All About The Chinese Space Programme

Go Taikonauts!

龙腾太空

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The search operations for the landing of the Chang'e 5 lunar mission were also supported by a 23-man-strong militia cavalry team of Siziwang Banner. The cavalrymen team trained around the landing site for more than 10 days before the landing. The main task was to patrol the landing area and support the search for the capsule, making sure the ground support personnel and the recovery team could focus on their work. Credit: Xinhua

Content

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by Jacqueline Myrrhe

SPACE TRANSPORTATION

CZ-5

The rocket parts for the launch of the Chang'e 5 lunar exploration mission, the 5th CZ-5, arrived at Wenchang Space Launch Centre on Hainan Island in late September. Engineers assembled the launcher and tested all systems. Eventually, the 878 t rocket was moved in vertical position to the launch pad in the morning of the 17 November. The transfer process took 2 h. Final examinations and tests were conducted on the rocket before the launch.

CZ-5 Y5 rocket on 17 November 2020 at the Wenchang spaceport. Credit: Xinhua

CZ-8

On 16 December at 8:20 BJT, the new rocket CZ-8 Y1 was vertically transported to the launch tower of the Wenchang Space Launch Centre. After that, the rocket was fuelled and readied for launch on 22 December.

With the CZ-8 variant of the Long March family of launchers China introduces a rocket with simple and quick launch preparations to meet the demand for cost-balanced and frequent medium-size launches. Combined with a future reusability, the CZ-8 could become a competitive commercial launcher. Additionally, it is planned to have the rocket production close to Hainan Island to save on transport, repeated testing and checking. Improved efficiency could lead to launch readiness in 7 to 10 days, done by approx. 40 people. The reusable CZ-8R variant is expected to launch around 2025. The 1st stage, consisting of a core and 2 side boosters, will be designed for engine-propelled vertical landing on a floating platform and will be reusable. China Aerospace Science and Technology Corporation (CASC) is currently working on that version.

CZ-9

Xu Hongliang, Secretary-General of the China National Space Administration (CNSA), said at the opening ceremony of the Wenchang International Aviation and Aerospace Forum on 24 November that the CZ-9 is in the research and development

The CZ-8 Y1 carrier rocket at the Wenchang Space Launch Centre on 16 December 2020. Credit: Xinhua

stage and is expected to enter service around 2030. Developed by China Academy of Launch Vehicle Technology (CALT), the super-heavy rocket will be 93 m tall, have a lift-off weight of 4,140 t and a thrust of 5,760 t. Its core stage will be about 10 m in diameter while the 4 side boosters will have a diameter of 5 m. The rocket's P/L capacity will be around 140 t into LEO or 50 t into Earth-Moon transfer trajectory. (CZ-5 has a max. LEO P/L capacity of up to 25 t).

Engineers at CASC have started tests of the YF-130 liquid oxygen/kerosene dual chamber engine with 500 t-thrust. The 1st stage of the CZ-9 will be powered by 4 of those YF-130 engines. At Wenchang, a new launchpad and new testing and support facilities for the CZ-9 are planned.

The CZ-9 will be a key component for lunar manned missions and robotic deep-space exploration. CASC has estimated that from 2030 to 2035 about 10 CZ-9 will be needed annually to serve China's national demand.

Wenchang International Aviation and Aerospace Forum

More than 300 officials, scientists, engineers, business experts, delegates, and representatives from the embassies of Argentina, Brazil, France, Germany and Italy, as well as those from international space organisations took part in the 2-day forum on 24 and 25 November. For the 1st time such a forum was hosted on Hainan Island. Authorities of the island province are determined to develop local space-related industries as a new engine for its economy.

Part of this move is the construction of the Hainan International Aerospace City as a home for the aerospace industry and space economy and as an industrial cluster comprising high-end aerospace research, development and manufacturing.

AAPT - Engine Test

On 30 December, engineers successfully conducted a 130 s long test run of a new solid rocket booster engine at the Academy of Aerospace Solid Propulsion Technology (AAPT) in Xi'an. The 3-segmented booster engine with a diameter of 3.2 m is currently the most powerful solid-fuel rocket engine with the largest thrust (260 t), diameter, propellant mass and the longest ignition time in China. The test verified the engine's design requirements. The booster is divided into several sections and each section has its own hull, adiabatic structure and propellant chamber. This makes it possible to adjust the engine performance to the mission profile ranging from manned Moon landing and deep-space exploration and is suitable for large and heavy rockets to conduct space missions. AAPT also plans to develop a 400 to 500-t thrust solid rocket engine.

CALT's smart rockets

The CZ-2C, launched on 26 October from Xichang demonstrated and verified during the drop-off of the payload fairing CALT's smart rocket technology. The payload fairing was equipped with a landing zone safety control system supporting more accurate predictions on the drop-off range.

CALT started its research and development programme for smart rocket technology in 2018. The aim is to monitor flight conditions by on-board systems so that if necessary, the flight path can be autonomously recalculated and corrected. That would enable rockets to independently detect and handle possible hazards and adjust their trajectory instead of following a pre-set path and manoeuvres without emergency response capability.

In addition, experts at CALT's Beijing Aerospace Automatic Control Institute develop machine-learning capabilities for rockets enabling them to adapt to complex environments and emergencies. The goal is to equip China's major launch vehicles until 2025 with an initial learning capability.

CAST

CAST engineer Cai Xiaodong on the challenges in 2020

Cai Xiaodong said he had a "bumper harvest" kind of year in 2020. With China Academy of Space Technology (CAST), Cai is the Chief Designer of the power supply system for the Chang'e 5 probe and the Assistant Chief Designer of Tianwen 1, China's flagship space missions in 2020. Cai said the launches have been tense, exciting moments that are huge sources of pride.

Xichang Satellite Launch Centre (XSLC)

Over summer, the XSLC was modernised and upgraded to accommodate 30 instead of the usual 17 annual launches. The renovation comprised the launch towers, refueling facilities, power supply and the communication system to improve reliability, safety and cadence. The launch of GF-13 on 12 October was the 1st launch after the completion of work.

Yuanwang 3 (YW-3)

The 2nd generation space tracking ship YW-3 left port on 19 November for supporting the Chang'e 5 (CE-5) lunar sample return mission. With Yuanwang 5 and Yuanwang 6 also on sail, 3 space tracking vessels were on duty. Yuanwang 7 was undergoing repair and renovation by that time.

Yuanwang 5 (YW-5)

On 14 December, YW-5 returned to its home port in Jiangsu Province. The vessel sailed 18,000 nautical miles and supported 3 space missions within 82 days. Together with YW-6 and YW-3, it provided tracking service for the CE-5 mission. In 2020, YW-5 has been at sea for 223 days and travelled 51,000 nautical miles.

Yuanwang 6 (YW-6)

After a 96-day sail in the Atlantic and Pacific Ocean and supporting 2 space missions, China's 3rd generation space tracking ship YW-6 returned to the home port of the China Satellite Marine Monitoring and Control Department on 17 October. One tracking included the launch of the Tianwen 1 on 23 July. After that, YW-6 moved to the Atlantic, hitting bad weather but arriving in time for the next task.

On the way back to the home port, the crew started preparations for follow-up tasks. After arrival, the staff took a rest, replenished consumables, and prepared for the next mission. Because of the corona pandemic, the crew did not leave in-between cruises. Most of the staff spent 188 consecutive days on board.

Yuanwang 6 returns to port on 17 October. Credit: Xinhua

The beacon ball is released on board of YW-6 to check the tracking performance of the equipment. Credit: Xinhua

YW-6 departed on 13 November for multiple spacecraft monitoring missions. The ship had completed an overhaul, equipment precision appraisals and training of crew members before the departure. The ship headed for a 90-day sail in the Pacific and the Indian Ocean.

The 1st task was tracking the CE-5 mission. About 6 min after the launch, YW-6 detected and locked on to the target, and completed its monitoring. Approximately 30 min into flight, YW-5 continued the task. The maritime monitoring process lasted in total 1,100 sec. The ships sent accurate real-time data to spacecraft control centres in Beijing and Wenchang.

After conclusion of the task, YW-5 and YW-6 left their positions in the Pacific Ocean and sailed to their next locations, while YW-3 participated in the follow-up monitoring operation for CE-5.

In 2020, the Yuanwang fleet has accumulated more than 900 days of maritime operation and sailed 150,000 nautical miles what is a record in the numbers of days on sail and in the frequency of missions.

MANNED SPACEFLIGHT

New group of taikonauts

On 1 October, CMSA announced the selection of the 3^{rd} batch of taikonauts for the upcoming space station missions. The group includes 17 men and 1 woman. The selection started in May 2018, ran over 2 stages and finished recently. In total 2,500 candidates took part in the selection process. The 18 taikonaut candidates will get different training: 7 will become Space Pilots, 7 Spaceflight Engineers, and 4 mission Payload Specialists. Next, they will start their advanced taikonaut training before being assigned to a space mission.

Pilots and Flight Engineers are responsible for controlling and managing spacecraft and related technical tests. Payload Specialists are experts in on-orbit operation of space science experiments and the research facilities. Space Pilots were selected from active Air Force staff, Flight Engineers were selected from engineering and technical personnel of aerospace engineering institutions, and Payload Specialists were selected from the space science and space applications community or from the field of manned aerospace engineering. CMSA did not reveal the selection criteria.

With progress in the manned exploration programme, China intends to select more batches of taikonauts in the future. In the past, China had 21 astronauts from 2 generations. Among them, 11 have taken part in spaceflights during 6 missions.

Chinese Space Station - CSS

At the beginning of October, all testing of the core module of the CSS has been completed and testing of the CZ-5B launcher was in its final phase. The launch was expected for spring 2021. Once the core module is in orbit, the Tianzhou 2 cargo spacecraft and Shenzhou 12 (SZ-12) crewed spacecraft will be launched. The SZ-12 crew will work for 3 months before Tianzhou 3 will launch and the 2^{nd} space station crew will arrive with Shenzhou 13 (SZ-13). The SZ-12 and SZ-13 crews are responsible for the verification of new technologies, including spacewalks, robotic arms and energy generation. After that is done, 2 more cargo craft and 2 more human missions will launch. In total 11 missions are planned for the CSS assembly until 2022. They include the launch of the Tianhe core module, the Wentian and Mengtian science modules, 4 Shenzhou crewed missions and 4 Tianzhou cargo spacecraft. The manned missions will be extended to about 3 to 6 months. As of 2023 the main science and research utilisation of the CSS can start.

Committee on Space Science and Application of Manned Space Engineering

The 1^{st} meeting of the Committee on Space Science and Application of Manned Space Engineering was held in Tianjin on 31 October 2020. It was organised by the China Manned Space Engineering Office (CMSEO) and attended by approx. 60 experts. The purpose of the committee is to facilitate the exchange among top domestic scientists and technical experts in the fields of space science, space research, space application, human space research, and space technology for identifying leading space science and applications for manned space platforms, continue to produce major scientific and technological achievements, and effectively support China's strategy of strengthening space science and space technology.

The committee meeting reviewed the Chinese Space Station (CSS) development project, planned for the station's utilisation phase and looked into the details of its operations.

The Space Station Utilisation Group suggested a total of 11 research areas and 34 research topics in 3 fields of space science research and application, space human research, and space technology research.

Space Food

Weining Xuerong Biotechnology Co., Ltd., is one of the biggest edible fungus breeding facilities in China. In 2013 the company and the China Space Foundation established an edible fungus research institute in Changchun, Jilin province. The research is aimed at the development of a small-sized fungus production facility in future space stations.

DEEP-SPACE EXPLORATION

MOON

Chang'e 1 (CE-1) – Chang'e 2 (CE-2)

Deep-learning for deep-space

On 22 December, an international team of lunar scientists, led by researchers from Jilin University, published in *Nature Communications* an article about the use of CE-1 and CE-2 data and stratigraphic information for automatic crater detection and age estimation of craters in the lunar mid- and low-latitude regions. The researchers applied machine-based learning on an initial data model to train a neural network. By doing so, 109,956 new craters were identified which is more than a dozen times more than the initially known number of recognised craters. Traditional automatic identification methods are influenced by the subjective expertise of scientists and programmers and are less good in finding irregular, overlapping or eroded impact craters.

The method also estimated the age of 18,996 newly detected craters larger than 8 km in diameter. With the results, a new database was established. The new method can be applied to crater studies for planetary research and was already applied to the identification of small impact craters at the CE-5 landing site.

Yang, Chen; Zhao, Haishi; Bruzzone, Lorenzo; Benediktsson, Jon Atli; Liang, Yanchun; Liu, Bin; Zeng, Xingguo; Guan, Renchu; Li, Chunlai; Ouyang, Ziyuan, 2020, Lunar impact crater identification and age estimation with Chang'E data by deep and transfer learning, *Nature Communications*, 11, 1, 6358, DOI: 10.1038/s41467-020-20215-y

Chang'e 3 (CE-3)

CE-3 landed on the Moon in December 2013. Until today, some scientific instruments on the lander are still producing data.

Chang'e 4 (CE-4)

7^{th} batch of science data released.

On 9 October, the National Space Science Data Centre of the Lunar and Deep-Space Exploration Research Department of the National Astronomical Observatory released the 7^{th} batch of science data. The batch included data from 4 science payloads collected during the 10^{th} lunar day:

Lunar lander

- Low-frequency radio astronomy instrument.

Yutu 2 rover

- Lunar radar.
- Panoramic camera.
- Infrared imaging spectrometer.

In total 360 data files with 3.15 GB of data were released.

23^{rd} lunar day

The CE-4 lunar lander woke up on 11 October at 11:56 BJT and the Yutu 2 (YT-2) rover woke up on 10 October at 18:57 BJT. CE-4 has survived 647 Earth days on the Moon.

During the 23^{rd} lunar day, YT-2 moved northwest toward the basalt area with high reflective surface material. While driving to that location, the near-infrared imaging spectrometer was operated for the investigation of a 30 cm diameter lunar rock. All systems on the lander and rover worked smoothly during the 23rd lunar day.

IAF Award for Chang'e 4

In recognition of the exploration and science achievements of the CE-4 mission, the International Astronautical Federation (IAF) awarded the World Space Award to the leaders of the Chang'e 4 team Yu Dengyun, Sun Zezhou and Wu Weiren. The award recognises outstanding contributions to space science, space technology, space medicine, space law or space management.
Yu Dengyun, the Deputy Chief Designer of China's Lunar Exploration Programme (CLEP), gave a highlight lecture at the 71st International Astronautical Congress 2020 on 12 October to mark the award. Yu Dengyun is also the Deputy Director of the Science and Technology Committee of the China Aerospace Science and Technology Corporation. Wu Weiren is CLEP's Chief Designer. Zezhou Sun is the Chief Designer of the CE-4 systems.
The **technological breakthroughs** of the CE-4 mission are:

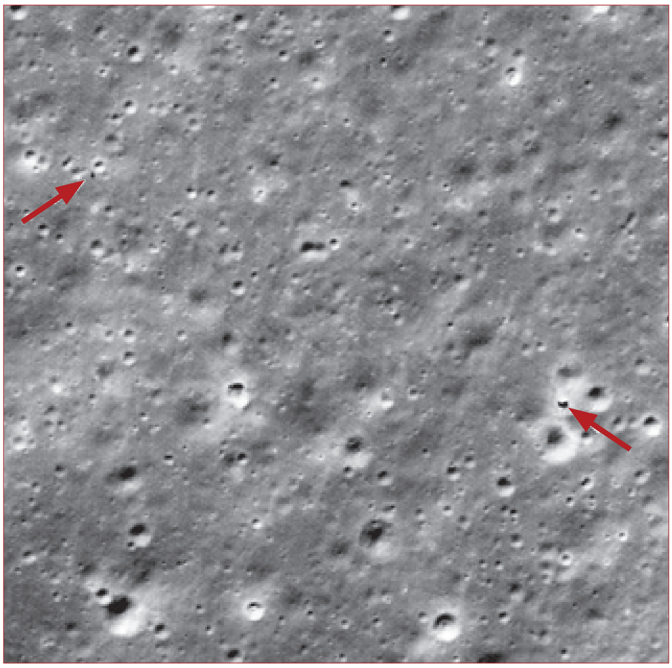
- continuous, reliable communication with the far side of the Moon through the Queqiao relay satellite.
- capability for autonomous, high-precision landing in complex terrain on the lunar far side. The available landing area for Chang'e 4 was 5% that of Chang'e 3, which landed on the near side in 2013.
- breakthroughs in ground control and launch systems.
- 1st radioisotope thermoelectric generator developed in China.
- Longjiang-2 microsatellite.

The **science highlights** of the CE-4 mission are:

- insights into the lunar subsurface structure using a surface penetrating radar.
- data on potential radiation doses astronauts will receive on the Moon.
- discovery of the composition of materials by the rover.
- unprecedented low-frequency radio astronomy measurements.

LROC imagery show Yutu's traces

On hand of LROC imagery (Lunar Reconnaissance Orbiter Camera on NASA's Lunar Reconnaissance Orbiter), NASA's LRO team can trace Yutu 2's traverses on the lunar surface. Estimated from the tracks until 18 October 2020, the rover has travelled 502 m since its landing. The rover may have backtracked occasionally, meaning this value is the minimum distance. The straight-line distance from lander to rover is 385 m.



Arrows indicate Yutu-2 (left) and Chang'e 4 lander (right). Rover tracks are faintly visible between the lander and Yutu-2. LROC image acquired 18 October 2020, M1357657468LR, enlarged 2x. Credit: NASA/GSFC/Arizona State University

23rd lunar night

The CE-4 lander switched to dormant mode on 23 October at 21:40 BJT and the YT-2 rover, at 12:00 BJT the same day.
The research team used the lunar night to analyse the transmitted data. As of 24 October, the CE-4 lunar probe had been on the far side of the Moon for 660 Earth days and the rover has travelled 565.9 m. The 24 October was also the anniversary of the launch of CE-1. With CE-1, China became in 2007 the 5th nation to launch a lunar probe. 7 years later on 24 October 2014, the experimental lunar probe CE-5 T1 was launched to test technologies in preparation of the Chang'e 5 sample return mission.

