiren noted that with the landing on the far side, China has caught up with the international level of space exploration and added: "On the far side of the Moon, the Chinese did a good job."

Congratulations

NASA Administrator **Jim Bridenstine** via Twitter: "Congratulations to China's Chang'e-4 team for what appears to be a successful landing on the far side of the Moon. This is a first for humanity and an impressive accomplishment!"

Dmitry Rogozin, Head of the Russian state space corporation Roscosmos:

"On behalf of Roscosmos State Corporation and on my own behalf, I want to congratulate you and the entire team of the China National Space Administration (CNSA) on the successful launch of the Chang'e 4 mission - the first soft landing on the far side of the Moon in the history of mankind." He noted that Russia and China cooperate fruitfully in the field of space activities. "We are pleased that the energy of the Chang'e 4 mission is provided through radioisotope sources, produced in Russia," he said. "I am confident that in the future we will have many more opportunities for effective cooperation for the benefit of our countries."

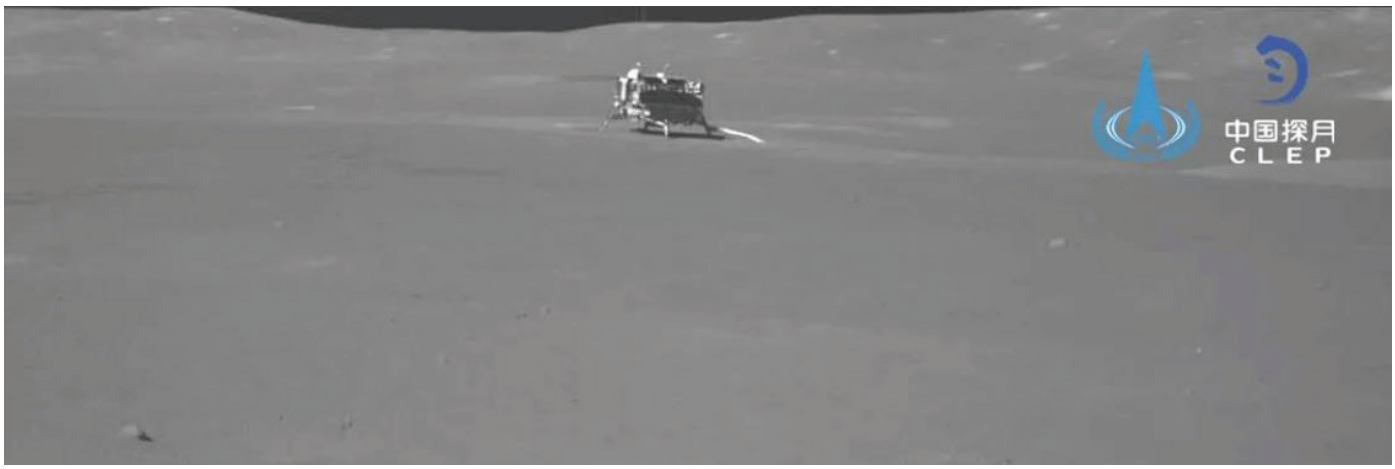
Charles Bolden, astronaut and former NASA administrator: "China should feel very proud of having accomplished this. Anytime you can do something that has not been done before, it's a reason for excitement and celebration."

Simonetta Di Pippo, the Director of the United Nations Office for Outer Space Affairs, said: "The Chang'e 4 mission marks an incredible milestone in the history of space exploration. This is not only a great success for China, but also a major step for the international space community."

Netizens

Along with saying "hi" to Yutu-2, many netizens wish the rover a more stable and safe journey on the Moon. "Little bunny, take it slow. Don't fall in that crater," said Weibo user "Small island Ye".

"Rabbit, you have a house guest," writes "CoderLiu666" on Weibo. "Your brother is here. Although he is on the far side, you are not lonely anymore."



Wuhan - Space City

China's Commercial Space Cluster in the Central Region

by Blaine Curcio (Orbital Gateway Consulting)

Panorama view from the Yellow Crane Pagoda in Wuhan. The town is considered to be a 3D traffic hub: roads, rails, rivers, airport. Since recent, space can be added.

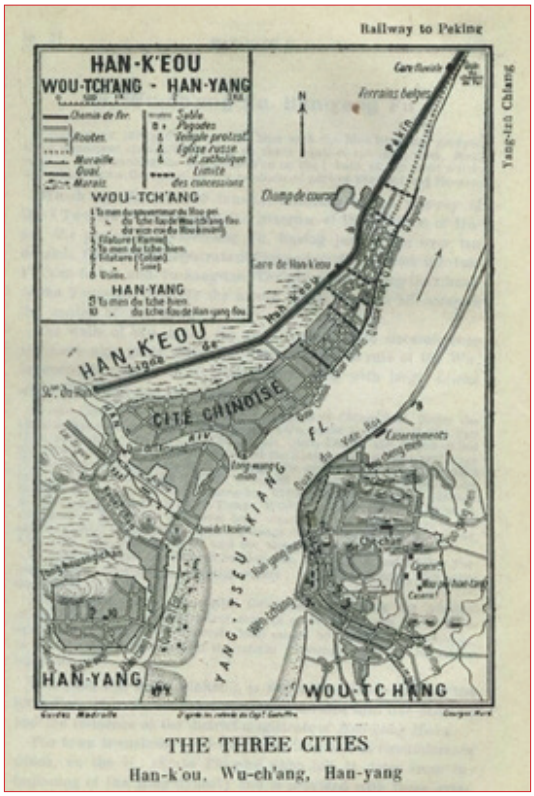
When one reads about an event in the Chinese space industry, the chances are fairly good that the event is taking place in Beijing, or is involving a company that is headquartered in Beijing. Indeed, unlike the US or Europe, both of which have somewhat spread out space industries, the Chinese space industry is very concentrated on Beijing, with this being the center of government, and thus implicitly the center of most of the largest SOEs (state-owned enterprise). However, a handful of other cities in China have smaller clusters of space companies, many of which have seen significant growth since the opening of the industry to more commercialization around 2014.

While I am far from an expert on any of these cities (except Shenzhen), I have traveled to many of them, several of them multiple times, and often for space-related activities. Combined with a variety of consulting and research work with Chinese companies, these experiences have given me perspective of how these different cities fit into the broader Chinese space industry and economy as a whole. That being said, I welcome you to the first article in the "Emerging Chinese Space Cities"-Series, a profile on the space industry of the city of Wuhan.

General Background

Wuhan is the capital of Hubei Province, and is located roughly in the geographic center of the Eastern half of China in which >90% of the country's population live. A city of around 11 million and known as the "thoroughfare of China" due to its highly centralized location, Wuhan is sometimes likened to my hometown of Chicago, insofar as both cities are major rail hubs at the center of a large country. Prior to 2020, most people in the West had likely not heard of Wuhan, but of course the city has since become extremely well-known for the most tragic of reasons, that being its location as the first major epicenter of the 2019-2020 Novel Coronavirus Outbreak. The city has since made an admirable recovery, and indeed, its space industry has been extremely visible during the outbreak in very positive and innovative ways, as we will discuss below.

Despite having only recently become very famous in the west, Wuhan has been a major city in China for millennia. The city is famous for, among many other things, its ré gān miàn, or hot dry noodles, and its cherry blossoms, which locals will say may rival the beauty of Japan's. Wuhan has some of the most interesting early 20th-century western architecture in China, with former foreign concessions hiding such gems as a Bank of New York Mellon building from the early 1900s. Known as one of China's Three Furnaces (along with Nanjing and Chongqing), Wuhan is also very, very hot in the summer, which combined with the humidity make furnace a very appropriate name indeed.

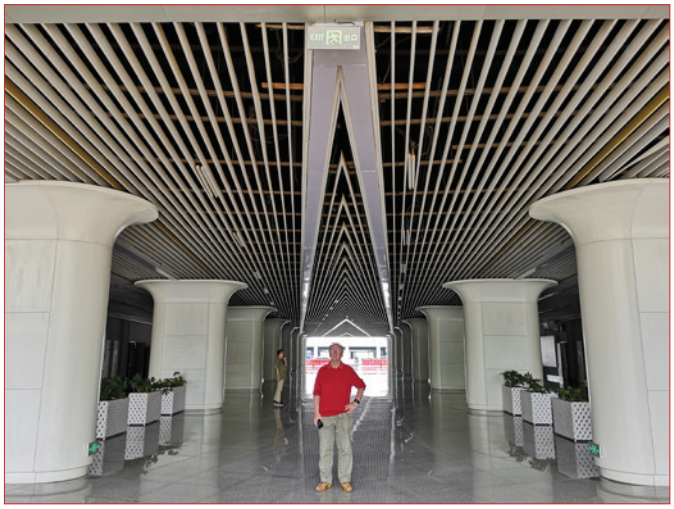


Map of "The Three Cities" from 1912. University of Texas Archives

Located at the confluence of the Han and Yangtze Rivers, Wuhan today is in fact the combination of what was formerly three separate cities, namely Wuchang, Hankou, and Hanyang (武昌，汉口，汉阳). As a result, modern-day Wuhan is a sprawling city spread over almost 10,000 km^2, which is to say, it may take 1.5 hours to drive from a major train station to the hotel or airport, depending on traffic and where one's hotel is.

Wuhan's size makes it a ripe target for China's urban infrastructure development. Enormous highway interchanges dot the cityscape, and new metro lines have been springing up at an impressive clip. For example - during my second time to Wuhan in September 2018, I was attending a dinner with several Chinese launcher companies, some several km from the conference hotel and convention center. After dinner, my Chinese hosts were planning to go on for karaoke, and having already had my fill of báijiǔ (a Chinese liquor fermented from sorghum that is ~50-60% alcohol by volume) and dinner, I elected to call it a night instead and go back to the hotel. Wuhan in late September is quite nice, with evening temperatures of around 15-20 Celsius. The weather, the báijiǔ, and the ubiquity of absurdly cheap shared bicycles was a match made in heaven, and so I decided I would bicycle back to the hotel using Baidu maps as a guide. Easy enough! I started riding down the street, with relatively few cars and an open road. Except, after 10 minutes or so, the road ended. Because, it was still being built. Scanning Baidu Maps for alternatives, and peering ahead into the darkness to see how impassable the construction site was, I eventually gave up, found a safe place on the sidewalk for the bike, and called a cab. Lesson? Wuhan is a nice city, but in late 2018, it was still under construction.

My third trip to Wuhan, in March 2019, I was staying in a different part of the city, in the heart of the Optics Valley, a government-designated zone for companies doing technology related to optical lenses/optics. In the 7 months since my second visit, Line 2 of the metro had been extended to now reach the area of my hotel. Incredibly, since my aforementioned 2nd visit in September 2018, Wuhan has opened 61 new metro stations, according to the Wikipedia page for Wuhan metro.



Wuhan's metro stations are new, clean and chic, like this one: Wuhan Expo.