8th batch of science data

On 3 November 2020, the National Space Science Data Centre released the 8th batch of CE-4 science data collected during the 11th lunar day. The data provides insight in the morphology, composition, geological structure and low-frequency radio environment of the far side of the Moon. In total 493 files with a data volume of 2.76 GB were published.

Lander payload

- Low-frequency radio spectrum analyser: 2C level scientific data.

Rover payload

- Panoramic camera: 2B level scientific data.
- Lunar radar: 2B level scientific data.
- Infrared imaging spectrometer: 2B level scientific data.

With that release, 8 batches of scientific data of CE-4 have been publicly released and users can access relevant data resources on the web portal of the Virtual Space Science Observatory of the National Space Science Data Centre (vsso.nssdc.ac.cn). The centre will also continue to publish more scientific data on lunar and deep-space exploration in the virtual space science observatory and the data resource catalogue of the China Science and Technology Resource Sharing Network.

24th lunar day

The CE-4 lander and rover have resumed work for the 24th lunar day. YT-2 woke up on 9 November at 10:17 BJT and the lander woke up on 10 November at 3:12 BJT.
Since its landing on the Moon on 3 January 2019, lander and rover have survived 677 Earth days on the Moon. During the 24th lunar day, YT-2 continued moving northwest toward the area with high surface reflectivity. The 4 scientific instruments on the rover - a panoramic camera, a lunar penetrating radar, a visible and near-infrared imaging spectrometer and the Swedish Advanced Small Analyzer for Neutrals – collected data.

24th lunar night

On 25 November, lander and rover finished their operations and went into dormant state for the lunar night. YT-2 rover has accumulated nearly 590 m of traversing the lunar surface since its deployment after landing. It has been operating for 692 Earth days.

25th lunar day - 600 m milestone

On 22 December, by the end of the 25th lunar day, Yutu 2 has survived 719 Earth days and travelled 600.55 m on the far side of the Moon.

25th lunar night

On 22 December, the lander and the rover ended operation for the 25th lunar day and switched to dormant mode in preparation for the lunar night.

Chang'e 5 (CE-5)

For a detailed mission report compare the article in GoTaikonauts! Issue no 31, p. 24-28 and this issue, p. 29 -35.

Chang'e 6, Chang'e 7, Chang'e 8 (CE-6, CE-7, CE-8)
Future Moon missions outlined – Begin of 4th Phase of CLEP (China Lunar Exploration Programme)

According to CNSA mission planners, CE-6 is scheduled to be launched around 2023 and bring rock and soil samples from

the lunar South Pole back to Earth. The exact launch date and landing site of the CE-6 mission will be determined based on the results of the CE-5 mission. It might well be that CE-6 will sample the far side of the Moon. That is depending on whether Queqiao is still functioning or not.
CE-6 will consist of 4 components: orbiter, lander, ascender and re-entry module. In addition to its own mission payloads, CNSA will allocate 20 kg of payload capacity – 10 kg on the orbiter and 10 kg on the lander - for other national and foreign users, as well as Chinese private enterprises.
However, CE-6 will launch after CE-7 because the mission goal of CE-7 is to conduct a thorough investigation of the lunar south pole in 2024. CE-8 will be tasked with testing and verifying high-technologies that are of interest for future Moon expeditions, including a possible lunar outpost.

MARS

TIANWEN (TW-1)

Selfies en route to Mars

As of midnight on 30 September, Tianwen 1 (TW-1) has flown about 188 million km and was 24.1 million km away from Earth. All systems were in good condition. On 1 October, CNSA released mid-flight images by and of TW-1 on its way to Mars. It was the 1st time that the probe took a selfie. The images were captured by a mini-sensor installed on the outer wall of TW-1. On command from Beijing Aerospace Control Centre (BACC), the sensor separated and its 2 wide-angle lenses took one picture per second. The images were sent via Wi-Fi to the planetary probe and from there transmitted to Earth. The photo opportunity coincided with China's National Day on 1 October. So far, the probe performed 2 orbital corrections to adjust its trajectory.

The National Flag

The selfie shows the Chinese national flag, since the red colour sticks out from the otherwise golden-silver colour of the spacecraft and the dark backdrop of space. The flag on TW-1, weighs about 144 grams, is about 39 x 26 cm in dimension, and slightly smaller than a piece of A3 paper. It was sprayed onto the probe with special paint and overprint technology.

3rd orbital correction

TW-1 conducted its 3rd orbital correction on 28 October at around 22:00 BJT. Its 8 smaller 25 N engines worked simultaneously. The manoeuvre also served as a test of the engines. TW-1 has been 97 days in orbit, flown about 256 million km and was 44 million km from the Earth at that day. All probe systems were in good condition.

Deep-space manoeuvre

On 9 October, at 23:00 BJT, Tianwen 1 successfully conducted a deep-space manoeuvre for adjusting the flight route. The main engine fired for over 480 sec what was a relatively long burn. The manoeuvre enabled a fuel-saving flight and prepared for the arrival at Mars and the to-follow critical Mars orbit insertion manoeuvre beginning of 2021 at a distance of 193 million km from Earth. The planetary probe will travel along the Earth-Mars transfer orbit for about 4 more months. The total distance TW-1 has to fly is about 470 million km.

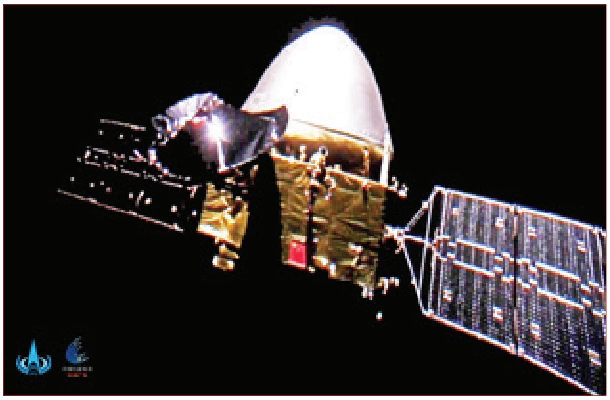
Tianwen 1 will travel more than 470 million km before getting captured by the Martian gravitational field on 10 February, when it will be 193 million km from Earth.

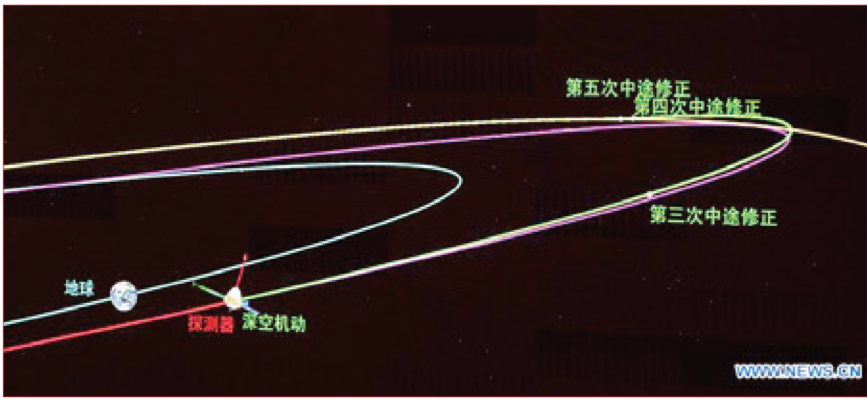
After the probe enters Mars orbit, it will revolve around the planet for 2 ½ months to investigate the planned landing site. The mission's goal is to deploy a rover in May on the southern part of Mars' Utopia Planitia for scientific surface surveys.
TW-1 is the world's 46th Mars exploration mission since October 1960, when the Soviet Union launched the world's first Mars-bound spacecraft. Only 17 of those missions were successful.

Deep-space antenna

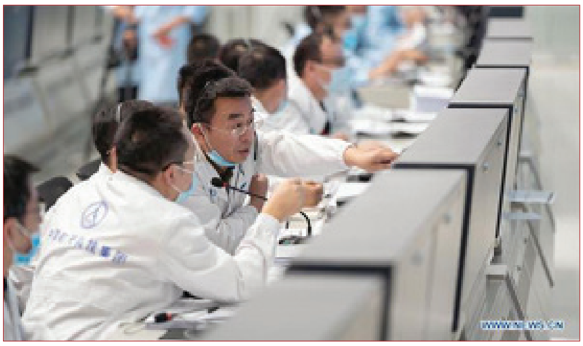
On 17 November, after 2 years of construction and testing, China has inaugurated its 1st deep-space antenna at a ground station in Kashi, near Kashgar in Northwest China's Xinjiang Province. The system, operated by the Xi'an Satellite Control Centre, is a set of four 35-m diameter radio telescopes - 3 of

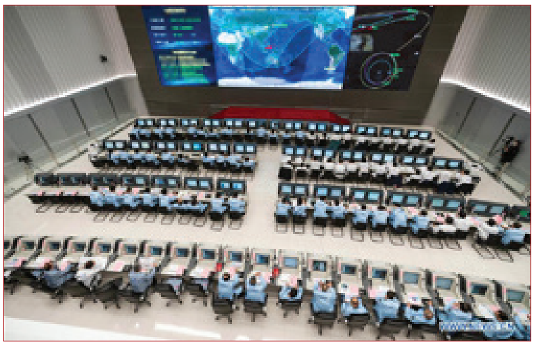
Manoeuvre/ activity	Date/time	Distance to Earth/ flown distance	activity
Tianwen selfie	1 October 2020 (China's National Day)	24.1 million km / 188 million km	The photo was taken by a mini wide-angle camera, initially mounted on the probe's outside and released by command from mission control.
Deep-Space manoeuvre	9 October, 23:00 BJT	29,4 million km / 210 million km	Tianwen's 3,000 N main engine worked for 480 sec to adjust the flight trajectory.
3rd orbital correction	28 October, around 22:00 BJT	44 million km / 256 million km	Adjustment of transfer trajectory as preparation for the arrival in the gravitational field of Mars.
1st in-orbit self-check	17 November	63.8 million km / 300 million km	Several sub-systems were checked. All worked nominal. The average flight speed was: 23 km/s - 2 million km/day
	14 December, 21:00 BJT	100 million km / 360 million km	TW-1 has been in space for 144 days and about 12 million km away from Mars.





left: TW-1 as seen on its 1st space selfie. The solar panels and the high-gain antenna are well recognisable. The silver-white section is the Mars entry module and heat shield, hosting the Mars rover. Credit: CNSA right: A map on the screen of BACC. It shows the Tianwen maneuvre from 9 October. Credit: Xinhua/Cai Yang





far left: Technical personnel work at the BACC in Beijing, on 9 October 2020 when TW-1 successfully conducted a deep-space manoeuvre. Credit: Xinhua/Cai Yang

left: View into the mission control centre during Tianwen's manoeuvre on 9 October. Credit: Xinhua/Cai Yang

them are newly built. They form an array capable of recording signals equivalent to a single 66-m radio telescope. The system can track a single deep-space probe while each of the telescopes can individually monitor multiple objects. Also, it can form arrays with other national or global observatories and carry out joint VLBI radio astronomical observation activities.

The Kashi antenna system has enhanced data-receiving sensitivity and can provide high-performance support to different kinds of deep-space missions and will be directly used for tracking and monitoring the Tianwen 1 probe and the upcoming CE-5 lunar sample return mission.

Since 2012, China has been building its deep-space network. Besides Kashgar it has ground control stations in the eastern city of Qingdao and northeastern city of Jiamusi, and in Argentina's Neuquén province. Additionally, a 50-m antenna in Miyun, near Beijing, and a 40-m antenna in the southwestern province of Yunnan were built.

The 1st of the 35-m Kashi antennas under construction. Credit: Lu Long / Kashgar Observation and Control Station

China, the Moon, Mars, and beyond - an opportunity for human cooperation

SpaceNews published a commentary by Louis D. Friedman of *The Planetary Society* in which he advocates closer international cooperation in deep-space exploration, including China: "Each nation's current lunar and Mars programs would continue on their current course, but could be gradually enhanced with international cooperation while serving the bigger context of human activity on the moon and Mars. Those expecting commercial development and other private ventures on the moon will find Earth's nearest neighbour large enough to accommodate lots of interests. China's presence is not uncertain - they are doing that anyway. The scale and the reality of lunar development can only be enhanced by coordination and cooperation."

SCIENCE

HXMT (Hard X-ray Modulation Telescope) - FAST (Five-Hundred-Meter Aperture Spherical Radio Telescope)

On 28 April 2020, for the 1st time NASA's Swift Observatory, Fermi Gamma-ray Space Telescope and the Neutron star Interior Composition Explorer (an X-ray telescope on the outside of the ISS), the Canadian Hydrogen Intensity Mapping Experiment (CHIME) and the U.S. Survey for Transient Astronomical Radio Emission 2 (STARE2) as well as ESA's INTEGRAL satellite and the Chinese Huiyan X-ray satellite (Hard X-ray Modulation Telescope - HXMT, also known as Insight) registered a very short but extremely bright burst of radio waves, identified as a fast radio burst (FRB) and since then designated FRB 200428. FRB is a pulse of radio waves that can release as much energy in a millisecond as the sun produces in a day. It was the 1st FRB ever detected from within our galaxy and could only have come from a rare type of star with extremely strong magnetic fields and known as a "magnetar" - in this case from SGR (Soft Gamma-ray Repeater) 1935+2154 about 30,000 light-years away. The magnetar was active when the FRB 200428 was detected, emitting bursts of x-rays and gamma-rays. Although scientists believe that they had pinpointed the origin of FRB 200428, the final piece of the puzzle was still missing, which was needed to confirm that SGR J1935+2154 had indeed produced the radio bursts.

HXMT temporarily changed its observation plan in April 2020 to focus on SGR J1935+2154. Seven hours after the ground control sent the observation command, HXMT detected a very bright x-ray burst from SGR J1935+2154 which occurred about 8.6 seconds before the FRB 200428 burst. Thanks to the state-of-the-art equipment on Insight scientists discovered the time gap to be 8.62 seconds, which is consistent with the amount of time that the radio wave signal was delayed by the interstellar medium. This confirmed that the X-ray burst and FRB came from the same event. Compared with other space telescopes, HXMT provided the most detailed temporal and spectral information in understanding FRBs and magnetars. The research was conducted jointly by scientists from the Institute of High Energy Physics (IHEP) under the Chinese Academy of Sciences, Beijing Normal University, University of Nevada Las Vegas, Tsinghua University and other institutions. The findings have been published in *Nature Astronomy*. The HXMT science team considered it pure luck that its telescope caught the significant signal. Later during the day, the sky region of interest came into view of FAST which had been observing the region before. Two days later, researchers from Beijing Normal University, Peking University and the National Astronomical Observatories used FAST to help in the characterisation of the event and strengthen the interpretation of the FRB event.

HERD (High-Energy cosmic-Radiation Detection)

The HERD (High-Energy cosmic-Radiation Detection) facility has been proposed as one of several space astronomy payloads onboard the CSS, planned for operation starting around 2025 for about 10 years. HERD is a China-led mission with key European contributions led by Italy. The HERD proposal has passed the joint international review organised by the Italian Space Agency (ASI) and the Centre for Space Utilisation of the Chinese Academy of Science. The primary scientific objectives of HERD are:

- Indirect dark matter search with unprecedented sensitivity;
- Precise cosmic ray spectrum and composition measurements up to the knee energy;
- Gamma-ray monitoring and full sky survey.

HERD is composed of 4 scientific instruments. The main one is a homogeneous, almost cubic calorimeter made of about 7,500 LYSO (Lutetium-yttrium oxyorthosilicate) cubic crystals and capable of accepting particles incident on its top face and four lateral faces. Each sensitive face is instrumented with a silicon tracker, and covered by a plastic scintillator detector to separate gamma rays from charged particles. Additionally, a transition radiation detector is located on one lateral face for energy calibration of Terra-eV particles. The novel design and key specifications of HERD instruments have been successfully verified with beam tests at the CERN Super Proton Synchroton.

Yongwei Dong, Shuangnan Zhang, Giovanni Ambrosi, (2019), Overall Status of the High Energy Cosmic Radiation Detection Facility Onboard the Future China's Space Station - HERD Collaboration, *Proceedings of Science, 36th International Cosmic Ray Conference (ICRC 2019), 24 July-1 August 2019, Madison, WI, U.S.A.*, DOI: 10.22323/1.358.0062

Space-ground astronomy

As part of the Chinese Space Station Telescope (CSST) project, the 3-year long construction phase of a Space Science Centre has begun at the Sun Yat-sen University in Guangzhou, Guangdong province. The CSST, planned for launch in 2024, is an optical telescope for sky surveys. CMSEO plans to build 4 CSST science centres nationwide with Sun Yat-sen University as the lead institute. The other 3 will be located at Peking University, the National Astronomical Observatories, and the Yangtze River Delta region. The network of space science centres will use the space-based telescope for coordinated space science research in the fields of galactic cosmology, stars and planets, compact stars and sources of gravitational waves, and space experiment technologies.

WUKONG (DAMPE) - extended mission

On 17 December, the operational phase of the Dark Matter Particle Explorer - Wukong was extended by another year, as it is still functioning well after 5 years in space. The satellite was launched in December 2015 as China's 1st dark matter research satellite. Its initial lifetime was designed for 3 years, but already at the end of 2018 the operation was extended by 2 years.

After another evaluation of the satellite's health in 2020, it was concluded that the key performance indicators have barely degraded since start of operation.

As of 17 December, Wukong has orbited the Earth 27,822 times in a 500 km SSO, detecting around 9.36 billion cosmic particles. Wukong completed its original objectives in the search for the invisible dark matter by detecting the high-energy electrons and gamma rays in space, which might be generated in the process of annihilation or decay of dark matter. The satellite has also been used for astrophysical studies and researching the origin of cosmic rays.