All of this is to say, Wuhan is above all a city that has experienced enormous development over the past several years, and will continue to develop over the coming several years, even despite the significant setback of the coronavirus in 2019-2020. The city's importance to the Chinese government from a strategic perspective as the sort of "largest city in Central China" (a region that could, depending on definition, encompass several hundred million people), its several excellent universities, and its fairly large broader economy will mean that Wuhan will consistently remain among China's top 10 cities in terms of overall size/development. It is with this backdrop that we can dive into Wuhan's space industry, past, present, and future.

The Core of the Space Industry at the Han and Yangtze

Wuhan's inland location, as well as its location on two major rivers, make it an ideal location for manufacturing large, complex things that require delicate shipping, usually by boat. This would include missiles and rockets. Historically, the company in China most commonly associated with missiles is CASIC. CASIC is one of the world's largest companies, ranked #322 on the Fortune Global 500, and #80 in China, with total revenues of nearly $38B in 2019, and with more than 150,000 employees across more than a dozen subsidiaries. Apparently, China and its allies buy many rockets.

Former Logo of the Sanjiang Group

One of CASIC's largest subsidiaries is the Sanjiang Group, also known as the Fourth Academy of CASIC. Prior to 2011, Sanjiang was two separate entities, namely the aforementioned Fourth Academy of CASIC, and the Ninth Academy of CASIC. Before that, Sanjiang was known as Base 66. Originally created in 1969, Base 66 was a missile base located in a remote mountainous area of Hubei Province. One of the most influential figures in the early days of Base 66 was Wang Zhenhua, a Chinese rocket scientist who was educated at the Moscow Aerospace Academy from 1956 to 1962. Notably, Wang was present in the Soviet Union during the launch of Sputnik, and indeed during what could be considered a golden era in Soviet space development.

The former Yuan'an site of Base 66 operations was converted into a museum/park dedicated to Base 66.

In 1993, Base 66 was moved to Wuhan and renamed Sanjiang Aerospace Group, aka the Ninth Academy of CASIC. Today, Sanjiang and its subsidiaries are essentially the core of the space industry in Wuhan, with the company having the resources, including political, financial and technological, to "make things happen" in space in Wuhan.

Wuhan's high-speed train station is fancy and big. Credit: GoTaikonauts!

Today, Sanjiang has a diversified business that is primarily not rocket-related. Tellingly, Sanjiang's website lists commercial space as the first of its four key verticals (along with liquified natural gas (LNG) extraction and transportation chain, heavy machinery and trucks for mining, and lasers for precision cutting and welding). Within the commercial space vertical, Sanjiang's activities include the Kuaizhou rocket (manufactured by subsidiary Expace), satellite payload and platform development, and space-based IoT systems.

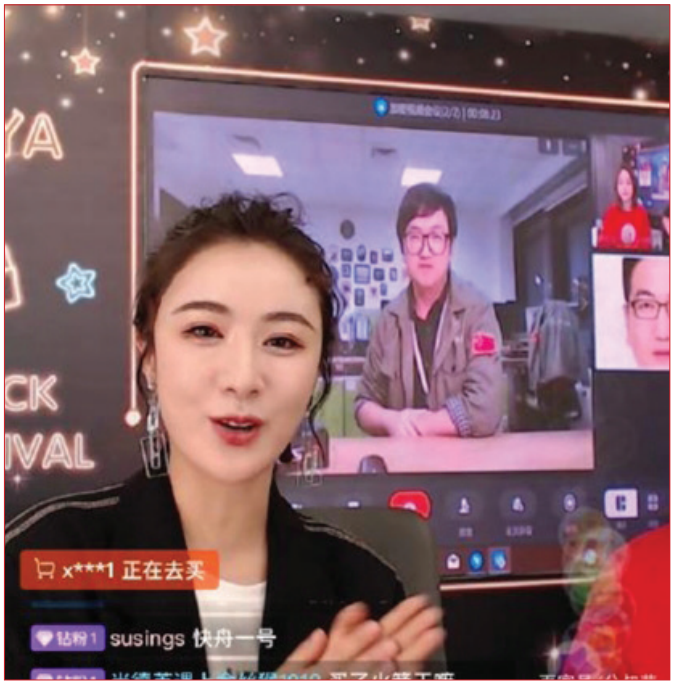
The other CASIC subsidiary in Wuhan that is not directly a subsidiary of Sanjiang is the Space Development Research Company (航天科工空间发展有限公司), a satellite manufacturer founded in 2017.

Sanjiang's Subsidiaries - Wuhan's Fast-Rising Stars

Sanjiang has several space-related subsidiaries headquartered in Wuhan. Likely the most famous to now is Expace, China's most advanced "commercial" launch company. Expace is a "nominally commercial SOE", which is to say that most of its shares are owned directly by SOEs or the government, but it still has a mandate to make money, and thus function as a commercial company. In the case of Expace, its shareholding is indeed quite SOE-centric, with Sanjiang Group owning nearly 70% of the company's shares, and with several local Hubei Province hi-tech funds with varying relation to CASIC owning an additional 10-15%. As a result, Expace has benefited from the "best of both worlds", insofar as having access to technological, financial, and regulatory benefits that only SOEs have, while also having some freedom to do unconventional things.

An example of each: Expace was the first commercial company to achieve access to China's launch sites - a notoriously tricky proposition given the fact that the launch sites are controlled by the PLA. Expace also has access to significant funding, with the company having closed a RMB 1.2B (US$180M) round of funding at the end of 2017, at a time when the next-largest funding round for a private launch company in China was a RMB ~200M round by OneSpace (LandSpace since completed a RMB 500M round….still only 40% the size of Expace's).
On the other hand, Expace has been far nimbler and more creative than many SOEs in China. The company achieved a

huge public relations coup on April Fool's Day 2020, when they live-streamed the auction of a Kuaizhou-1A rocket. Not only did the rocket sell to Charming Globe for US$5.6M, but perhaps more importantly, the live stream was viewed by several million people live. And, it was searched by more than 500 million people in the 48 hours thereafter. Overnight, Expace became perhaps the most famous space company in China, and indeed, briefly probably the most famous Chinese space company in the world.



Charming Globe adding 1x Kuaizhou-1A to their shopping cart in front of a few million netizens. The whole publicity stunt was made in Wuhan! Credit: Expace

While Expace has likely become the most famous Sanjiang subsidiary in Wuhan, that is not to say that they are the only one - far from it! Sanjiang's aforementioned space-based IoT systems business line is represented by another Wuhan-based company, LeoBit Technologies, also known as Xingyun, a narrowband IoT constellation. LeoBit has a similar ownership structure to Expace, with 1/3 owned by Sanjiang, 1/6 owned by Expace (which as mentioned above is itself mostly owned by Sanjiang), and an additional ~40% owned by local government funds, and around 10% owned by national government funds.

LeoBit's Xingyun project aims to launch 80 satellites to low Earth orbit (LEO) to provide global IoT services using narrowband (most probably L-band). The company is one of CASIC's "Five Clouds" projects, which also includes the larger, Beijing-based Hongyun constellation. LeoBit recently collaborated with Expace to conduct a heartwarming rocket launch that saw a rocket commemorating the people of Wuhan, with the rocket manufactured by Expace, launching two Xingyun satellites manufactured by LeoBit, with one of the satellites named Wuhan. The two local companies conducted the launch on 12 May 2020, some few weeks after their city emerged from complete lockdown, a clear indication of the resilience of the companies and the industry more broadly, not to mention the city and people of Wuhan.

Overall, Sanjiang and its family of subsidiaries and related companies have formed the core of the Wuhan space industry for years (and in the case of Sanjiang, decades). Their efforts towards commercial space have more recently led to the construction of the Wuhan Aerospace Industrial Base, a huge project involving facilities for manufacturing up to 20 rockets and 120 satellites per year. A recent CGTN video showed the satellite production facility coming back online following the outbreak, and also showed the impressive scale of the project more broadly. Moving forward, the future of the space industry in Wuhan will be closely tied to the activities of CASIC and the Sanjiang Group. With that being said, the city also benefits from some limited private space sector, which often can go unnoticed in the shadow of the giant SOEs.

Link to CGTN video on the Satellite Industrial Park at the Wuhan National Aerospace Industry Base.

Wuhan's Other Space Economy - Private Companies and Universities

Wuhan is home to several downstream Earth observation (EO) data analytics companies, for example Jiahe Info, Baotianqi, and Sunrise. These three companies would use EO data, largely from free satellites such as LandSat, but also in some instances paid satellites, and conduct data analytics on the data for sale to customers in industries such as agriculture, insurance, or finance. Having visited one of the companies, I found that they set up in Wuhan because there are strong universities, especially in geospatial imaging and EO, and that the cost of labor is relatively lower than places like Beijing. Indeed, for an average graduate in Wuhan, a salary of RMB 7,000-10,000 can be quite good when considering that apartments cost ~RMB 20,000-40,000 per square meter. When considering that jobs in Beijing do not pay so much more (perhaps 30-50%), but apartments would cost RMB 50,000-100,000+ per square meter, it can be no wonder that some graduates would choose to come to Wuhan.

Indeed, some of the students would not even choose to come to Wuhan - they would already be there. Various sources have claimed that Wuhan has the most students of any city


Architecture rendering of the Wuhan Satellite Industrial Park. Credit: sasac.gov.cn


Beginning of 2020, the roof of the main building of the Wuhan Satellite Industrial Park was finished after more than 180 days of construction. This milestone achievement marked the 1st phase completion. Covering more than 70,000 m², the park comprises 6 individual buildings. The operation of the park is expected to start in autum 2020. The Wuhan Satellite Industrial Park will become the world's first scientific research base to develop cloud-based micro satellites and a smart satellite production line including research and development, design, assembly, and testing. It is expected that 100 satellites could be produced at the park annually when it opens for operation. Credit: CGTN

in the world, and while I have not been able to independently verify this claim, it seems undeniable that Wuhan has….a lot!...of universities, and thus students. Several of China's top universities, including the Huazhong University of Science and Technology and Wuhan University are located there, along with the Wuhan University of Technology and the Chinese University of Geosciences, Wuhan Branch. The Chinese Academy of Sciences (CAS) also has a large national-level research center in Wuhan, with research focused on optical fiber.

On the whole, while the number of private space companies in Wuhan remains relatively small, the huge budgets of projects being done by companies such as Expace and Xingyun may allow for a more diverse supply chain, and thus more diverse space economy, to form.

Wuhan's Strategic Advantages - A Connector within China, and beyond

Wuhan's space industry, and broader economy as a whole, benefit from several advantages related to connectivity. Due to its location in roughly the geographic center of the highly populated eastern half of China, Wuhan is within ~4 hours high speed rail of most major cities in China, namely Beijing, Shanghai, Guangzhou, etc. Indeed, during a visit to a Wuhan-based EO data services company in March 2019, your correspondent was told that the company seldom traveled for work by airplane - train was more convenient, more consistent, and oftentimes faster. This is especially true because in the case of cities like Beijing or Shanghai, the airports are very far out of the city, while the high-speed rail stations are near the center of the city. For this reason, Wuhan's location at the center of China's huge high-speed rail network is a significant advantage for the city moving forward.