APPLICATIONS

Carbon sinks

In a publication for *Nature* science magazine, an international team of researchers showed that the combination of space-borne observations of vegetation with data recorded on 6 ground locations between 2009 and 2016 gives new results in the size of China's land biosphere carbon sink. Space-borne observations of vegetation greenness show a large increase over time. The results reflect a previously underestimated land carbon sink over southwest China (Yunnan, Guizhou and Guangxi provinces) throughout the year, and over northeast China (especially Heilongjiang and Jilin provinces) during summer months. These provinces have implemented rapid afforestation of progressively larger regions, with provincial forest areas increasing annually by between 0.04 million and 0.44 million hectares over the past 10 to 15 years.

China is currently the single largest emitter of CO_2, responsible for approximately 27% (2.67 petagrams of carbon per year) of global fossil fuel emissions in 2017. Understanding of Chinese land biosphere fluxes has been constrained by limited data coverage. Using the new data, the study estimates an average Chinese land biosphere sink of −1.11 ± 0.38 petagrams of carbon per year during 2010 to 2016. This means that the Chinese land biosphere can absorb approx. 45 % of China's annual anthropogenic CO_2 emission.

The Southwest carbon sink contributes about -0.35 petagrams per year (31.5% of the Chinese land carbon sink) and the Northeast sink contributes about -0.05 petagrams annually, equivalent to 4.5% of the Chinese land carbon sink.

Wang, Jing; Feng, Liang; Palmer, Paul I.; Liu, Yi; Fang, Shuangxi; Bösch, Hartmut; O'Dell, Christopher W.; Tang, Xiaoping; Yang, Dongxu; Liu, Lixin; Xia, ChaoZong, (2020), Large Chinese land carbon sink estimated from atmospheric carbon dioxide data, *Nature*, 586, 7831, 720-723, DOI: 10.1038/s41586-020-2849-9

Environment

Researchers and engineers at CASIC Smart Industry Development, a Beijing-based subsidiary that specialises in smart city solutions, made use of CASIC's satellite, system engineering, IoT, software and sensor technology resources to design a sophisticated system to monitor and detect water pollution. A pilot project for water quality forecast and early-warning was started in December in cooperation with the Chongqing Environmental Monitoring Centre in Chongqing, the largest city in southwestern China.

Engineers have finished design work for the system's basic structure and initial functions. With the assistance of Big Data, cloud computing and AI, the system is collecting data from major rivers, reservoirs and lakes in the industrial hub and based on that will forecast the water quality, assess risks and hazards and trace and analyse pollution, as well as provide long-term solutions and emergency-response plans. Once completed, the system can produce water quality forecasts for the next 3-7 days, allowing water and environmental protection authorities to take measures ahead of possible pollution events caused by natural elements, such as algae blooms. Currently, water management departments rely on on-site inspections and data collected through existing monitoring devices. As part of the trial programme, 22 online water-quality monitoring devices, 10 streamflow monitoring apparatus, 4 dam inspection systems and some other instruments have been set up along the Tiaodeng River.

Heritage Conservation

High-tech laser scanning by instruments on board aerial drones combined with satellite remote sensing data are used to document and survey the Badaling Great Wall and create a “Digital Great Wall”. Until the end of 2020 the full length of the 179.2 km of the Great Wall in Yanqing district, Beijing will be digitised by the Yanqing Institute of Cultural Relics and the Beijing Institute of Conservation and Design of Ancient Architecture. A high-precision 3D model of the Great Wall has been built to support maintenance and protection. It also serves as a reference model for the protection of the Great Wall in other provinces of China. The National Cultural Heritage Administration has launched a pilot project in 15 regions to use drone and space data for the protection of the Great Wall.

Medical Application

In mid-October it became known that the TEDA International Cardiovascular Hospital in Tianjin Municipality implanted a 63-year-old male patient with an artificial heart based on a rocket's servomechanism, driven by a hydraulic pump. The 180-gram hardware, smaller than a fist, is called "HeartCon". HeartCon is the outcome of a cooperation between the hospital and CALT which started in 2009. Magnetic and fluid levitation, which are used in rocket servo technology, were applied to produce an implantable 3rd generation ventricular assistive device - a mechanical pump to support heart functions while causing less damage to patients' blood than previous types. While the servomechanism on a rocket has higher requirements regarding speed and power, the artificial heart demands safety and miniaturisation. It is hoped that with advancing technology, the artificial heart can completely replace transplants.

Global atmospheric land surface re-analysis system

The first global atmospheric/land surface re-analysis system and products of the China Meteorological Administration (CMA) has passed operational review. The R&D team from the National Meteorological Information Centre integrated a wide range of historical observation data, and developed the re-analysis products since 1979. Data sets from different sources were conditioned for re-analysis with modern methods and technology. lobal re-analysis products boast wide application in fields such as weather, climate, ocean, hydrology, geography, and ecological environment.

Integrated Meteorological Observation Experiment

An integrated, multi-platform observation experiment, using ground-, ocean- and space-based observation of typhoon Nangka was successfully carried out from 12–14 October in the coastal areas of central-northern South China Sea. Typhoon Nangka made landfall in Qionghai, South China's Hainan province on 13 October. Fengyun 4 and Gaofen satellites, aeroplanes, drones, sounding rockets and airborne laser radar delivered high-resolution data during the 3-day experiment. It was the largest scale scientific typhoon experiment with most observation facilities so far.

WMO INFCOM Meeting

On 9 November, the 1st virtual session of the Commission for Observation, Infrastructure and Information Systems (Infrastructure Commission, INFCOM) of World Meteorological Organisation (WMO) was held. The 5-day online meeting was coordinated from Beijing. Issues like rules of procedure, data exchange, WMO integrated global observing system, and WMO information system were discussed.

Meteorological Training Course

From 9 to 11 December, the 5th International Training Course on Tropical Cyclone Monitoring and Forecasting was held online by CMA, the World Meteorological Centre Beijing and the Regional Training Centre Beijing. The training for 92 participants from Myanmar, Malaysia, the Philippines, Bangladesh, Thailand, India, Sri Lanka, Nigeria, Yemen, Qatar, Pakistan, Somali, and Oman focused on enhancing the operational capabilities of tropical cyclone forecasters from Economic and Social Commission for Asia and the Pacific (ESCAP)/WMO Typhoon Committee and Panel on Tropical Cyclones Members.

Green tide and sea surface temperature satellite monitoring

By the end of 2020, CMA confirmed that the nationwide green tide (fast-growing macroalgae bloom) and sea surface temperature satellite monitoring will start from 1 January 2021. This initiative will reinforce the construction of an integrated satellite application system, promote and regulate satellite monitoring operations, and formulate the application service operational layout at the national, provincial, municipal and county level. The project will enable regular and ad-hoc operational products, including the location, the coverage, distribution, and change trends of the green tide as well as sea surface temperature distribution features analysis, and sea surface temperature change trend analysis.

The National Satellite Meteorological Centre and meteorological departments of the coastal regions will produce monthly and quarterly sea surface temperature satellite products while during the typhoon warning period, daily sea surface temperature satellite remote sensing monitoring products will be released. CMA has also published relevant technical guidelines, technical procedures, monitoring approaches and product specification of green tide and sea surface temperature satellite monitoring.

Quantum Communication

On 16 October, the Central Committee of the Political Bureau of the Communist Party of China (CPC) held the 24th Group Study Session on the research and application of quantum science and technology, discussing strategic planning and forward-looking layout for the development of quantum science and technology in China. The applications of quantum science and technology involve 3 fields: quantum communication, quantum computation and quantum precision measurement. Experiments including the quantum science satellite Mozi and the quantum communication line between Beijing and Shanghai enabled the prototype of the first space-ground integrated quantum communication network.

Strategic Science and Technology

In late October a summary of the 14th Five-Year Plan was released. The document includes a list of “forward looking and strategic” key technologies for state-sponsored research: AI, quantum communications, integrated circuits, health, and biological engineering are supposed to reduce dependence on foreign critical core technologies and enable Chinese scientists and researchers to obtain a better understanding of frontier sciences.

In a related 5-year plan document, the NDRC (National Development and Reform Commission) names the areas of strategic scientific frontier exploration and technologies: the evolution of the cosmic structure, the origin of life, cognitive science and atomic physics, molecular breeding of plants and livestock, gene editing, new materials, astrodynamics, in-orbit spacecraft servicing, and space manufacturing.

SATELLITE

APPLICATIONS

New data-sharing platform for near-space research

In December, the Aerospace Information Research Institute (AIR) under the Chinese Academy of Sciences (CAS) released the Scientific Experimental System in Near Space platform for sharing near-space science data generated from various scientific experiments and data analyses, covering meteorological, hydrological and geographic information. The data spans multiple fields including biology, atmosphere, electromagnetics and radiation.

APStar-6D

CASC announced on 9 December that it has successfully completed the in-orbit delivery of the APStar-6D communication satellite to the customer, Shenzhen-based APT Mobile SatCom Limited. APStar-6D is a part of China's 1st global high-throughput broadband satellite communication system, serving users across the Asia-Pacific region.

50th anniversary of Fengyun (FY) satellite programme

2020 marked the 50th anniversary of China’s Fengyun Satellite Programme. Up to now, China has launched 17 FY meteorological satellites, with 7 in operation. FY satellites are arranged in series. The odd number series comprises the polar-orbiting satellites and the even number designation is given to geostationary satellites.

Chinese Premier Li Keqiang stressed during a symposium on 10 October in appreciation of the Fengyun anniversary the importance of the FY satellites as an important national space infrastructure and a significant symbol of the modernisation of the country's meteorology. He encouraged the meteorological community to speed up efforts of strengthening China’s meteorological competence and further enhance the capabilities for disaster prevention, reduction and relief.

Also, the Fengyun Meteorological Satellite System is

The Fengyun meteorological satellites in 2020. Credit: National Satellite Meteorological Centre (NSMC) of China Meteorological Administration

an important component in the World Meteorological Organisation's (WMO) Space-based Observing System as well as the International Charter on Space and Major Disasters.

The estimated annual economic benefits of the Fengyun satellites is between 50 and 100 billion RMB (7.4 - 14.8 billion USD) based on the fact that nearly 70 % of the natural disasters occur due to meteorological factors.

2020 Fengyun Satellite User Conference

From 28 to 29 October, the 2020 Fengyun Satellite User Conference was held in Suzhou, Jiangsu province. The conference was co-sponsored by CMA, CNSA, CAS, and CASC and attended by high-ranking representatives of those entities. Also, representatives from the Ministry of Natural Resources, Ministry of Ecological Environment, Ministry of Water Resources, Ministry of Agriculture and Rural Affairs and Ministry of Emergency Response and meteorological departments participated in the conference mirroring the importance of Fengyun satellite data and products which have been widely applied in sectors like ocean, agriculture and rural affairs, forestry, ecological environment, water resources, transportation, aviation and electric power.

Overall, 500 experts and scholars from 110 institutes discussed the technical advances of the Fengyun satellites and exchanged the latest application technologies.

FY satellites have played an increasingly important role in the global meteorological community. National departments will further pool strengths to promote the high-quality development of the FY satellite programme, increase scientific innovation, improve technical capabilities, elevate high technological application level like satellite remote sensing, deepen international exchanges and cooperation, and forge a new international cooperative landscape of FY satellites.

At the conference, CASC announced it will develop 7 new meteorological satellites during the 14th Five-Year Plan period (2021-2025). The planned satellites will have higher spatial resolution and shorter imaging time, supporting high-precision stable meteorological observation and improve emergency response capabilities in disaster prevention and relief.

The conference introduced an Academic Commission and invited 17 academicians from the domestic remote sensing field to serve as President and Commissioners.

The Journal of Remote Sensing

The Journal of Remote Sensing is another scientific publication within the scope of the "Science Partner Journals". It is an online-only Open Access Science Partner Journal published in affiliation with Aerospace Information Research Institute, Chinese Academy of Sciences (AIR-CAS) and distributed by the American Association for the Advancement of Science (AAAS). Like all partners participating in the Science Partner Journal programme, the *Journal of Remote Sensing* is editorially independent from the *Science* family of journals and AIR-CAS is responsible for all content published in the journal. The focus is on articles about the progress of science and technology of remote sensing, as well as research results of remote sensing in areas such as resources and environment, disaster monitoring and interdisciplinary applications. The aim is the promotion of international academic exchange. Wu Yirong, Director General of AIR and a CAS academician, is the Chief Editor of the journal. The editorial board consists of 30 international experts from China, the United States, France, Australia and India. The 1st issue will be published online in early 2021.

SAR imaging satellite

China plans to launch a new Synthetic Aperture Radar (SAR) imaging satellite for monitoring Arctic shipping routes. Jointly developed by the Sun Yat-sen University in Guangzhou and the China Academy of Space Technology, the satellite will be launched in 2022 in a 720 km SSO. With a daily revisiting time of most areas along Arctic maritime routes, the satellite will be able to generate high-quality SAR satellite imagery with 50 m resolution and 300 km width. Its data will be used to monitor and predict sea ice, climate change and marine disasters, supporting the safety of Arctic shipping routes.

Space Debris – in-orbit passage

The defunct Soviet satellite Cosmos-2004, launched in 1989, and a Chinese upper stage from the CZ-4C Y4 launched in 2009 crossed on 16 October at 00:56 GMT at a height of 991 km over Antarctica without colliding. Earlier estimates gave a collision risk of 1:10. It was reported that the two objects passed each other at a distance of 8 to 43 m. Other calculations predicted a 1:23 billion collision risk with a 70 m distance between both objects during passage.

5G Ground-to-LEO Connectivity

In November, China Aerospace Science and Industry Corporation (CASIC) conducted China's 1st technology demonstration of 5G ground-to-LEO connectivity. Engineers and crew aboard a maritime patrol ship off the coast of Daishan county in Zhejiang province made 5G phone calls, held video conferences with their colleagues on land, and used internet services. The signals were transmitted through a gateway station mounted on the vessel and CASIC's experimental broadband communications satellite in LEO. The involved 247 kg small satellite was launched on 22 December 2018 (BJT) with a CZ-11 and operates in a 1,100 km SSO. It exceeded its designed operational life of 1 year and is expected to continue operating.

The tests also examined the application potential of IoT technology in maritime industries. Data, collected by equipment and "smart suits" worn by the ship's crew, was transmitted using the LEO connection. Considering that many 'blind areas' in terms of telecommunication services are at sea, the commercial viability of this technology could enable the use of telephone and internet services anywhere in the world.

As of October, China had more than 700,000 5G base stations in operation, serving over 180 million user terminals.

NAVIGATION

BeiDou Navigation Satellite System (BDS)

During the Beidou Summit Forum on 14 October, the 2.0 version of the Beidou high-accuracy positioning service platform was released by the China Academy of Information and Communications Technology (CAICT). With a 1.2 m positioning accuracy, the platform enables mobile phone-based vehicle positioning precise to the level of a traffic lane on the road. The service can be used by updating the mobile phone software and firmware, without the need for additional hardware.

BDS complies with ICAO standard

The Civil Aviation Administration of China (CAAC) and the China Satellite Navigation Office informed on 17 November that BDS has passed an assessment of standardisation work by the International Civil Aviation Organisation (ICAO). For the 1st time the BDS-3 civil signals received and passed the systematic technical verification by an international organisation. The ICAO has the highest requirements for global navigation satellite systems.

A total of 189 performance indicators of the system were verified by technical experts of the 6th Navigation Systems Panel (NSP/6) of the ICAO held from 2-13 November. This review approved BDS-3 for global civil aviation.

The ICAO navigation system expert group will report the meeting result to the Air Navigation Commission for further discussion. Then, ICAO will solicit the opinion from all countries on the draft report. After confirmation, the BDS-3 system will be officially written into ICAO standards and announced.

Backed by China's civil aviation authorities and the China Satellite Navigation Office, a joint team has spent 10 years of drafting and verifying BDS standards for applications in the civil aviation sector.

In a next step, the standards for BDS applications in the global civil aviation sector and for developing BDS-based air navigation equipment will be formulated. With a fleet of 6,408 aeroplanes, including 3,771 transport aircraft and 2,637 general aircraft, China has the world's 2nd largest civil aviation market. BDS has been installed on about 300 general aircraft, accounting for 11 % of the total in China.

11th China Satellite Navigation Conference

The 11th China Satellite Navigation Conference 2020 took place from 23 to 25 November in Chengdu, Sichuan province. Themed "GNSS (Global Navigation Satellite System), New Global Era," this year's conference, postponed from 2019, featured seminars, forums, academic exchange, exhibitions and science popularisation activities.

Discussions around the prospects of applying BDS to the Internet-of-Things (IoT) were one focus of the 3-day event. The forum is the 1st significant event on satellite navigation in China following the commissioning of the BDS-3 system on 31 July 2020.

Over 100 enterprises showcased products and services based on BDS, covering a wide range of areas including surveying and mapping, navigation, 5G, IoT, autonomous driving, and disaster reduction and relief.

According to a report released by the China Satellite Navigation Office at the conference, the total output value of China's satellite navigation and location services industry has increased by more than 20 % annually for the past 10 years, hitting 345 billion RMB (52.5 billion USD) in 2019. It is expected to exceed 400 billion RMB this year.

The applications of the BDS in emerging industries such as unmanned aerial vehicles (UAVs), outdoor robots and autonomous driving may bring exponential growth to the BDS-related industry.

On 23 November, Beijing-based Unicore Communications, Inc. released a new-generation high-precision positioning chip that supports BDS-3 and can meet the needs of high-end applications such as autonomous driving and UAVs. It is considered the most advanced positioning chip China has developed to date and is among the most advanced worldwide. (BDS and GLONASS are compatible. BDS and GPS are compatible and interoperable.) The near-term aim is building a comprehensive national positioning, navigation, and timing (PNT) system based on the BDS by 2035.

China-ASEAN BDS Application and Industrial Development Forum

The China-ASEAN BDS Application and Industrial Development Forum was held under the umbrella of the 17th China-ASEAN Expo end of November in Nanning.