More broadly, Wuhan has a role as a connector between China and the broader Eurasian landmass. Indeed, CASIC's China Commercial Aerospace Forum, held in Wuhan most years in September, is held at the "Eurasia Convention International Hotel", and the city is one of two departing stations for cargo trains going between Europe and China, with trains departing Wuhan bound for Duisburg, Germany having started running again as early as late March. Moving forward, if air travel is more permanently impacted by Covid-19, Wuhan may find its role as a railway hub even more important.

Conclusions - The Takeaways from Wuhan

The city of Wuhan may have hit its short-term peak in media recognition for negative reasons in 2020. However, moving forward, we are likely to hear news from Wuhan about a wide variety of more positive things. Indeed, just weeks before the writing of this article, Chinese Premier Li Keqiang announced that in the future, China will have two cities designated as "World Cities". The first, unsurprisingly, is Beijing. The second, perhaps surprisingly, is Wuhan. In addition, two cities were named Nationwide Economic Centers - Shanghai, and, you guessed it…Wuhan! Two cities were also named as international transportation hubs….Beijing and Wuhan. Finally, two cities named as Global Cities (not the same as World Cities above - first is 世界城市, second is 全球城市) are Shanghai and Shenzhen. Apparently, Wuhan's future will be worldly, it will be economically vibrant, it will involve its role as a transport hub, but it may not be global….whatever that means.

Ultimately, Wuhan is today one of the 5 most important space cities in China, and one of the "second-tier" of cities after the center, Beijing. Next time, we look forward to discussing Harbin, the home of the 2018 China Space Day conference, and most certainly not known to be one of China's three furnaces. Until then, stay safe!

The Yellow Crane pagoda - the historical landmark of Wuhan.
Credit: GoTaikonauts!

Wuhan is famous for its cherry trees. The campus of the university attracts every year crowds of tourists.
Credit: Miao Jian/China Daily

Commemorative Expace rocket with Xingyun satellite named for Wuhan.
Credit: Expace/CASIC

China, sanctions and spaceflight

by Brian Harvey

Christopher Cox is not one of the names that first comes to mind in considering the Chinese space programme, but he is one of the most important personalities to affect its recent trajectory. As a congressman in Washington DC, his 1999 report was probably more influential than any other.[1] The Cox report led to the renewal of severe sanctions on the Chinese space programme, grounded its rocket fleet, isolated China from the developed world and cost it millions of lost revenue. More than 20 years later, those sanctions are still in effect, with no prospect of their lifting. Related measures have kept China out of the International Space Station, obliging China's space programme to be more independent and set its own course apart from the global spaceflight industry. The effects are quite personal, preventing American personnel from even talking to Chinese space officials except in limited circumstances, barring the Chinese from international conferences and prohibiting their setting foot in NASA facilities.

The practical impact of sanctions has been described in existing accounts of the Chinese space programme and it is not the purpose of this analysis to re-rehearse that narrative.[2] Rather, it is to set the broader context of sanctions over the past hundred years and how they have affected the politics of China and its space programme. In doing so, use is made of the scholarship of Shu Guang Zhang, who has provided the most learned examinations of what will be called the sanctions régime.[3]

Contrary to popular impressions, sanctions are neither novel nor specific to China. Sanctions have been in place against China since 1949, remained in place when their operation relaxed in the 1970s and 1980s, but were then re-applied with renewed vigour in 1999. There has been no period without sanctions, only periods of their lesser application. Second, they have not been applied solely to China, being also applied to the Soviet Union and Russia, but with a different timetable. Sanctions against the Soviet Union and Russia were applied from the same year, 1949, to 1995, much less so in the last four post-Soviet years. They were removed, but then applied with new force, not least to the space programme, from 2014. In sum, the application of sanctions has been a normal, conventional, standard instrument of United States and European policy toward China and the Soviet Union and Russia for the most of the period since the second world war and remains so. That this is not part of a popular perception of this relationship is a tribute to the manner in which sanctions have been applied and the lack of media interest.

The idea of sanctions dates back to the 19th century, when they were seen as an attractive alternative to war. High hopes were held by its advocates that the application of sanctions would have severe, immediate, decisive economic effect that would quickly halt aggressors in their tracks. Sanctions were an especially attractive alternative after the military failure of the American, British and French invasion of the Soviet Union in 1919. The then President, Woodrow Wilson, favoured sanctions as tool of foreign policy, with its adoption by the League of Nations as its enforcement method of choice.[4] Sanctions became a popular element in American foreign policy, with no less than 110 sanctions Acts subsequently approved by the congress. The standard model was the Export control Act, 1940, directed against Japan and it was the template for what followed. The model was extended in 1951 with the Battle Act, which not only applied sanctions to the transgressor, but to anyone assisting the transgressor, epitomized by the subsequent, appropriately entitled Trading with the enemy Act. The most relevant current legislation to China is the International Traffic in Arms Regulation (ITAR), 1976.