During the forum, 3 agreements on cooperation in Beidou applications were signed by companies from China, Thailand, Cambodia and the Philippines.

Ran Chengqi, Director of the China Satellite Navigation Office, said the service performance of the BDS system in the ASEAN area of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam is among the best in any region worldwide.

During the forum, a China-ASEAN BDS base was established in Nanning to better serve ASEAN countries.

Time Transfer Performance

Researchers from the Time Keeping Laboratory of the National Time Service Centre of the Chinese Academy of Sciences analysed the time transfer performance of the BDS-3 signals and found out that it is over 50% better than that compared to the BDS-2 satellites and making the new BDS-3 signals comparable to that of GPS and Galileo.

To evaluate the time transfer performance of BDS-3, the pseudo range measurement noise, precision of conventional common view (CV) and all-in-view (AV) time comparison and the instability of the precise point positioning (PPP) time transfer were analysed. The results were published in the journal *Metrologia*.

Wei Guang, Jihai Zhang, Haibo Yuan, Wenjun Wu, Shaowu Dong, (2020), Analysis on the time transfer performance of BDS-3 signals, *Metrologia*, 57, 6, 065023, DOI: 10.1088/1681-7575/abbcc1

Beidou in 2020

According to the Ministry of Transport (MOT), China has BDS equipment in over 6.9 million commercial vehicles. About 31,400 postal and express delivery vehicles, 1,369 public transport ships and 300 general-purpose aircraft have BDS installed. China has issued a special plan for the application of BDS in railways, highways, waterways and civil aviation and is improving the standards and specifications for BDS terminals installed in vehicles, ships and aircraft to facilitate the application.

Since the opening of BDS to global users, major international smartphone manufacturers, including Apple, have widely supported Beidou. In the 4th quarter of 2020, 79 % of the smartphones in the Chinese market had applied for network access to support BDS positioning.

In October 2020, China and Russia agreed to increase the compatibility and interoperability of their global satellite navigation systems.

In 2020, the total output value of China's satellite navigation and positioning services industry reached 403.3 billion RMB (about 63.3 billion USD), up 16.9 percent compared with the volume in 2019.

BEIDOU APPLICATION

A geodetic masterpiece - measuring the height of Mt. Everest

The height of Mt. Everest as agreed between Nepal and China and announced on 8 December 2020 is 8,848.86 m.

President Xi Jinping sent a letter to his Nepalese counterpart, Bidya Devi Bhandari, to praise the work of the teams from both countries which carried out independent mountain tours and processed and evaluated the gained data.

The Chinese team succeeded to reach the summit during their 3rd attempt on 27 May. (compare: GoTaikonauts! issue no. 32).

The teams from China and Nepal calculated the height of Mt. Everest independently from each other, each team using their own collected data. Nepal had previously adopted an estimated height of 8,848 m made by India in 1954, while China measured it at 8,844.43 m in 2005. The difference in the figures takes into account the snow cap. Another problem was that China

used the Yellow Sea as the sea-level reference for the peak, but Nepal used the Indian Ocean. In line with international practice, it was finally decided to use the parameters of the alternative Global Geodetic Observing System endorsed by the International Association of Geodesy. The determination of the height of the mountain also answered the question whether the 2015 major earthquake changed the size of the peak.
The agreement between Nepal and China has also economic impact. Until now, most Everest climbers would take the route to the peak from Nepal earning them a certificate with the higher height in contrast of approaching the peak from the Northern, Chinese side. With the height harmonised the difference remains in the pricing. Nepal charges 50.000 USD per person heading towards the base camp while China charges 25.000 USD.

TELECOMMUNICATION / COMMERCIAL

13,000 satellite LEO constellation

At the beginning of October Larry Press, Professor of information systems at the California State University, mentioned in a blog of the CircleID website that China has submitted a spectrum application with the International Telecommunication Union (ITU) for two constellations named GW-A59 and GW-2 for a total of 12,992 satellites intended for orbits with an inclination between 30 to 85 degrees. Bhavya Lal, a Washington DC-based analyst, confirmed the announcement of a constellation with nearly 13,000 satellites.

COMMERCIAL SPACE

6th CCAF - China (International) Commercial Aerospace Forum in Wuhan

The 6th China (International) Commercial Aerospace Forum (CCAF) took place from 19-20 October 2020 as a hybrid event, hosted in Wuhan. Under the topic "Enjoy commercial aerospace in the cloud, leading the digital economy" more than 200 government officials, representatives from companies, universities, social organisations, investment and financing entities along with observers from China and space experts from Russia, the United States, Germany, France, and Italy joined the 2 days of the forum to discuss cutting-edge concepts, innovations, and development models in the field of global commercial space.
The CCAF is guided by the Ministry of Science and Technology, CNSA, CMSEO, and Hubei Provincial People's Government. It is co-hosted by CASIC, China Group Co., Ltd., China Aerospace Foundation, and China Astronautical Society.
Wang Zhonglin, Secretary of the Wuhan Municipal Party Committee of Hubei Province, Hao Chun, Director of CMSEO, Yuan Jie, Chairman of CASIC, and Yang Baohua, Deputy General Manager of CASC, attended the forum.
Fu Zhimin, Chief Technical Officer at CASIC said at the opening ceremony that China will continue building space infrastructure, enhance the capability of commercial space systems, and integrate them into major national development strategies. Advancements in the commercial space sector will also drive the sustainable development of strategic emerging sectors such as the digital economy, intelligent manufacturing and new materials. Part of that process is CASIC's continued development of the Kuaizhou series of launchers, taking advantage of their low cost, high reliability and short preparation time. CASIC's aim is to double the number of launches by 2023. Right now, CASIC is working on the development of the 25-m tall Kuaizhou 11 with a lift-off weight of 78 t and a 1-t payload capacity into a 700 km SSO.
CASIC's Hongyun system, China's 1st LEO broadband communications experimental satellite and ground facilities, has completed hundreds of in-orbit tests and produced a large quantity of data, laying a solid foundation for the construction of a space-based internet, Fu pointed out. CASIC intends to place more than 150 Hongyun satellites in a 1,000 km orbit around 2023.
The Xingyun project, China's first self-developed space-based IoT constellation, has currently 2 satellites in space. CASIC aims to deploy 12 Xingyun 2-series satellites in 2021 to join the first 2 spacecraft and then establish a small test system. The constellation is expected to be complete in 2023 with 80 LEO narrowband communications satellites and will be ready to provide low-cost and reliable services to global users in 2025.
The rocket industrial park in the Wuhan National Aerospace Industry Base has the capacity to produce 20 solid-fuel launch vehicles per year. The satellite industrial park inside the base will have an annual production capacity of 100 to 200 small satellites by the end of 2020.
China will enhance international cooperation and expand the global resource allocation capacity of commercial space technologies and products. The nation aims to provide more commercial space services to global users, especially to countries along the Belt-and-Road region. The forum also offers an important platform for international exchange and cooperation in the space industry, Fu said.
CASIC chairman Yuan Jie stressed that China's commercial space industry will scale new heights under the new economic development pattern of "dual circulation," in which domestic and overseas markets complement and reinforce each other, with the domestic market as the mainstay.
The forum was live streamed on CASIC's webportal. The replays of the conference talks are available online.
The CCAF is China's 1st and most important professional forum in the field of commercial aerospace. Started in 2015, the forum has been held for 6 consecutive years and has become the meeting place for national and international space professionals.
Already before the event, on 18 October, Huang Zhicheng of Foresight Think Tank gave a Cloud Course on the topic "Commercial Aerospace leads the new era of space economy", summarising the status in the global commercial space sector.

Report about the 6th CCAF by Blaine Curcio and Jean Deville

The replay of all conference talks is available on the conference website: https://ccaf.casicloud.com/2020/agenda_detail_en.html

Part 1: Context CCAF/ CASIC/Wuhan

Part 2: Talks non-CASIC companies

A new chapter in the 'space economy'

On 16 October, commercial space leaders, the President of the IAF, and young Chinese space entrepreneurs gathered on CGTN prime-time daily talk show "Dialogue" to discuss the "New Era in Commercial Space" and to share their insights on the quickly rising commercial space sector. "We're facing a high market demand for satellite launches … They are already queuing, waiting to be sent into space," said Kevin Xu, General Manager of Global Marketing and Services of Landspace, developing the Zhuque-2 liquid launcher, which is expected to become operational next year to meet the market demand for lower cost launch services.

Smart Satellite Manufacturing Facility

After 429 days of construction time, CASIC Space Engineering Development in Wuhan finished on 30 December 2020 building China's 1st smart satellite manufacturing facility in the Satellite Industrial Park of the Wuhan National Space Industry Base, in Xinzhou district. Also, the installation of equipment was ready by the end of 2020. Engineers and technicians are busy with testing until March when the highly automated satellite production is about to start. Once the full capacity is reached, the annual output of the factory will be 240 smallsats for CASIC's Hongyun broadband constellation, consisting of more than 156 communications satellites.

Once completed, the 28.4-hectare Satellite Industrial Park will be used for the research and development of space hardware and applications, including satellite internet and micro satellites, and will provide support for space monitoring, data processing and operations.

In addition, a manufacturing complex for CASIC's Kuaizhou rockets, just across the street from the satellite park, started with 1st phase operation at the 68.8 km^2 Wuhan National Space Industry Base, China's 1st commercial space industry hub. The rocket complex includes factories, testing facilities, office buildings and a power station. CASIC aims for an initial annual production capacity of 20 Kuaizhou rockets.

Photo taken on 28 December 2020 shows the smart production line of small satellites in the Wuhan Smart Satellite Manufacturing Facility. Credit: CASIC/Xinhua/Tan Yuanbin

CAS Space - Zhongke Aerospace

At the beginning of October, the city administration of Guangzhou and CAS Space started the construction of a rocket production facility in Guangzhou's Nansha district.

The initial annual production capacity is projected to be 30 rockets by the end of the 1st implementation phase around 2022.

The 40-hectare industrial complex will house facilities for designing, manufacturing, assembling and testing of liquid- and solid-propellant rockets as well as other space companies related to rocket engines, satellites and ground control and tracking. The project is part of a larger joint Guangzhou-CAS effort for a 99 km^2 Science City in Nansha which will become the research and industrial base for more than 10 CAS research organisations.

CAS Space is developing the Zhongke (ZK) launcher, a solid-propellant rocket with a payload capacity of 1.5 t.

The company has signed agreements of intent for launch service with 2 satellite manufacturers in Shanghai and Changchun.

The 1st launch of ZK-1 is planned for September 2021 with a space science satellite built by CAS.

CGWIC (China Great Wall Industry Corporation) - APT Satellite

On 6 November, CGWIC and APT Satellite signed a contract on the in-orbit delivery of the APStar-6E Satellite, to be launched in 2023 aboard a CZ-2C rocket.

The small GEO satellite, with a mass of around 1,300 kg, will be developed by CAST. The contract is worth 137.6 million USD including launch and insurance.

APStar-6E is a GEO high-throughput communication satellite based on the DFH-3E small satellite platform. Compared to the traditional satellite platform, DFH-3E is a highly cost-effective solution for regional and global satellite operators with less investment. APStar-6E will use a Ku-band HTS communication system to provide broadband satellite telecommunication services to the Asia Pacific region. CGWIC and APT, together with CAST and CALT, will establish a Joint Venture for the project.

Changguang Satellite (CGST)

On 28 November, CGST announced the completion of a 2.464 billion RMB (375 million USD) Pre-IPO round of financing. The investors include Hainan Qianyu, Haitong Innovation Private Equity, Shenzhen Venture Capital, Chentao Capital, CICC Capital, Yuzhi Capital, Hainan Jinkaiye, Hainan Kaixing, Loudi Yiding, Zhuque Equity, Matrix Partners China, Kunpeng Yichuang, HKUST iFlytek, Shanghai Sunda Investment, Zhongke Chuangxing, Jilin Zhongke Venture Capital, BRIC One, Changchun New Investment, Taihao (Shenzhen) Fund, PricewaterhouseCoopers, etc. The original shareholder Jilin Provincial Government Guidance Fund, Shenzhen Chenrui and the company's core fund continued to increase their capital.

The financing will be used for the construction of the Jilin 1 satellite constellation, the development of remote sensing data applications and the implementation of talent teams. The company plans to place 60 satellites in orbit in the 1st phase to achieve a global revisit time of 30 min. In the 2nd phase the network of 138 satellites should enable a global revisiting time of 10 min.

At the same time, the company will aim at key applications in the field of agriculture, forestry, water conservancy, transportation, environmental protection, urban construction, and other areas.

China Rocket

On 2 December, China Rocket Co., Ltd. - a subsidiary of CASC's China Academy of Launch Vehicle Technology, and the municipal government of Haiyang in Shandong Province signed a contract to build a 163-hectare production base for 20 solid-propellant rockets annually, including Smart Dragon series carrier rockets. The production base will also offer services such as rocket assembling, testing and seaborne rocket launch for domestic and overseas aerospace companies. The production facility is part of a comprehensive aerospace project currently under construction in Haiyang City. With an investment of 23 billion RMB (about 3.5 billion USD) and a planned area of 1,860 hectares, the project includes an aerospace industrial park, a homeport for seaborne rocket launches, and an aerospace-themed tourist park.

Video with footage and animation of the sea launch facility

China Rocket approved on 31 December 2020 the Smart Dragon 3 (SD-3, Jielong 3) project. Its 1st launch, from a platform at sea, is planned for the 1st half of 2022.

The 4-stage solid-propellant launcher, designed for land and sea launches, will have with 1.5 t to a 500 km SSO the largest and the highest carrying capacity among the Dragon series. In case of sea launch, the assembly and testing of the SD-3 will be carried out in Haiyang Port in Haiyang, Shandong Province. To meet the large-scale commercial launch demands, the rocket's multi-satellite launch capability is able to carry more than 20 satellites in a single mission, while the cost is just 10,000 USD/kg.

China Satellite Communications

China Satellite Communications, a CASC subsidiary, which offers satellite communications and broadcasting services worldwide, has announced a plan to raise up to 3.3 billion RMB (506 million USD) by selling shares to a group of investors. China Satellite plans to use the funds for 3 satellite services projects.

ChinaSat-16 5G Test

ChinaSat announced in November the country's 1st 5G broadband test using Ka-band GEO-HTS capacity, with the company's ChinaSat-16 satellite. The tests were carried out in cooperation with China Mobile and Huawei, and achieved download speeds of ~90 Mbps, upload speeds of 3.5 Mbps. China Satcom has been the 1st company in China to use 4G via Ka-band satellite, and is planning for 5G and 6G via GEO-HTS.

A model of the Jielong-3 (left) and its predecessors. Credit: China Rocket

China Telecom

China Telecom plans to launch the StarNet constellation of 10,000 satellites over the next 5-10 years. For that, the state-owned China StarNet enterprise will be established in Shanghai. At the same time, experts raised their concerns about StarNet's viability because China's 4G and 5G ground-based telecommunications infrastructure was well developed and accessible throughout the country including Tibet, Xinjiang and Inner Mongolia thanks to the initiative by the Central Government to expand telecom services with its no-village-left-behind project, implemented by China Telecom, China Mobile and China Unicom.

Deep Blue Aerospace

In December, Deep Blue Aerospace Technology Co., Ltd., conducted a wet dress rehearsal of its 7.3 m tall "Nebula-M" technology verification test vehicle. The company stated that it plans to follow up with static fire tests and subsequent hop tests for its reusable liquid-fuelled Nebula 2 rocket. The 2.25 m diameter Nebula 1 has a P/L capacity of 500 kg to 500 km SSO and the 3.35 m diameter Nebula 2 of 4.5 t to LEO.

Expace

Expace released photos of its Mingfeng methalox engine at the end of November. The engine completed a systems-level hot test, with the test verifying the integrity of the engine system, thrust chamber, combustor, turbo pump, valve, and final assembly.

Galactic Energy

At the end of October Galactic Energy announced a 200 million RMB (30 million USD) Series A round of funding, with investors including Qifu Capital, Dawa Capital, and others. The funds will be used to accelerate the development of the Ceres 1 and Pallas 1 rockets, expected to launch in 2020 and 2022, respectively.

Considering that Galactic Energy was founded in 2018 only and having now raised approx. 500 million RMB in total, the company is moving rather fast.

Galaxy Space

Galaxy Space completed a B+ round of a not specified amount of funding, with the company achieving a valuation of 8 billion RMB. The lead investor in this round is Nantong Technology Venture Capital. Other investors include Shunwei, Matrix China, and Chaos China. The new funding will support the construction of Galaxy Space's previously unveiled "Satellite Superfactory", in Nantong, near Shanghai. The highly automated factory will have an annual production capacity of 300-500 satellites per year.

IMST

In mid-December, the German government blocked an attempt by a CASIC subsidiary to buy the German company IMST which is among others, a provider of antennas for satcom and radar and known for radar module innovation which support 5G and 6G telecommunications solutions. IMST is also a key partner to the German Aerospace Centre (DLR).

Under new rules the German government may intervene if a foreign investor attempts to buy a 10% stake in a German company, rather than the previous threshold of 25%.

iSpace

During the 6th CCAF iSpace's Vice President Huo Jia discussed the company's plans for the Hyperbola 2 (HB-2) launcher, as well as projects beyond the HB-2 development. Until the end of 2020, iSpace intends to conclude a 100 km vertical take-off and landing experiment with HB-2 to test the landing process, engine throttling and control systems. A full orbital test would then follow. The Hyperbola 3 will become a medium-lift rocket, which could be converted to a heavy-lift launcher by adding 2 or 4 side boosters. Currently, the company is busy with the development of the 100 t-thrust Jiaodian 2 methalox engine.

iSpace performed in November supersonic wind tunnel tests of its Hyperbola rocket 1st stage vertical landing phase. For 2021, the company plans incremental take-off and landing tests starting in the range of meters and advancing to the kilometre level.

Also, the production of the fuel tank for the HB-2 rocket was completed. HB-2 will use liquid methalox fuel.

Landspace

In Episode 6 of the Dongfang Hour China Spacenews Roundup end of December, Blaine Curcio and Jean Deville had an exclusive conversation with Kevin Xu, Chief Marketing Officer at Landspace and one of the company's first employees. The conversation touched upon a wide-range of topics - asking Kevin Xu why he changed from a state-owned company to a private enterprise, what the status of the Chinese commercial space sector is and what the situation with Landspace is. The talk gives very interesting first-hand insight into Landspace's ambitions.

APSCC 2020 E-Series - Small Launchers - Is Government Key to Success?

Peter DeSelding is interviewing the heads of 3 international space start-ups among which is Roger Zhang, CEO of China's Landspace.

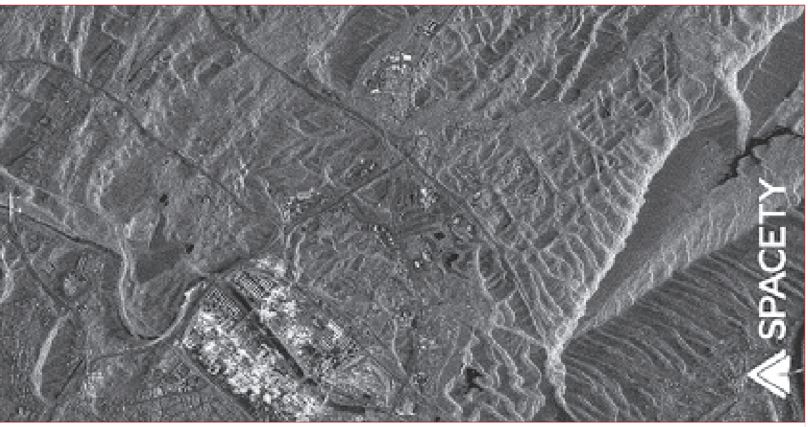
OneSpace

OneSpace announced a C-round of funding of an undisclosed amount in early-September. Investors are Liangjiang Investment Fund, Zhengxuan Investment, HIT Robotics Fund, and Huijin Capital. Most of them were already previous investors. With Liangjiang Group based in Chongqing where also OneSpace's HQ is, the engagement represents the latest example of a trend of the close involvement of regional and provincial governments.

SpaceTY

SpaceTY released on 30 December the 1st SAR imagery from its Hisea 1 (HS-1) satellite, the 1st commercial SAR satellite world-wide. It was launched on 22 December on board the CZ-8. Already 3 days after launch the company got the first data from the SAR instrument and on 27 December the 1st batch of imagery. The resolution is 3 m per pixel and 1 m with the spotbeam. SpaceTY aims for a 50 cm resolution once the planned 56 satellite TY-MiniSAR constellation is in space. The 185 kg C-band Synthetic Aperture Radar satellite HS-1 is the 1st satellite for that constellation. HS-1 is equipped with a ThrustMe's Iodine Electric Propulsion system by French start-up ThrustMe for attitude control, collision avoidance and de-orbiting at the end of its projected 3-year lifetime.

Before Hisea 1, the Beihangkongshi 1 cubesat, operated by SpaceTY was launched on 6 November 2020 by a CZ-6 and also equipped with a NPT30-I2-1U Iodine Electric Propulsion system by ThrustMe. After weeks of satellite commissioning, the propulsion system was successfully tested during two 90-



3 m resolution SAR image of Tennessee received by SpaceTY on 27 December. Credit: SpaceTY

min burns on 28 December 2020 and 2 January 2021, resulting in a total altitude change of 700 m.

Xi'an Ziyou Xingchen Tech Company

Xi'an Ziyou Xingchen Tech Co. (Freedom Star) is a new solid rocket developing company from Xi'an/Shaanxi Province. The company recently completed engine tests.

2020 investment in Commercial Space Sector

China's commercial aerospace sector saw in 2020 investment of 6 billion RMB (933 million USD), up from 1.9 billion RMB (296 million USD) in 2019, according to data platform Tianyancha.

INTERNATIONAL COOPERATION

AOGEO - Asia-Oceania Group on Earth Observations

On 31 October, the 3rd AOGEO (Asia-Oceania Group on Earth Observations) Workshop concluded in east China's Changzhou. The online meeting was attended by approx. 100 representatives from 16 countries and several international organisations. AOGEO has become the most extensive framework for international cooperation in the field of Earth observation in the Asia-Oceania region. The Group on Earth Observations (GEO) is an intergovernmental, consensus-based partnership that improves the availability of, access to and use of Earth observations for a sustainable planet. GEO comprises 4 regional initiatives, one of which is AOGEO. China was the rotating chair of the Group on Earth Observations (GEO) in 2020.

APSCO (Asia-Pacific Space Cooperation Organisation)

On 13 and 14 October, an APSCO delegation, led by Secretary-General Dr. Li Xinjun, visited the Northwestern Polytechnical University (NPU) to review existing cooperation, discuss options for new joint projects, and have a tour of NPU's research facilities and laboratories.

Over the last 2 years, APSCO and NPU have run the "APSCO-NPU Development Base for Aerospace Talent", which is a series of special knowledge training courses and hands-on experience on aerospace technologies as well as competitions for students and professionals from APSCO Member States. The cooperation also includes an internship programme. Both sides are interested in developing new training and education methods.

During the visit, Dr. Li Xinjun was awarded as the honorary researcher of NPU for his special contribution on talent cultivation and capacity building in aerospace technology.

APSCO - BRAIA (Belt-and-Road Aerospace Innovation Alliance)

APSCO representatives attended the BRAIA 2020 Council Meeting and General Assembly Meeting on 20 October, where BRAIA's research cooperation projects, future work plans and projects, the role of the Regional Development Centre-Africa and the Regional Development Centre-South Asia, and BRAIA new membership applications were discussed. APSCO supports the capacity building, education and training opportunities related to space in the Asia Pacific region.

APSCO – SOAP (Stereoscopic Seismic-ionospheric Observation Application Platform)

Most of the APSCO Member States are earthquake-prone countries in the Asia-Pacific region. The APSCO Earthquake Research Project is aimed at earthquake disaster-preventing research, by using observations from CSES satellite (China Seismic-Electromagnetic Satellite) in combination with ground-based observatories from Member States and other remote sensing data on the electromagnetic field, ionospheric parameters, and from infrared and hyperspectral sensors. All those data sources are integrated into the Stereoscopic Seismic-ionospheric Observation Application Platform (SOAP). The SOAP Opening Ceremony was held on 22 October 2020 at the National Institute of Natural Hazards (NINH), Ministry of Emergency Management of China (MEMC) in Beijing. After that, a technical visit to the NINH facilities included the dedicated lab created by NINH for the APSCO SOAP project coordination.

BOTSWANA

In November Botswana's Ministry of Environment, Natural Resources Conservation and Tourism (MENT) and China's Ministry of Ecology and Environment (MEE) signed a Memorandum of Understanding (MoU) to strengthen their efforts in dealing with climate change. One initiative will be the design of the Botswana Meteorological Satellite Transportable Ground System (BMTGS) by MEE and the delivery of components until 2022.

The BMTGS will be developed by Space Star Technology Co., Ltd., (SSTC) and includes a mobile antenna, data processing unit and power supply. Botswana engineers and technicians will be trained in-ground system design, operation, and maintenance to ensure the system's efficient operation once it is functional.

BRICS

In ESPI Insights, Issue 11, November 2020 it was reported that Brazil, Russia, India, China and South Africa (BRICS) concluded an agreement for a 3-year research project on quantum communication during the BRICS Civil Forum 2020 which took place from 23-25 September 2020 under Russian BRICS Chairmanship. The goal of "Satellite and fibre-optic communication of quantum communications" is to develop an intercontinental satellite quantum communication channel. The initiative is led by Rostec State Corporation and includes the participation of an international consortium of universities and institutions.

Ethiopia

The Ethiopian Remote Sensing Satellite 1 (ETRSS-1), the nation's 1st satellite, has been handed over to its Ethiopian operators during a delivery ceremony mid-December in Beijing. China also trained Ethiopian experts in satellite operations and climate change research. China will continue supporting Ethiopia's space capability development.

ETRSS-1 was built by CAST and launched in December 2019. The costs of the satellite's research, construction and launch were covered by the Chinese government.

EUMETSAT

On 23 November, experts from the China Meteorological Administration (CMA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) discussed meteorological satellite programmes, data exchange, and meteorological scientific cooperation. Both sides introduced their development programs and emphasised the success of the existing cooperative mechanism and are open to initiate more in-depth cooperation in fields like high-level dialogue, satellite data exchange and redistribution, remote sensing products application, and technical exchanges. Before that meeting, the 5th Technical and CMA-EUMETSAT Workshop was held online.

FRANCE

During a phone conversation on 9 December, Chinese President Xi Jinping and French President Emmanuel Macron reached consensus on the next stage of China-France space cooperation. The two Heads of State instructed their relevant departments to step up the implementation of more cooperation in fields such as biomedicine, biological breeding, Moon and Mars exploration and satellite research and development.

ITALY

China and Italy agreed during the 10th Joint Meeting of the China-Italy Government Committee on 29 December 2020 that space is one area for future cooperation. The meeting was co-chaired by China's Foreign Minister Wang Yi and Italian Foreign Minister Luigi Di Maio.

The Joint Press Release of the meeting mentions that both sides will continue to cooperate in the CSES-2 mission (China Seismo Electromagnetic Satellite 2), promote cooperation in the field of space sciences and space exploration, life sciences under the condition of microgravity as well as telecommunications, including quantum communication. Both countries agreed to continue exploring the flight opportunities related to Italian experiments aboard the Chang'e 6 and asteroid missions. Both sides intend to continue discussing the implementation of the HERD (High Energy Radiation Detector) scientific experiment on board the Chinese Space Station.

Link to PDF of the Joint Press Release of the 10th Meeting of the Government Committee Italy - China (in Italian language). Space related topics are mentioned under point 21:
https://www.esteri.it/mae/resource/doc/2020/12/comunicato_congiunto.pdf

Seychelles

Meteorological experts from The Republic of the Seychelles participated in the China Meteorological Administration (CMA) International Distance Training Course on the Application of Fengyun Satellite Products. They learned to use meteorology satellite data for tracking tropical cyclones and compile correct weather forecasts.

In 2020, CMA has held 5 online sessions of international training courses, participated in by 1,440 trainees from over 90 countries. Training content covers short-term climate monitoring and forecasting techniques, ground observation facilities installation, utilisation and maintenance, meteorological disaster preparedness technology, satellite product application, and other topics. Previously, this kind of training was carried out in China and about 300 trainees would participate in those courses each year.

RUSSIA

21st session of the Russian-China Subcommittee for Space Cooperation

On 19 October, the 21st session of the Russian-China Subcommittee for Space Cooperation took place via videoconference. The meeting was opened by Zhang Kejian Head of CNSA and Dmitry Rogozin, Director General of Roscosmos. Both sides reported on the latest developments in their respective space programmes, discussed the continuation of the work and protocol issues.

Prime Ministers agree on extended space cooperation

In the afternoon of 2 December, Premier Li Keqiang co-chaired the 25th Regular Meeting with Russian Prime Minister Mikhail Mishustin via video link. Mikhail Mishustin congratulated China on the successful landing of Chang'e 5 on the Moon and expressed Russia's willingness to accelerate space cooperation with China.

China-Russia lunar base cooperation

Sergey Savelyev, Deputy Director General for International Cooperation at the Russian state space corporation Roscosmos told Russian news agency TASS that Roscosmos is in talks with its Chinese colleagues to determine scientific tasks of mutual interest for a lunar base and to discuss technical aspects of the project's implementation. Talks with other space nations for participation in the project will be done once the agreements with the Chinese partners are worked out and a legal basis for cooperation is in place.

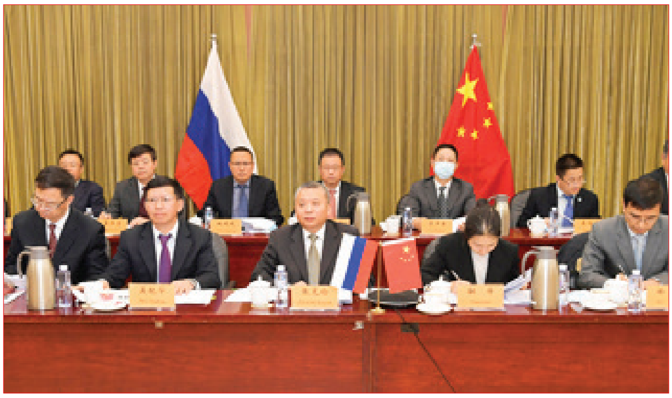
In December 2020, Roscosmos Director General Dmitry Rogozin said during a roundtable at the Russian Federation Council, the Upper House of the Russian parliament, that already in June, China suggested inviting Europe to the Moon exploration programme.

UKRAINE

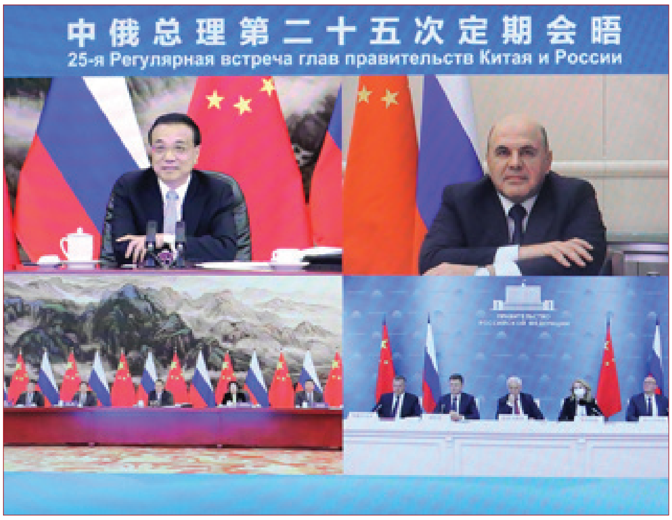
On 22 October, the 6th Meeting of the Ukrainian-Chinese Sub-Commission on Space Cooperation of the Commission on Cooperation between the Governments of the Ukraine and China was held online.

The meeting was co-chaired by the Head of the Ukraine State Space Agency, Volodymyr Usov and the Head of CNSA, Zhang Kejian. The event was also attended by representatives of leading enterprises and universities of the rocket and space industry of both nations. The parties discussed the results of the Ukrainian-Chinese Space Cooperation Programme for 2016-2020 and agreed to expand the mutual cooperation for the next 5-years from 2021 until 2025. The framework consists of 69 joint projects with a total contract value of more than 70 million USD. The cooperation programme will be the main one for joint medium-term activities of the two countries in space exploration. During the meeting, an agreement on the establishment of a joint laboratory of space science was signed and an agreement to strengthen the exchange of information on space activities of the two countries was reached.

The next meeting of the subcommittee on cooperation in the field of space is scheduled for 2021 in China.



21st session of the Russian-China Subcommittee for Space Cooperation. Credit: CNSA



Chinese Premier Li Keqiang and Russian Prime Minister Mikhail Mishustin announced the cooperation after meeting by video link. Credit: Xinhua

4th Consultative Meeting CMA and WMO

On 22 December, the China Meteorological Administration (CMA) and World Meteorological Organisation (WMO) held online, the 4th Consultative Meeting to promote regional meteorological cooperation in particular along the Belt-and-Road, review the achievements of 2020 and plan ahead. In 2020, both sides have cooperated with the World Meteorological Centre-Beijing (WMC-BJ), and other WMO centres for the implementation of the programmes of WMO at the regional level. Good results have been achieved in the application of Fengyun meteorological satellite services, the promotion of cooperation through global and regional centres, and international training. Both sides will continue to promote Fengyun satellites services on a global level, implement WMO demonstration programmes, meteorological cooperation and capacity building in countries along the Belt-and-Road.

MISCELLANEOUS

Why Is China Going to the Moon?

Following the successful conclusion of the Chang'e 5 mission, Namrata Goswami is taking a look at the motivations driving China's lunar programme for the political journal *The Diplomat*.

For China, the Moon is a pit stop or a base to enable it to become a truly space faring nation, reflecting civilisational vibrancy, ideological superiority, and technical prowess. Based on this, Namrata Goswami identifies 3 main reasons for China's lunar ambitions:

"Reason 1: The Moon Is a Tremendous Supplier of Energy
Reason 2: Demonstrating China's Space Capacity
Reason 3: China as the 21st Century Space Icon

Xi aspires to achieve an authoritarian-led space order with economic generosity and a carefully constructed narrative of "benefiting humankind". Lurking behind that feel-good narrative, however, is a highly nationalistic and ambitious space programme that aspires to establish China as the leading nation in space innovation by 2049. China's sophisticated lunar capacity plays a critical role in achieving that goal. That is why the Moon matters most."

2020 Global Multi-Hazard Alert System in Asia (GMAS-A) Workshop

On 15 December, the 2020 Global Multi-Hazard Alert System in Asia (GMAS-A) workshop was held online. Main topic was the challenges and opportunities of the meteorological early warning capacity in Asia. The participants agreed that emerging risks are not confined to a certain country and therefore, cross-nation and cross-sector cooperation should be reinforced regarding management mechanism and technological innovation, data sharing and coordination. Experts from meteorological departments from Indonesia, Japan, Turkistan, Myanmar, Thailand, and China briefed on weather and climate conditions in their respective countries, and early warning information, and proposed the establishment of online coordination mechanism of members. They also suggested ways to deepen the exchange of experiences such as workshops and training courses, and cross-sector programmes under the framework of the World Meteorological Organisation (WMO) to further elevate the early warning capacity in Asia.

EXHIBITION

The re-entry capsule of the Shenzhou 10 crew spacecraft arrived in the hometown of Chairman Mao Zedong in Shaoshan, Central China's Hunan Province on 20 December. It was officially handed over to the museum on 25 December with a ceremony. The spacecraft will be stored and exhibited in the Shaoshan Mao Zedong Memorial Museum, a national 1st-grade museum. It has a suitable indoor environment that meets the temperature and humidity requirement of storing the returned capsule. Also, out of the 5 million annual visits to the museum and 20 million to the city's scenic area, 45 % are middle and primary school students.