1949 was the key year, for this saw the introduction of sanctions against both the Soviet Union (and eventually 16 socialist countries) and China. Its principal instrument was actually a committee, the Coordinating Committee for Multilateral Export Controls, COCOM, called in the case of China: ChinaCOM (or ChinCOM) until the two were merged in 1956. COCOM met weekly in Paris and although this was never said, convened in the United States embassy annex, being attended by representatives of every participating state, namely those of the North Atlantic Treaty Organization (NATO). It was informal and kept neither minutes nor records. There was no democratic scrutiny: the British parliament was told that one could not bring to account an organization that had no formal existence in the first place. Unlicensed export was automatically illegal, so COCOM issued licences for exemptions of goods considered for export to the sanctioned countries. Any one country could propose a veto of such licences. In practice, the United States were dominant on the committee and their veto was normally fatal for any proposed exemption. To close off evasion through other countries, COCOM was also applied on an off-the-record basis by neutral, non-NATO members (for example, Ireland's overstaffed embassy in Helsinki ensured the compliance of its exporters). In Europe, COCOM was replaced by the Wassenaar Arrangement (1995), signed in the Netherlands but operated from Vienna, but this was an anti-proliferation instrument. No less than 42 states participated, including Russia and it was primarily directed against proliferation against axis of evil countries (e.g. Iran, Democratic People's Republic of Korea).

The severity and suddenness of the 1949 sanctions took the new Chinese government by surprise. COCOM prohibited the export to the sanctioned countries of ten embargoed categories, for example electrical equipment, rubber, precision instruments, power generators, electronics, transport, petroleum, metalwork and minerals, especially if of value in the atomic, military or industrial fields. This included anything that could be considered 'dual use' i.e. it could be used for civilian and or military purposes, a classification into which space technology fitted quite easily. For example, air traffic control equipment and computers were quickly deemed to be 'dual use'. In the case of aircraft, the problem was not their airframes but their navigational equipment, which under dual-use theory could be adapted for sinister purposes. It is not difficult to see how these broad terms of reference included everything that would be needed for a space programme and how it forced these countries to become self-reliant in space technology. The impact of the sanctions was in practice greater, for China was starting from such a low base, with diesel engines for trucks representing the outer limit of its technology at that time. Zhou Enlai was right when he said, on the occasion of the launch of China's first satellite 50 years ago, 'We did this through our own, unaided efforts'. Although western media criticized China in this period for its isolation and introspectiveness (for example, its television did not cover the American Moon landing), this isolation was an artefact and outcome of western policy.

We know little to nothing of what went on in COCOM, except for some issues that occasionally spilled into the public domain, but compliant western media rarely mentioned the word 'COCOM'. Aviation was one such example, where COCOM became involved in the sale to China of British Viscount aircraft (1962), Comets (1964), 46 Tridents (1965) and 200 Harrier jets

Trident. Credit: GBNZ Chinese Air Force

Zhou Enlai 1959. Credit: Archive author

(1972). American objections in COCOM successfully held up and reduced the Viscount and Trident sales to six; defeated the Comet and Harrier sales, even though Britain argued that Harriers were purely defensive (during its 1983 war with Britain, Argentina might have taken a different view). Faced with American opposition through COCOM, even the British foreign secretary at the time was persuaded that Comets could be 'the sinews of war', which might have surprised its main operators, British European Airways (BEA) and the British Overseas Airways Corporation (BOAC). In reality, these arguments might have had less to do with security and more to do with who sold most in the world aviation market. Further battles were fought over electronics, with leading companies seeking COCOM exemptions: Thompson (France); GEC (Britain); Philips (Netherlands) and Siemens (Germany). Not only did COCOM succeed in directly preventing the transfer of technologies to the Soviet block and China, but had the indirect, intended effect of dissuading almost any high-tech contact. Ironically, one of the six Tridents was set aside for zero-gravity training for China's first group of astronauts.[5]

The sanctions imposed against China (ChinaCOM) were much harsher than those applied against the Soviet Union and its socialist block. In effect, they were a complete blockade, with trade between the US and China falling from $232m a year before the revolution to $0m by 1950. Although this riled the United States, sanctions against China were applied with less severity by the European countries, which the Americans called the 'China differential'. Britain was the principal offender through its colony of Hong Kong, which became one of the world capitals of sanctions-evading smuggling.

Sanctions caused three important consequences for the space programme.

First, sanctions forced China into a mammoth effort to survive, which took the form of a rapid transition to a command economy ('Socialist Reconstruction'), whose legacy is the state-based space companies of today. Without sanctions, a stronger private sector might have persisted in China as it did in some of the socialist block countries (e.g. Poland, where agriculture remained private). ChinaCOM sanctions actually made its economy *more* communist, more state-led.

Second, it prompted an almost immediate Chinese engagement with the Soviet Union, including a 1954 technical accord whereby the USSR supplied R-2 rockets and guidance systems that enabled the start of its space programme and sent hundreds of scientists to work in China. This legacy can still be seen in the space designers, technicians and students who trained in the USSR and even in the architecture of Jiuquan cosmodrome.

Third, during the period when Zhou Enlai was not only prime minister but foreign minister (1949-58), China began a diplomatic offensive with the developing world. The implications of this for the space programme did not become apparent until many years later. Zhou Enlai's initiative was not just about diplomatic recognition and an attempt to cultivate allies in a friendless world, but about building long-term economic relationships. The principles of China's help to the developing world would have been recognized as good practice in the west many years later. Such aid had an emphasis on barter, necessary granted the lack of hard currency on both sides; building key industrial facilities; technical assistance and training; self-determination and independence; unconditionality ('no strings'); financial packages on low or no-interest terms; and high-tech-rich with the provision of the most advanced technology. It was a centralized system considered to have highly efficient delivery. The first candidates for the aid programme were Sri Lanka, Indonesia, Egypt and Cambodia. In a second wave, Zhou Enlai made an African tour to fourteen countries from December 1963 to February 1964, including Algeria, Ethiopia, and Tunisia. The proportion of aid in China's national budget was 3%, at a time when western nations struggled to reach the global target of 0.7% set in 1969. This group of aided countries became important for the space programme in the following century.

Soviet help led Mao Zedong to believe that China could soon launch its own satellites and his 1958 announcement that 'We too must build artificial satellites' was noticed in Washington DC. Bad enough that the Russians were already beating them in the space race but for the Americans the humiliating prospect that China might do so too caused alarm.[6] The principal beneficiary of this hysteria was Japan. American policy had been concerned with the efforts of Tokyo University's Hideo Itokawa to build an indigenous launcher.[7] Now the policy changed to supporting a Japanese space programme, albeit under strict supervision. The Americans provided technical support and licences to the Japanese government to develop the N-rocket.

The sudden American *volte face* of China policy in 1972, with the visit by President Nixon to China, marked a relaxation of the sanctions although the supervisory systems remained fully in place. A wide range of restrictions of 'non-strategic' categories was lifted, in effect putting China on the same basis as the USSR. COCOM permitted the export of Landsat data, important

Richard Nixon (left) and Zhou Enlai (right) Credit: PRC 10th anniversary photo collection. Credit: Creative Commons.jpg Richard M Nixon Presidential Library.

Reagan (left) Cox (right). Credit: US Congress.

because China had no knowledge or experience in this field. The Americans were now sanguine about Chinese satellite launchings. There was no congressional opposition, indeed a consensus verging on celebration that American foreign policy had found a way to use China to isolate the traditional enemy, Russia, what is called 'triangular diplomacy'. A high point was 1979 when, after the Islamic Revolution in Iran, the CIA was allowed a station in Korla missile base to listen in to Russian radio traffic. That same year, Deng Xiaoping visited the United States and an agreement for technological cooperation was signed. In 1985, 21 high-tech items were taken off the sanctions list. In 1990, China was permitted to launch western satellites, deemed by COCOM to be exports, but through the still-in-place supervisory framework, which imposed quotas (nine, then eleven launches); prices (not more than 15% less than world prices) and security requirements (e.g. 24 hr guard of western satellites in preparation for launch). There were limits though, the US vetoing export of a high-speed computer: China turned to Japan for the computer, but the Americans vetoed that too (China built its own computer anyway). China pressed insistently for many years for participation in the International Space Station - in 1988 the congress encouraged Chinese participation. This finally hit a wall in late 1994 in the Department of State, which would have been the COCOM operator. Unsurprisingly, there seems to be no paper trail on this critical decision.[8]

The satellite launching arrangement broke down with the failures of three Chinese western launches: Optus B2 (1992); Apstar 2 (1995) - both likely due to western insistence on flying unsuitable fairings - and Intelsat 708 (1996), which between them led to allegations that China was purloining western technology. In 1998, the House of Representatives voted to investigate, appointing congressman Cox. This decision in effect repudiated the Nixon consensus of working with China dating back to 1972. The key person here was Newt Gingrich, who in 1994 masterminded the first Republican majority in the House since 1954. His importance has generally been underestimated outside the United States, which tends to focus on presidential rather than congressional politics, but his influence and that of his colleagues was profound. Unlike the consensual 1950s, this Republican majority was combattive, shrill, and partisan, its most memorable but arguably least important action being the impeachment of the President. In time, anti-China sentiment became a dominant theme of foreign policy, one led by the congress, not the president. The Cox report led to the China sanction Act, 2000, which essentially brought the relationship back to that of 1949-72. Under the subsequent Wolf amendment, contacts with China were prohibited. Breaking international convention, visa refusals of Chinese space officials became the norm. The 'trading with the enemy' motif was reapplied: in 2003 Europe was accused of 'treachery' for considering Chinese participation in its navigation system Galileo. Europe caved in. Although China had already launched a navigation satellite prototype, Beidou, Europe's enforced denial led eventually to a Chinese government decision (2006) to develop its own in-house operational system.

The Democratic party fell into line with the Republicans, restoring the pre-1972 anti-China consensus. Chinese revenues from satellite launches fell from $147m (1997) to $23m (1999) to $0m (2000) in a market worth $2.7bn. European companies, principally French (e.g. Thales), tried a workaround of satellites with not a single American component, called 'ITAR-free' and with Apstar 6 in 2005, western - but not American - satellites were once more flying on Chinese launchers. The infuriated Americans responded with a 'not a nut or bolt' policy and threatened sanctions on the Europeans, so in 2013 Thales quietly announced its withdrawal from the satellite market in China. That marked the end of European ITAR-free launches.

The next stage in this cat-and-mouse story was that China turned to developing countries in Africa, Asia and South America to launch communication satellites, very much following the foreign policy principles set down by Zhou Enlai in the 1950s mentioned earlier. These were all-in packages that provided for the satellite, its launch, training and finance, updating model of assistance set down in the 1950s. In a secondary development,

Newt Gingrich. Credit: Needpix

other projects involved navigation and Earth observation satellites. A striking feature is that they included the very countries that benefitted from the first round of Chinese development aid in the 1950s and the Zhou Enlai tour of 1963-4: Sri Lanka, Indonesia, Egypt, Cambodia, Algeria, Tunisia. None of these countries were part of the COCOM régime and much less significant for American commercial interests. In effect, China was forced into a secondary, peripheral market. Even still, the connection of the space programme to such countries was sufficient to attract criticism in the American press, its tracking station in Patagonia attracting the ever-vigilant eye of the *The New York Times*. It is possible that contemporary analysts of Chinese foreign policy, who portray such relationships as a new - and often sinister - development, have not read the principles of foreign aid set down by Zhou Enlai in the 1950s and 1960s.