Zhang Xiaoguang, Shenzhou 10 crew member, was present during the hand-over ceremony in Shaoshan.

It is planned to exhibit also Chang'e 5 lunar samples in the Shaoshan museum.

2020 marked the 50th anniversary since Mao approved China's 1st manned spaceflight programme (Project 714), which included the Shuguang 1 spacecraft. Shuguang was never built but is considered as laying an important foundation for the development of the later manned space programme.

Zhang Xiaoguang, responsible for the docking of SZ-10 with Tiangong 1, unveiled the mission's re-entry capsule at a ceremony in Shaoshan, Hunan province. The capsule will become a permanent exhibit at the Mao Zedong Memorial Museum. Credit: China News Service

ON A SIDENOTE

China and Artemis Accords

During the Regular Press Conference of China's Ministry of Foreign Affairs on 15 October, Spokesperson Zhao Lijian was asked by the representative of the South China Morning Post: "NASA announced the signing of the Artemis Accords with seven other countries to set rules for exploring the Moon. China and Russia are not part of the Accords. What is your comment?"

Zhao Lijiang replied: "The exploration of the Moon is an important step in man's never-ending quest for the universe. China has always been committed to the peaceful use of outer space. Exploration and peaceful use of outer space is the common cause of all mankind and should benefit all mankind. China supports discussions on a legal system for space resource exploration on the UN platform within the framework of existing outer space rules to ensure that relevant activities are in line with the purposes and principles of the 1967 Outer Space Treaty. China is ready to continue international exchanges and cooperation with other parties in lunar exploration and work with other countries to make greater contribution to mankind's peaceful use of outer space and the building of a community with a shared future for mankind."

Russian-Sino space relations in good shape

Dmitry Rogozin, Director General of Roscosmos addressed the current state of affairs regarding Russian-Sino space cooperation during an online Heads of Agencies Panel at the 71st International Astronautical Congress on 12 October: "I would like to mention especially open and friendly relations with China, and China National Space Administration and its head, Mr Zhang Kejian. We believe there is more to come in these relations."

China as the U.S.'s competitor

Daniel Goldin, NASA's Administrator from April 1992 to November 2001, said in an online seminar hosted by Aviation

Week Network on 9 October, that China could be the U.S.'s next big competitor in space: "So my admonition to whoever is leading NASA, after January 2 next year: pay attention, China is out there, American leadership is absolutely necessary for the survival of democracy on our planet, and we need to learn how to go faster, and we need to damn-well get out of Earth orbit."
He also recalled: "I spent 25 years of my life at a company called TRW, now Northrop Grumman. I had a staff of 10,000 people. We were working to bring down the Soviet Union. I show up on my first day on the job [at NASA], and President George H.W. Bush asks me to go work with the Russians. It was a little traumatic."

Community of Shared Future for Humankind

"The Disarmament and International Security Committee (1st Committee) of the 75th session of the UN General Assembly adopted on 6 November a resolution about weapons in outer space, which contains the concept of "a community of shared future for humankind" put forward by China. A preambular paragraph of the resolution, titled "No First Placement of Weapons in Outer Space", reaffirmed that practical measures should be examined and taken in the search for agreements to prevent an arms race in outer space in a common effort toward a community of shared future for mankind. "No First Placement of Weapons in Outer Space" is a traditional resolution of the UNGA 1st Committee and has been adopted by a vote every year since 2014. The concept of "a community of shared future for humankind" has been included in the resolution since 2017. Outer space is also seen as the “common heritage of mankind". That is in line with the principles of the Outer Space Treaty, stressing that space is for the use of all, should be preserved for future generations, and is not controlled by any nation.

Biden space advisers urge cooperation with China

An article on webportal Politico cites top advisers to incoming U.S. President Joe Biden who point out that it's important to cooperate with China on space exploration, even as the incoming administration treats Beijing as its top economic and military competitor in virtually every other realm. There is the view that a limited space partnership between Washington and Beijing could reduce tensions and the likelihood of a destabilising space race. The move would be akin to the cooperation between the U.S. and Russia's civilian space programmes during the height of the Cold War.

TV series

"The Great Aerospace", a television series with stories of China's space projects, began filming on 6 December. A kick-off ceremony was held in Beijing, attended by representatives from the country's space sector including Yang Liwei. The series will focus on the development of the manned spaceflight capacities, the Chang'e lunar exploration programme and the Space Station project. The film crew will go to original locations such as the space launch sites in Jiuquan and Xichang, as well as other space landmarks.

Qian Xuesen: The man the US deported - who then helped China into space

The BBC published a story by Kavita Puri about the Chinese scientist who helped not one but two superpowers to reach the Moon but his story is remembered in only one of them.

link to the BBC article ...
https://www.bbc.com/news/stories-54695598

link to the BBC podcast...
https://www.bbc.co.uk/sounds/play/w3ct1642

Space Mass Wedding in 7 space cities

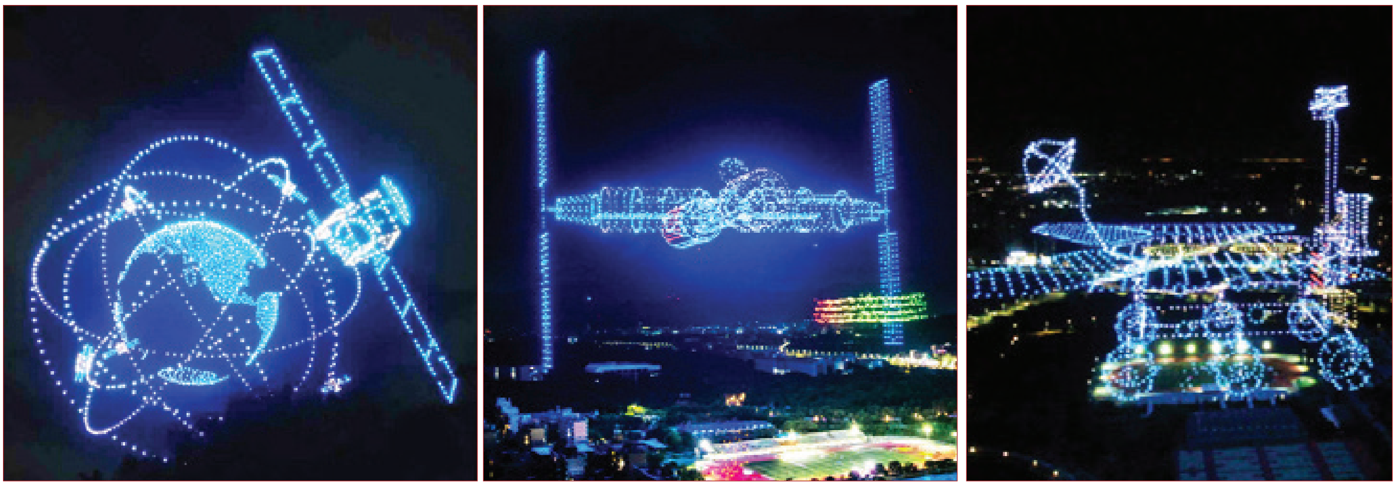
On 1 October, 301 couples working in the space sector held a joint wedding ceremony across 7 towns starting at 9:59 BJT. The linked locations and the number of couples were as follows: 82 couples in Beijing Aerospace City, 71 pairs in Jiuquan Satellite Launch Centre, 16 pairs at the Yuanwang Wharf of the China Satellite Marine Monitoring and Control Department, 35 couples in Taiyuan Satellite Launch Centre were planting each a tree, 45 couples in Xi’an Satellite Measurement and Control Centre, 37 couples in Xichang Satellite Launch Centre, and 15 couples in China Wenchang Space Launch Centre.

Drone World Record pictures China's space programme

https://www.guinnessworldrecords.com/news/2020/10/3051-drones-create-spectacular-record-breaking-light-show-in-china

or on YouTube:
https://www.youtube.com/watch?v=44KvHwRHb3A&feature=emb_logo

Shenzhen Damoda Intelligent Control Technology Co., Ltd., (China) in Zhuhai, Guangdong province formed a team to break the world record for the most simultaneously airborne Unmanned Aerial Vehicles (UAVs). On 20 September 2020, at 3:45:39 BJT, 3,051 UAVs took off and broke the previous records set by Intel Corporation (USA) with 2,066 UAVs in the air over Folsom, California, USA on 15 July 2018 and a 2,200 UAV display in Russia on 4 September 2020. The drone flight formations in Zhuhai formed pictures of China's space programme, such as the Tiangong 1, Beidou satellite system and China’s Space Station.



Drones are forming the Beidou Navigation System (left), the Chinese Space Station (middle) and the Zhurong Mars rover (right). Credit: Shenzhen Damoda

LAUNCHES

2019-071A
11 October 2020 - 16:57 UTC (12 October, 00:57 BJT)

launch site: Xichang Satellite Launch Centre (XSLC)
launcher: Chang Zheng 3B - CZ-3B
payload: Gaofen 13 (GF-13)

The launch of the GF-13 optical remote-sensing satellite from Xichang was the 1st launch after works for the modernisation of the space port finished. The launch pad and the ground systems were improved. Big efforts were made to introduce innovative support systems which shorten the time for launch preparations to meet the increasing demand for launch services.
Just over an hour after launch, CASC confirmed the successful launch of the GEO satellite. It will be positioned at 117,9°East and has a designed lifetime of 8 years.
The 4.6 t GF-13 is a box-shaped satellite with 2 solar panels and a 1.76 m diameter telescope unit with a 1.5 m telescope mirror. The 2 cameras work in the visible/near-infrared spectrum with 15 m resolution, in the micro-wave-infrared band with 150 m resolution and in the long-wave-infrared spectrum with a resolution of 400 m.
It will be mainly used for land surveys, crop yield estimations, environmental protection, weather forecasting, and early warnings, as well as disaster prevention and mitigation.
Gaofen 13 launch also involved the 1st use of an upgraded payload fairing for the Long March 3B.

2019-076A 2019-076B
2019-076C 2019-076D
26 October 2020 - 15:19 UTC (23:19 BJT)

launch site: Xichang Satellite Launch Centre (XSLC), LC-3
launcher: Chang Zheng 2C - CZ-2C
payloads: Yaogan 30-07-01 (YG 30-07-01, Chuangxin 5-19, CX 5-19)
Yaogan 30-07-02 (YG 30-07-02, Chuangxin 5-20, CX 5-20)
Yaogan 30-07-03 (YG 30-07-03, Chuangxin 5-21, CX 5-21)
Tianqi Xingzuo 06 (TQ-6)

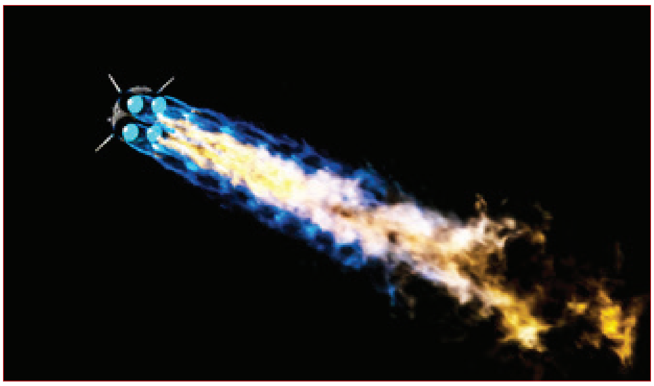
The 7th trio of Yaogan remote-sensing satellites have entered the planned orbit in 595 km altitude, inclined by 35°. By 7 November, the satellites reached their positions spaced by 120° to each other. The satellites will be used for electromagnetic environment detection and related technological tests.
As a secondary payload, a small **Tianqi 6** satellite belonging to the Tianqi narrow-band IoT constellation of Guodian Gaoke Technology Co. Ltd. was also on board. The Tianqi constellation is planned to have 38 satellites and to be completed before the end of 2021. So far, 6 satellites are in orbit now. Although focused on IoT, it also has AIS and ADSB capabilities serving the marine sector in Qingdao. The satellites will collect data for the marine logistics system and monitor the ocean's ecological environment. TQ-6 was reported to have also a camera for educational purposes on board.
According to CALT, the fairing was equipped with a landing zone safety control system to minimise the risk of hitting inhabited areas in the dropping zones. Major devices embedded in the system are all recycled from a former experimental launch in July 2020.
Also compare: "CALT's smart rockets" under TRANSPORTATION.

2020-079B	2020-079E	2020-079N?
2020-079F	2020-079D	2020-079L?
2020-079C	2020-079P	2020-079M?
2020-079A	2020-079J	
2020-079G	2020-079K	

06 November 2020 - 03:19 UTC (11:19 BJT)

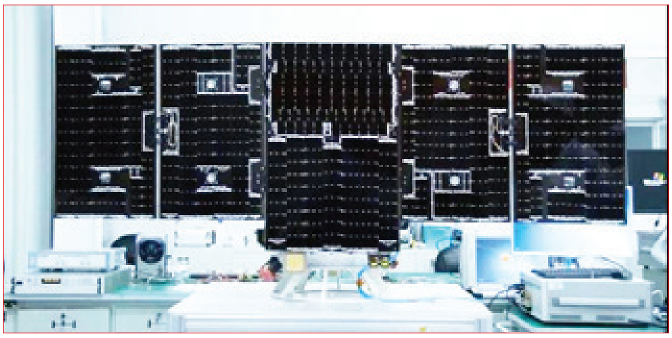
launch site: Taiyuan Satellite Launch Centre (TSLC), LC-16
launcher: Chang Zheng 6 - CZ-6
payloads: ÑuSat-09 (NewSat 09, Aleph 1-9, Alice (Ball))
ÑuSat-10 (NewSat 10, Aleph 1-10, Caroline (Herschel))
ÑuSat-11 (NewSat 11, Aleph 1-11, Cora (Ruto))
ÑuSat-12 (NewSat 12, Aleph 1-12, Dorothy (Vougham))
ÑuSat-13 (NewSat 13, Aleph 1-13, Emmy (Noether))
ÑuSat-14 (NewSat 14, Aleph 1-14, Hedy (Lamass))
ÑuSat-15 (NewSat 15, Aleph 1-15, Katherine (Johnson))
ÑuSat-16 (NewSat 16, Aleph 1-16, Lise (Meitner))
ÑuSat-17 (NewSat 17, Aleph 1-17, Mary (Jackson))
ÑuSat-18 (NewSat 18, Aleph 1-18, Vera (Rubin))
Tianyan 05 (MN50-3, UESTC)
Taiyuan BY70-3 (Bayi-03, BY70-03)
Beihang Kongshi 1 (Beihang SAT-1, TY-20)

The CZ-6 launched a cluster of 13 satellites into a 470 km heigh and 97.3° inclined SSO. 10 out of the 13 satellites were the commercial remote sensing satellites ÑuSat 9 to 18 (NewSat). They are owned and operated by Uruguayan/Argentine company Satellogic and were built at its production facility in Uruguay. The satellites got named after 10 pioneering women in science, technology, engineering and mathematics.
Satellogic is the world first vertically integrated geospatial analytics company – what means: from the design and manufacturing up to the operation of the satellites including the data products is all done by one company.
Each of the 10 ÑuSat weighs about 41 kg, is equipped with multi-spectral and high-resolution imagers and has a design life of 3 years. They will become part of the 90 satellite Aleph-1 network. 21 of them are in orbit, of which 17 were launched by China. The constellation will provide global commercial remote sensing services with a resolution of under 1 m and a revisit time of up to 4 x per day. The launch is part of a service contract signed in January 2019 by Satellogic and China Great Wall Industry (CGWIC). CGWIC will also launch the rest of the satellites for the initial 90 satellite Aleph constellation while Satellogic plans to use SpaceX launch services for the 2nd generation constellation.



left: A CZ-2C takes off from XSLC with a new triplet of Yaogang satellites. Credit: Yu Ming/China Daily
right: The CZ-2C payload fairing is lifted by a crane in September 2020. Credit: CASC

The 10 Satellogic NewSats. Credit: Satellogic



UESTC satellite. Credit: UESTC

Additionally, 3 Chinese satellites were on board.

MN50-3, Tianyan 05, UESTC

Tianyan 05 is also called UESTC-Sat, after the University of Electronic Science and Technology of China in Chengdu. The 70 kg satellite, based on the MN50 bus, was jointly developed by UESTC, MinoSpace and ADASpace. The imaging payload can deliver data for smart city construction, disaster prevention and mitigation, land planning, environmental protection, and the monitoring of major infrastructure construction. On board was also the world's 1st 6G THz experimental communication payload for testing new spectrum bands that will be used for future networks with superior speeds, capacity, and latency. Although it is not yet known how fast 6G is, experts' estimation is somewhere in the range of 100-500 GHz, about 100 times faster than 5G.

Taiyuan BY70-03, Bayi-03, TY-20

Taiyuan BY70-03 (Chinese Youth Science Satellite BY-03), is a 30 kg amateur radio satellite which was built for the China Centre for Aerospace Science and Technology International Communications (CCASTIC) and the North-western Polytechnical University (NPU) with the involvement of students from the Taiyuan Jinshan Middle School.

The satellite is equipped with an UV-telescope for observing celestial bodies. The telescope was developed by Origin Space, a Chinese asteroid mining company. It also carries an imager for Earth observation and educational activities.

Beihang Konghsi 1, Beihang SAT-1

Beihang Konghsi 1 is a 12U scientific, experimental cubesat and was built by SpaceTY and Beihang University (BUAA). It carries technology payloads which includes a ThrustMe NPT30-I2-1U electric propulsion system by French startup ThrustMe. It is a follow-up to the cooperation between ThrustMe and SpaceTY when the first NPT30-I2 was launched on the Xiaoxiang 1-08 satellite on 3 November 2019. During that mission, critical technologies for iodine storage, delivery, and sublimation as part of an in-orbit demonstration of ThrustMe's I2T5 iodine cold gas thruster were tested.

The NPT30-I2 thruster uses iodine propellant, reducing cost and complexity for spacecraft control or de-orbit manoeuvres. After several weeks of satellite commissioning, the NPT30-I2-1U propulsion system was operated during two 90-min burns resulting in a total altitude change of 700 m.

On 28 December 2020, the 1st iodine electric propulsion system to be launched into space was successfully fired, with a 2nd successful test on 2 January 2021.

The satellite will also carry out in-orbit experiments including receiving and retransmitting ADS-B signals from aircraft, and exploring laser data transmission technologies. Beihangkongshi 1 is the 1st technology demonstration mission in China to demonstrate the technology for automatic airplane tracking. It can provide information services such as communication, navigation, and surveillance for a wide range of aviation users, and enhance the capabilities of existing air traffic control systems.

2020-080A
07 November 2020 - 07:12 UTC (15:12 BJT)

launch site: Jiuquan Satellite Launch Centre (JSLC), mobile base/separate place for commercial launches
launcher: Ceres 1 (Gushenxing-1)
payload: Tianqi 11 (TQ-11)

The 1st launch of the solid-propellant Ceres 1 rocket by Galactic Energy (Beijing Xinghe Dongli Space Technology Co. Ltd.) successfully placed the 50 kg data relay microsatellite Tianqi 11 (TQ-11) into a 500 km orbit, inclined by 97.4°.

TQ-11 is another data collection and transmission satellite for the Tianqi IoT constellation of Guodian Gaoke Technology Co. Ltd. It was built by Shanghai ASES Spaceflight Technology Co. Ltd. TQ-11 is also named ASES-014, Scorpio 1 or Apocalypse 11.

Galactic Energy is the 4th Chinese commercial launch provider to attempt an orbital launch (after Landspace, OneSpace, iSpace). The 4-staged Ceres 1 is powered by solid fuel in the first 3 stages and by liquid fuel in the advanced upper stage, conducting the orbit insertion. The payload capacity is 350 kg to a 200 km LEO or 230 kg to a 700 km SSO. Ceres 1 is 19 m tall, has a diameter of 1.4 m, and has a launch mass of 30 t.

Galactic Energy is re-using demilitarised solid motors for its Ceres 1 rocket which is the 1st step in the development of the larger Pallas 1, a kerosene fuelled rocket with reusable boosters and VTVL technology (vertical take-off - vertical landing).

The Galactic Energy team nicknamed their mission „I believe I can fly“, celebrating the launch delayed from the beginning of 2020 because of the Corona pandemic.

The Ceres 1 is named after the 1st asteroid/dwarf planet discovered in 1801. Ceres is the goddess of agriculture and harvest in Roman mythology.

The Pallas 1 consequently got the name of the 2nd asteroid discovered by humans. The name Pallas refers to the Greek goddess Athene.

2020-082A
12 November 2020 - 15:59 UTC (23:59 BJT)

launch site: Xichang Satellite Launch Centre (XSLC), LC2
launcher: Chang Zheng 3B - CZ-3B
payload: Tiantong 1-02

Tiantong 1-02 is a S-band mobile telecommunication satellite, operated by ChinaSatcom. It was launched into geostationary transfer orbit and will reach its designated position in GEO within a week. It is the 2nd and strongly improved satellite for the Tiantong 1 satellite mobile communication system, consisting of a space segment, ground segment, and user terminals. Tiantong 1-01, the 1st satellite of the constellation, was launched in August 2016.

Both Tiantong satellites were built by CAST based on the DFH-4 satellite bus. The box-shaped, 4.6 t satellite has 2 solar panels and a big, deployable parabolic antenna. Its designed life time is 15 years.

The system will provide mobile communication services including voice, short text message and data. For that the CMMB-multi-media standard is used. The satellite will serve 300,000 terminal users from a wide variety of industries in China and the neighbouring region, including countries in the Asia-Pacific, Middle East and Africa, in particular in region without terrestrial communication infrastructure.

2020-087A
23 November 2020 - 20:30 UTC (24 November - 04:30 BJT)

launch site: Wenchang Space Launch Centre (WSLC), LC101
launcher: Chang Zheng 5 - CZ-5
payload: Chang'e 5 (CE-5)

The launch sent China's 6th lunar mission (including CE-5 T1) into LEO and from there onwards into Earth-Moon transfer trajectory. The CE-5 lunar sample return mission was planned to bring 2 kg of lunar material back to Earth, concluding the 3rd Phase of China's Lunar Exploration Programme - CLEP.
The 8.2 t lunar probe consisted of an orbiter, lander, ascent stage and return capsule. The lander is based on the CE-3 spacecraft bus, equipped with 2 solar cells, 4 landing legs and a controllable main engine. It has a sampling system for the surface operations and technical support systems, panorama camera, spectrometer.
On 1 December, the lander touched down at 51.9°W, 43.1°N in the region of Mons Rümker in the Ocean of Storms (Oceanus Procellarum). Shortly after landing, 1.731 kg of lunar material was sampled, only a little bit short of the planned 2 kg. Already on 3 December the ascent stage took off again into lunar orbit. After rendezvous and docking, the sample container was transferred to the return capsule. On 6 December UTC the ascent stage undocked and impacted the lunar surface 44 h later near 0°E, 30°S. On 12 December UTC, the orbiter made an orbital manoeuvre which prepared for departure to Earth 24 h later. On 16 December UTC the return capsule separated from the orbiter and started a skip-reentry. The orbiter continued its mission and arrived at Earth-Sun-L1. The re-entry capsule successfully landed in Siziwang Banner on 16 December 2020 at 17:59 UTC (17 December 01:59 BJT).
A detailed 2 part mission report can be found in GoTaikonauts! Issue no 31, page 24-28 (Part 1) and in this issue on pages 29-35 (Part 2)

2020-092A
06 December 2020 - 03:58 UTC (11:58 BJT)

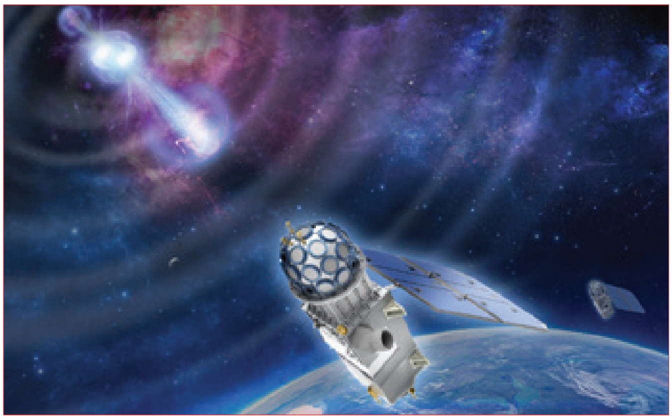
launch site: Xichang Satellite Launch Centre (XSLC)
launcher: Chang Zheng 3B/G5 - CZ-3B/ G5
payload: Gaofen 14 (GF-14)

For the 1st time the CZ-3B launched an EO satellite into SSO. For that purpose, the G5 variant was used which has a 90 cm extended payload fairing. CALT engineers introduced another 12 modifications in the rocket's control system software and in the manufacturing process to ensure that the rocket is optimised for SSO missions.
The GF-14 satellite is a box-shaped satellite with 2 big solar panels. The payload consists of an extensive set of 3 cameras for high-resolution overview and topographic imaging. It was reported that the remote sensing system was built in Belarus. The data delivered by the satellite are global high-definition stereoscopic images that can be used to generate large-scale digital topographic maps, digital orthophoto maps and other products.
Gaofen satellites are part of China's CHEOS programme - China High-Resolution Earth Observation System.

2020-094A
2020-094B
09 December 2020 - 20:14 UTC (10 December - 04:14 BJT)

launch site: Xichang Satellite Launch Centre (XSLC)
launcher: Chang Zheng 11 - CZ-11
payloads: GECAM-A (Xiaoji)
GECAM-B (Xiaomu)

The GECAM (Gravitational Wave High-energy Electromagnetic Counterpart All-sky Monitor) mission is composed of two identical small satellites: Xiaoji and Xiaomu (also: KX 08A and KX 08B).
The satellites, built by the Shanghai Engineering Centre for Microsatellites, have a mass of 150 kg each, are 130 cm tall, equipped with a solar panel and have a box-shaped satellite body with a payload section consisting of 25 gamma-ray detectors and 8 particle detectors and arranged like a dome at the one end of the satellite body. They are positioned in a 600 km orbit on opposite sites of the Earth in a way that both together can monitor the whole sky.
The two satellites will be used for the detection of electromagnetic counterparts of gravitational waves and to monitor high-energy celestial phenomena such as gravitational wave gamma-ray bursts, high-energy radiation of fast radio bursts, special gamma-ray bursts and magnetar bursts, and to study neutron stars, black holes and other compact objects and their merger processes. In addition, GECAM will detect solar flares, terrestrial gamma ray flashes and terrestrial electron beams, as well as further investigate their physical mechanisms.
The GECAM project is under the responsibility of the Chinese Academy of Sciences. Chinese scientists proposed GECAM in 2016, just 1 month after gravitational wave detectors in the U.S. discovered a black hole merger. *Science* magazine reported that "the mission gives China an emerging role in what's called multi-messenger astronomy, which relies on gathering the complementary information carried by photons, gravitational waves, neutrinos, and cosmic rays that can be emitted simultaneously by cosmic events. In the case of gravitational waves, for example, the additional electromagnetic signals can help distinguish neutron star mergers from black hole-neutron star combinations."


Artists Impression of GECAM. Credit: IHEP

2020-102C 2020-102D
2020-102B 2020-102E
2020-102A
22 December 2020 – 04:37 UTC (12:37 BJT)

launch site: Wenchang Space Launch Centre (WSLC), LC201
launcher: Chang Zheng 8 - CZ-8
payloads: Xinjishu Yanzheng 7 (XJY-7)
Hisea 1 (Haisi 1, MINISTAR-Bus)
Yuanguang
Tianqi 8 (Ping'an 1)
ET-SMART-RSS (Ethiopian-SMART-Remote Sensing Satellite; EthSat; Zhixing 1A)

The launch was the 1st flight of the new generation CZ-8 rocket. The launcher fills a gap for mainly commercial payloads in the range of 3-4.5 t to SSO. The payload capacity to LEO is 8.4 t and to GTO is 2.8 t.
The CZ-8 is 50.3 m tall, has a lift-off weight of about 356 t. It has a modular design and incorporates technologies that have been used by the CZ-3A and CZ-7.
The core stage has a diameter of 3.35 m and is propelled by 2 YF-100 engines burning kerosine and LOX. The 1st stage's 2 boosters have a diameter of 2 m each and are also powered by YF-100 engines.
Its core stages are basically identical to those used for the CZ-7 and CZ-3A. The 1st stage and boosters are intended for future recovery and reuse in a variant tentatively named CZ-8R.
The rocket's 2nd stage, derived from the CZ-3B's 3rd stage, has 2

YF-75 cryogenic engines (LH/LOX). Another variant is planned without boosters and will be named CZ-8A. The CZ-8 variants are intended to replace the older hypergolic CZ-2, CZ-3 and CZ-4 launchers. CALT's experts have estimated that there is a demand for 10 annual CZ-8 launches, with a soon available yearly production capacity of 20. The CZ-8 can be launched from Wenchang or Jiuquan.

15 min after lift-off, the 1^{st} launch of the CZ-8 rocket put the classified remote sensing technology test satellite Xinjishu Yanzheng 7 (New Technology Verification) into a 512 km SSO. The satellite was built by CAST. Very little detail became known about this satellite.

As secondary payloads, 4 other satellites were released in the same orbit as XJY-7.

Hisea 1, built by Tianyi Space Technology (SpaceTY) is the world's first miniaturised C-band Synthetic Aperture Radar (SAR) satellite with a phased-array antenna. The satellite is the 1^{st} of the company's TY-MINISAR series, the first generation of light and small SAR satellites. It is light weight, has a small volume, low-cost, and high-resolution. It is a flat-panel foldable satellite with a mass of 185 kg and a thickness of 7.5 cm. It has a resolution of 1 m in spotlight mode with a phased-array antenna. SpaceTY aims for increasing the resolution to 0.5 m, while further reducing the mass, the volume, and also the cost of the satellite.

On board is a ThrustMe's NPT30-I2-1U Iodine Electric Propulsion system to provide the satellite with crucial orbit maintenance, collision avoidance and de-orbiting at the end of its 3 years expected lifetime.

Hisea 1 was launched to meet the needs for monitoring of ocean and coastal areas and for ocean research. The imagery from the satellite will also be used for disaster management, agriculture, and infrastructure monitoring.

After commissioning and verification, on 25 December 2020 at 23:59 BJT, the 1^{st} radar data were received. On 27 December, the 1^{st} batch of high-res SAR images was acquired. The images were produced in strip mode with a 3 m resolution. The SAR imaging areas covered include Asia, North America, South America, Europe and Antarctica, with typical landforms of cities, mountains, fields, forests, rivers, lakes, glaciers and coasts. More testing and calibration will be done before SAR image data services will be provided to users.

Yuanguang is a 12U and 20 kg space science, material research and technology test satellite, jointly developed by Hubei University of Technology and SpaceTY. It has a tribology experiment on board, along with a material degradation, astronomical, biological and a GNSS-RO meteorology payload for Tianjin Yunyao Aerospace Tech Co.

Tianqi 8 is another satellite for the Tianqi (Apocalypse) IoT constellation for commercial company Guodian Gaoke - see above: launch 2020-080A

ET-SMART-RSS (Ethiopian-SMART-Remote Sensing Satellite) Ethiopia launched its 2^{nd} satellite with Chinese help. The Ethiopian Smart Remote Sensing Satellite, in short: ET-Smart-RSS, is a 8.9 kg, 6U cubesat for high-resolution Earth observation. The satellite was jointly built by engineers from the Ethiopian Space Science and Technology Institute (ESSTI) and Beijing Smart Satellite Technology (SMART - Beijing Zhixing Space Technology Co. Ltd.,). The preliminary design was conducted in Ethiopia, while detailed and technical works were undertaken in cooperation with Chinese experts in China via online-collaboration tools.

As a result of this cooperation, ESSTI and SMART are looking for opportunities to jointly develop business models in Africa. The Deputy Director General of the Ethiopia Space Science and Technology Institute (ESSTI), Yishrun Alemayehu, confirmed that the government of China paid about 1.5 million USD for the manufacturing costs and were funded via the BRI and Sunny Group. Ethiopia plans to launch 15 satellites between the next 10-15 years.

2020-103A
27 December 2020 - 15:44 UTC (23:44 BJT)

launch site: Jiuquan Satellite Launch Centre (JSLC), LC43/94
launcher: Chang Zheng 4C - CZ-4C
payloads: Yaogan 33
Weina Jishu Shiyan Weixing (Weina 2)

The new Yaogan 33 remote sensing satellite entered the planned orbit successfully. China assigned to this satellite the number of a satellite lost during a launch failure in May 2019. It is assumed that it is not a replacement just a re-use of the naming. There were not many details available on the launch or the satellite. However, it was reported that weather conditions at launch were extremely cold, bringing great challenges to the launch preparations. The ground team applied additional measures for protecting the hardware and equipment.

The mission also sent the **Weina 2** 'Micro-Nano Technology Test Satellite' experimental micro satellite into orbit.

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
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"I am rather thinking of a perspective in which there will be a balanced world space programme ..."

interview with Professor Michel Blanc

Prof. Michel Blanc in front of the Confucius statue on the campus of the Huazhong University of Science and Technology (HUST) in Wuhan, May 2019. Credit: Ms. Prof. Linli GUO

Prof. Blanc - you are mostly known as an astronomer at the Research Institute in Astrophysics and Planetology (IRAP - Institut de Recherche en Astrophysique et Planétologie) in Toulouse, France. With 244 publications assigned to you at the online science publication platform Researchgate, you are obviously a very experienced scientist. What is your main field of expertise? Which are your most important scientific achievements?

With a background as an astrophysicist, I have been a space scientist for quite a long time. I studied physics and mathematics at school and at the École Polytechnique. Then I did my master in astrophysics at the Observatoire de Paris-Meudon under the guidance of Prof. Evry Schatzman, one of the founders of modern astrophysics in France.

My professional career started as telecommunication engineer back when I was working for the French Administration for Telecommunications. There was a space environment department, because it was relevant to understand how radio waves are propagating in the medium of space. My PhD research about the ionosphere of the Earth brought me to geophysics. My PhD topic was about the global effects of magnetic storms and solar activity interacting with the Earth’s upper atmosphere and environment. That was my first achievement: I could show how the energy input into the upper atmosphere produced by solar activity, entering first through the polar regions, is redistributed throughout the globe by different propagation mechanisms which disturb the upper atmosphere and ionosphere, extending to mid-latitude and even up to the Equator. I did observations with the French ionospheric incoherent scatter radar and developed a model which showed how magnetic storms influence the global ionosphere.

In 1988 I was offered the position of director of the Midi-Pyrenees Observatory in Toulouse. Consequently, I moved towards astrophysics and planetary science. I was involved in the NASA-ESA Cassini-Huygens mission to Saturn - from the beginning in 1989 until the time when the probe was destroyed in Saturn’s upper atmosphere in 2017. I became a sort of specialist of Saturn’s magnetosphere. Then I was involved in Juno, the NASA mission which currently orbits Jupiter.

To answer your question about my main achievements, I would say 3 things. The first is my work about global effects of magnetic storms on the upper atmosphere of the Earth. Second, I would like to mention that I led the team that proposed to ESA the mission concept that was called by that time Laplace. It was a proposal to fly to the Jupiter system and its Moon Europa. The idea was finally implemented as the JUICE deep-space mission to be launched in 2023. The third thing I am proud of is that I have been the initiator and the 1st coordinator of Europlanet, which is a European network of planetary science and scientists. We used the Cassini-Huygens mission as a project around which to unite European planetary scientists. We had realized that there were almost as many Europeans as Americans involved in the Cassini-Huygens mission. But, while the Americans were all funded by NASA – giving them a frame for a sort of unity of action, the European scientists were all funded independently by their different national space agencies – with the consequence of scattered efforts. We realised that shortcoming and proposed to the European Union that we should have an umbrella entity for European planetary science. That's how Europlanet started. It was very successful, leading to an annual convention of European planetary science and to the development of community tools accessible to all Europeans, and beyond - I think that's the most important for me.