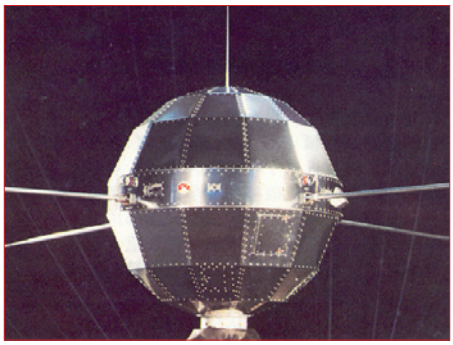
As in the 1950s, US actions had the effect of pushing China back toward its neighbour, Russia, with whom there had been almost no contact from the period of the Great Split (16 July 1960) to the fall of the Soviet Union (1991). The Chinese felt badly burned by their earlier experience, appropriately described as one of 'seeking aid while resisting influence'. In a 1963 post-Great Split report, China was critical of the Soviet Union withholding its most high-tech items and providing outdated or poor quality parts. Their first space cooperation agreement since 1954 was renewed in 1994, with cooperation areas and mechanisms, with the sale of particular items of equipment which this time China inspected first (e.g. docking devices, spacesuits, training). Parallelling the 1950s, the Russians have been proprietary about their best assets and have been slow to put their prized RD-180 engines on the table.

Overall, what was - and is - the impact of sanctions on China? Certainly in the area of the space programme, we can observe three phases:

- complete blockade, 1949-72;
- limited blockade, 1972-99;
- and a resumption of the full blockade from 2000, one which shows no sign of abating.

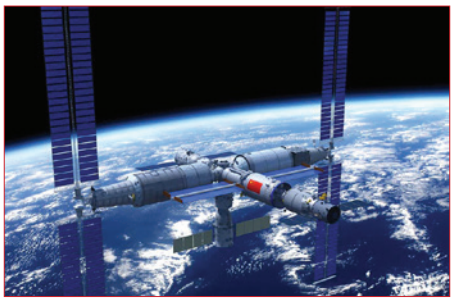
The denial of western technology slowed but did not halt the Chinese space programme, making its subsequent achievements 'through our own unaided efforts' all the more remarkable. Sanctions not only had an immediate physical impact, but a dissuasive effect, making any high-tech cooperation hard and not worthwhile. In effect, China followed a trajectory of enforced indigenization, most evident in obliging China to develop its own space station (1994) and navigation satellite system (2006), quite a legacy.

Second, China's exclusion from the world launcher market and its confinement to a commercially peripheral market denied it a revenue stream that could otherwise fund its space programme, revenue that has proved important for other countries, notably Russia. We can observe continuity in China's foreign economic relations, one in which the space programme now plays an important part. Another consequence of the sanctions policy has been to prompt China's cooperation with Russia, with China benefitting from the R-2 design (1950s) and specific technologies in the manned space programme (1990s). This axis may become more important, especially if there is more whole-hearted cooperation in rocket engine technology, where Russia has always been the world leader.



DongFangHong 1 - The development of China's first satellite was a result of many years of hard work and self-reliance. The development of the Long March carrier rocket had to be done from scratch. Credit: China internet

Beidou - China's indegenious satellite navigation system is complete. China tried to join Europe's efforts for the development of the Galileo navigation system which was met with strong objections by the US. In the consequence, the country went its own way. Credit: Beidou Satellite Navigation Office



Would China have been allowed to participate in the International Space Station project, it could have contributed redundancy in manned and cargo transport capacity. Instead, it is about to assemble its own orbital outpost. Credit: CMSA

Sanctions are likely to remain part of the world space industry for some time. Sanctions have shaped our quadri-polar space world 'the west' (Europe, the US and Japan); Russia; China; and 'the rest' (India and the smaller countries). The American discourse over cooperation with China, or not, has changed little since 1949. Shu Guang Zhang has warned us not to be over-impressed with the technical reasons presented for sanctions, like dual use technology. Historical, mindset and cultural attitudes are more important drivers - in which case sanctions may still be there for their hundredth anniversary in just over 25 years time, in 2049.

Endnotes

[1] United States House of Representatives: *US national security and military/commercial concerns with the People's Republic of China, submitted by Mr Cox of California, chairman*. Report 105/851. Washington DC, US Government Printing Office, 1999.

[2] This writer: *China in space - the great leap forward, 2nd edition*. Chichester, New York and Heidelberg, Praxis/Springer, 2019.

[3] Shu Guang Zhang: *Economic cold war - America's embargo against China and the Sino-Soviet Alliance, 1949-63*. Standford University Press, 2001; *Beijing's economic statecraft during the cold war, 1949-1991*. Woodrow Wilson Centre and Johns Hopkins Press, 2014.

[4] Hufbauer, Gary Clyde: *Sanctions-happy USA*. Washington Post, 12 July 1998.

[5] For the Trident story, see Engel, Jeffrey: *Cold war at 30,000 ft - the anglo-American fight for aviation supremacy*. Cambridge MA, Harvard University Press, 2007.

[6] Hunter, Cameron: *The rise of China in space - technopolitical threat construction in American public policy discourse*. Dissertation submitted to the University of Bristol for award of the degree of Doctor of Philosophy and Politics in the Faculty of Social Science and Law School of Sociology, Politics and International Studies, 2018.

[7] See this writer, Smid, Henk; Pirard, Théo: *Emerging space powers - the space programme of Japan, India, Iran, Brazil and Korea*. Chichester, New York and Heidelberg, Praxis/Springer, 2007.

[8] For the 1988 reference, see Hunter, op cit; for the 1994 discussions, see Patterson, J Barry: *China's space programme and its implications for the United States*. Research report, Maxwell Air Force Base, Alabama, 1995.