That is – indeed – very impressive but I cannot deduce from that the connection to China. How did it happen that you became interested in the Chinese space science programme?

Yes, because it came very late. In fact, I had been to China only once before 2016, but it was long ago, in 1985, and the country was very different from what it is now. And on that basis, to be honest, I didn't have a special interest for China. But in 2016, I was invited to a workshop about the theories and observations of the formation of planets at the International Space Science Institute (ISSI) in Beijing. At the same time there was a vacancy note for the Director of ISSI Beijing. I was curious and also, I was working at ISSI in Bern as a Discipline Scientist which meant I knew the ISSI system. ISSI Beijing is not a subsidiary of ISSI Bern but it is connected. I applied for the position, was interviewed and was selected. That's how it came that I started from the end of 2016 working part time in China. It was a little bit by chance, I would say.

Which task did you fulfil in Beijing? What was your assignment?

The main task at ISSI Beijing was to be the Executive Director. I had to plan the programme activities, workshops, forums and meetings. The mission of ISSI in general and of ISSI Beijing in particular is to connect the science community with the space programme and to organise meetings that would help produce science from current and past space missions and define science questions for new ones. The focus was always on the science side, not on the technology side. When I arrived in Beijing, I was the second director of the institute, continuing the work of my predecessor Maurizio Falanga. He was the person who established the system. The job consisted in organising meetings in support of several of the Chinese space science missions in preparation. It was very interesting to discover via this approach the Chinese space programme in a very concrete way: by meeting people who are interested in it and were preparing the different projects.

Looking back at this work from the today's perspective can you name any missions which were the result of your work or were influenced by your work or is it a bit a premature for that?

I worked on several missions but was never the initiator of a mission - they were all Chinese-designed and Chinese-conceptualised. My role was actually to work with the National Space Science Centre of the Chinese Academy of Sciences (NSSC, CAS) to help the mission teams to refine the science and gather more scientists around the mission. For example, when I was there, we had a forum about the future of planetary seismology. It was an international meeting where we discussed how seismology could be deployed on the Moon, on Mars, on other bodies of our solar system for maximising the scientific return. Discussion points would be for instance, how to study the Moon as a planetary body and understand its internal structure, the size of its core and so on. The same with Mars. The exchange at the forum was promoting, in that case, the scientific discipline of seismology in the field of planetary science. On another occasion, ISSI Beijing was even more the initiating part. I organised a meeting in January 2019 about the exploration of asteroids and on sample return missions from asteroids. At that time the Chinese Academy of Sciences was studying the possibility of such a mission. So again, we had a lot of participants from all over the world who are experts in both: in small bodies, asteroids and in the techniques and the science of sample return. In that case we were really at the beginning of the mission. Still, it was not us who decided the mission.

The mission on which I think I had the most important influence is one that is not yet flying. I was working with several Chinese colleagues on the conceptualisation of the science of a mission to the Jovian system. This mission to the Jupiter system and to Callisto is not yet decided.

Nevertheless, I can say, on this one I am the Co-Initiator. I hope it will fly. In fact, the success of Tianwen 1's Mars landing opens a lot of expectations because it demonstrates the incredible capacity and reliability of Chinese space flight.

Did you expect the successful Mars landing? Was it clear for you that the mission would be successful?

I must say: yes, like everybody I had some doubts. But on the other hand, I think I was on the hopeful side. The reason for that is that their very successful management of Chang'e 4 and Chang'e 5 tells us a lot. Look at Chang'e 4's landing on the far side - a totally automatic landing – enabled by a very smart robotic system. The spacecraft had a strong capacity of remote sensing and analysing, autonomous decision making, and obstacle avoidance. I think it was a brilliant demonstration of mastery. For going to Mars it's basically the same process except it's a little bit more complicated. But the other mission that really impressed me was Chang'e 5. It is a mission which accumulates difficulties and many possibilities of failing. First, you land on the Moon, then you have to deploy your sampling system, collect a sample, store it in a container, then you have to go back into lunar orbit successfully, conduct rendezvous in lunar orbit, transfer the sample to the return capsule and send the probe back for Earth gravity capture and re-entry. Well, it's very tricky – to say the least. And it worked two times: Chang'e 4's far side landing and Chang'e 5's sample return. No failures– just success. I knew that Mars was one step more difficult but I was confident.

Thank you for that expert's evaluation. Getting back to your work at ISSI Beijing - may I summarise what you said before: the Chinese came to you with their ideas about missions and you helped to find an international community to advise them or to give inspiration?

Yes, it's advice. Basically, you take a mission or the mission concept or an objective and you organise a meeting with experts who are going to help building what we call the science case, define what needs to be the measurement priority, what are the big science questions that this mission should address and so on. It is scientific advice and you may well say inspiration via a dialogue with experts. In fact, I should say that it is a very interesting job. Because you start from an idea of a space mission and you develop around it multi-faceted science cases, trying to understand and propose all the things that could be done and also all the science instruments that should be flown. These particular destinations: asteroids, Jupiter or Mars request mainly the same idea. And not to forget about astrophysics because China has a lot of astrophysics missions.

But does it mean you could make a difference? Did you have the feeling that your advice was taken or was it rather the situation that the Chinese had anyhow their own ideas and they only wanted to get confirmation from external experts that the way they're going is correct?

I think it was a useful role. Not as a person, I was just the convener or the host. The key element was to have in the meeting room at the forum, all the experts that are needed. The key importance of the job is to find the right experts and to have them come to Beijing for the exchange. At the end we write a scientific report and this report is going to be the substance of what we contribute to the Chinese space programme. This is the Taikong report published by ISSI Beijing and you can find it on the website.

http://www.issibj.ac.cn/Publications/Forum_Reports/201404/t20140404_119042.html

How is the position of ISSI Beijing within the Chinese institutional landscape? On the one side you have the NSSC and on the other side you have the China National Space Agency. Is there a kind of disconnect or how is the structure?

I never had a direct connection with CNSA. ISSI Beijing is funded by the NSSC and the Chinese Academy of Sciences. Within the Chinese space programme, CAS is the body which is responsible for building a science-driven programme. CAS may interface with CNSA, but not me.

We were working only on astronomical, Earth observation and planetary science missions.

For instance, we were not designing the Chang'e programme. That is in the realms of CNSA. It is important to distinguish in China the part of the space programme which is more technology-driven or capacity-driven and often initiated by CAST. The other part is led by the Chinese Academy of Sciences and is by definition more science oriented. There are these two "legs" and I was working for only one of the two legs.

I would say this situation is not very different from what happened in the USA. When we look at the start of the space era it started as a manned space programme. President Kennedy said "I want an American on the Moon by the end of the decade". That was not a primarily scientific motivation. It was about exploring space, pushing the borders, sending humans in space and being first. I have an impression that when the space programme starts, very often it starts by the development of capacities and then science sort of follows. At least at the beginning. But then there is a greater effect by the moment when scientists are given the capacity of flying instruments into space and of designing scientific mission concepts. When technology is enabling ways of studying the universe in space and from space, scientists will do it. And then space science becomes more and more important.

How was it to work in China? Is your assignment finished?

I worked for ISSI Beijing for one year and a half and after that I moved to NSSC as a visiting professor to work more directly on two projects: the Jupiter mission I mentioned before and another project which is not a space-related project. It is a ground-based observation project called the "International Meridian Circle

Programme". There is a Taikong report just published on that.

http://www.issibj.ac.cn/Publications/Forum_Reports/201404/W020201105365405876299.pdf (TAIKONG No. 19 - Science Objectives and Observation System for the International Meridian Circle)

The idea is to monitor the ionosphere and upper atmosphere and study the effects that magnetic storms, solar activity and the different types of disturbances coming from the ground, like earthquakes, have on it. Earthquakes may have an effect on the upper atmosphere, just like severe weather events or global warming, and by detecting and studying these effects you can also learn about their causes. I was asked to work on this project of deploying a global network of instruments on the surface of the Earth to monitor these different effects. I moved from being somebody who was hosting meetings and coordinating to being directly involved in two programmes. That was the time when I really had my first experience of direct collaboration with Chinese colleagues.

And how was it? How is it different or how is it similar to working in Europe?

At the beginning it's a little bit more difficult because of cultural differences. The way of working at the Chinese Academy of Sciences and in Chinese universities is different. But apart from that and once you know the people, I would say: the people I worked with - they are scientists and after some time you establish the same type of relationships that you have with your colleague next door here in Europe. I didn't feel such a big difference to be honest. But I don't speak Chinese which means there are things that I cannot grasp, for example everyday discussions in the corridor. But I liked it. I met many brilliant people.

Even more so, I found the right people everywhere in China. I visited many universities because at a certain point I was invited to give lectures. I went to Macau, Hong Kong, Shanghai, Nanjing, Hefei, Qingdao, Chongqing... I was in Wuhan in the spring of 2018. Everywhere I met interesting people. My visit in Chongqing, where they have a Department of Lunar Exploration, was very interesting. There is one point that I would like to add here, I mean from the human point of view. In China I felt particularly strongly the passion with the students - the excitement that space is new, it is a new frontier, they are very happy and proud to be part of the game, of the space programme in China. That also goes for the public. Again, I think this is how it must have been in the US at the time of the start of the space programme or in Europe when we started to go into space too.

What is your opinion about the space cooperation between China and Europe? Is it satisfying or could more be done?

I think there is already a lot of cooperation between European and Chinese scientists and institutes and this is further developing. The pandemic has slowed some projects because we have not met with each other now for almost two years. This is not good for cooperation but I suppose it will resume after the pandemic.

In fact, I have already been invited on a Visiting Professorship position at Peking University and again to NSSC. I am looking forward to going back to China.

Another aspect is that I think there are already many Chinese space missions on which European scientists are partners. There are European co-investigators in Chang'e 4. CNES is interested in participating in the analysis of samples returned by Chang'e 6.

Another example in a different domain is the study of the effects of earthquakes on the upper atmosphere. There is a Chinese satellite series which is called CSES (China Seismo-Electromagnetic Satellite). It is managed by the China Earthquake Administration (CEA). I know the team involved in this mission very well. They are studying the effects of earthquakes and of other phenomena on the upper atmosphere with excellent instrumentation from China, Italy and Austria and produce world-class science.

Another example is the cooperation between France and China. There are two ongoing joint space missions. One, the CFOSAT oceanography mission, is in operation and both sides are very happy about the already achieved results. The other one is SVOM (Space-based multi-band astronomical Variable Objects Monitor), which is a gamma-ray mission to study the gamma-ray universe. It is a very interesting mission with a balanced cooperation between the two partners, due to be launched in 2023.

Beyond that, ESA has in its science programme a joint science mission which the Chinese Academy of Sciences which is called SMILE (Solar wind Magnetosphere Ionosphere Link Explorer). This mission, which will monitor the magnetosphere of the Earth, is a very good example of cooperation, because the mission has been jointly designed by ESA and CAS from the very beginning.

There are also several successful joint ventures. It is in the interests of Europe that we have this dialogue with China and I think this dialogue has a good quality and is in a good state.

Could be done more? Considering that Europe is really a scientific continent where a lot of heritage is available and enormous expertise in particular in the national approaches where capacities were and are developed for leading space science?

I think we could do more. If I compare my case and look at the kind of cooperation with US-Americans or inside Europe, then I have to say our relations with China are not as deep and not as numerous. We are just starting to learn to work together with China. One reason is that we don't know the Chinese science communities very well. But also, the administrations are different and there are still question marks about an easier exchange of scientific information, in particularly data, samples and others. There is still room for progress but we can do it only by advancing our experience in cooperation.

Thank you! That ties it up very nicely. Just to conclude our talk: what is your personal expectation of the Chinese space programme? Where do you think China will be in 10 years from now? Is the country on the overtaking lane or is it just catching up? Has China the potential to become the leading space science nation?

I would say catching up quickly and becoming an even partner with the other space fairing nations. Personally, I don't see any reason why they would become the leader. I don't think it's particularly necessary. What is important is that they have a rich level of capacity that in the end will be comparable to the US and Europe. They are exactly on the right track for this. Probably at some point there will be areas where they will be the best, areas where the US or Europeans will be the best. I am rather thinking of a perspective in which there will be a balanced world space programme with each nation providing its own contribution on the basis of its particular interest, particular technology skills, and of the specific interests of its scientific community. But I don't think China will become particularly dominant. To be honest it would be good for nobody in fact.

I like your idea of a balanced global space programme where everybody contributes…

Maybe this is rather my dream than reality. But that's what I expect. That is how I see the future.

Thank you very-very much! The talk with you was very insightful! Thanks for that!

Starlink - CSS Near-Collision: Question, Solution and Opportunity

by Chen Lan

Last December, China filed a note verbale to the UN claiming that two SpaceX Starlink satellites made close encounters to the China Space Station (CSS) and the latter had to perform emergency manoeuvres to avoid a catastrophic collision. Now, the U.S. side has finally responded with another note verbale to the UN, as reported by SpaceNews on 15 February.

These encounters were quite special - not only because it happened during the period of increasing Sino-U.S. tension and involved satellites of a high-profile enterprise and China's proud Space Station which would easily trigger sensations in both countries, but also it's a rare case that an operational satellite still in control by the ground posed a threat to a manned spacecraft.

In December, there were only information from the Chinese side and unofficial third-party sources. We do not know what really happened inside SpaceX and possibly in relevant U.S. government bodies. Unfortunately, the recent U.S. note verbale did not provide too much further details either. Instead, it raised more questions.

Such events could easily be politicised considering the current geopolitical environment, which does not help solving the real problem in space. So, in this article, I just focus on technical and management aspects of the event, try to sort things out, so as to see what went wrong.

Let's put all available information on the table.

China's Note Verbale to the UN

China filed a note verbale to the UN Secretary-General on 6 December 2021. It was not reported until about three weeks after its submission. The note verbale claimed two close encounters:

"As from 19 April 2020, the Starlink-1095 satellite had been travelling stably in orbit at an average altitude of around 555 km. Between 16 May and 24 June 2021, the Starlink-1095 satellite manoeuvred continuously to an orbit of around 382 km, and then stayed in that orbit. A close encounter occurred between the Starlink-1095 satellite and the China Space Station on 1 July 2021. For safety reasons, the China Space Station took the initiative to conduct an evasive manoeuvre in the evening of that day to avoid a potential collision between the two spacecraft.

On 21 October 2021, the Starlink-2305 satellite had a subsequent close encounter with the China Space Station. As the satellite was continuously manoeuvring, the manoeuvre strategy was unknown and orbital errors were hard to be assessed, there was thus a collision risk between the Starlink-2305 satellite and the China Space Station. To ensure the safety and lives of in-orbit astronauts, the China Space Station performed an evasive manoeuvre again on the same day to avoid a potential collision between the two spacecraft."

Independent Orbital Analysis

Jonathan McDowell, a renowned and respected astrophysicist and space activity monitor, was the first one who independently confirmed the neatr accidents based on open orbital data. On 28 December, he tweeted his orbital analysis. The following figures show orbits of the Starlink and the CSS in July and October.

On 18 January, McDowell summarised the events in his prestigious Jonathan's Space Report No. 802 with the earlier conclusion further confirmed. He predicted a surprisingly close pass within 1 km (before the CSS's avoidance manoeuvre) in October. While the closest distance in the July encounter was seemingly missed in the published text.

"China has complained to the UN (in UN document A/AC.105/1262) that Starlink sats are buzzing the Chinese Space Station (CSS). Two incidents are mentioned, and analysis of the TLEs confirms that the close passes in question did indeed occur as described.

On Jul 1 at 0950 UTC the CMSEO (zhongguo zairen hangtian gongcheng bangonghsi, China Human Spaceflight Engineering Office) commanded the CSS to make an orbit adjustment to dodge Starlink 1095, which was in the process of lowering its orbit towards disposal; a close (km or less) pass would otherwise have happened at about 1315 UTC. It appears that the Starlink also made a small avoidance burn around the same time, but it sounds like there was no advance communication between SpaceX and the CMSEO about the pass.

On Oct 21 the then-recently-launched Starlink-2305 satellite was orbit raising through the altitude of the CSS and was predicted to pass within 1 km of the Chinese station at about 2200 UTC. The CSS made an orbit adjustment at about 0316 UTC to avoid the encounter. In this case Starlink-2305 does not appear to have made any avoidance burns."

U.S.'s Note Verbale to the UN

The U.S. filed a note verbale to the UN Secretary-General on 28 January 2022. It states:

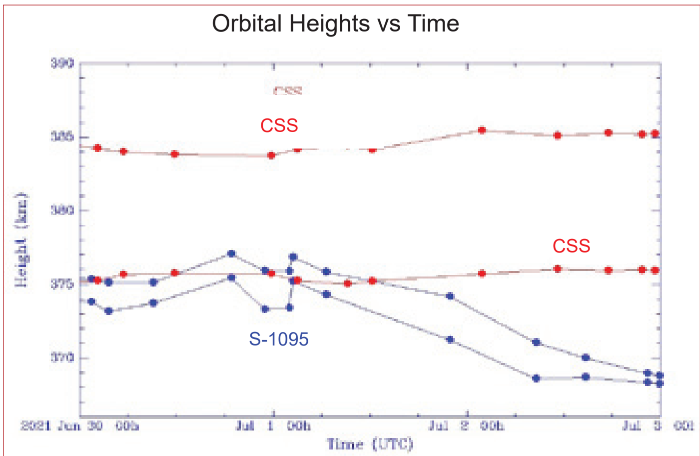


Figure 1: The July encounter. Credit: Jonathan McDowell (https://mobile.twitter.com/planet4589/status/1475626313423720449)

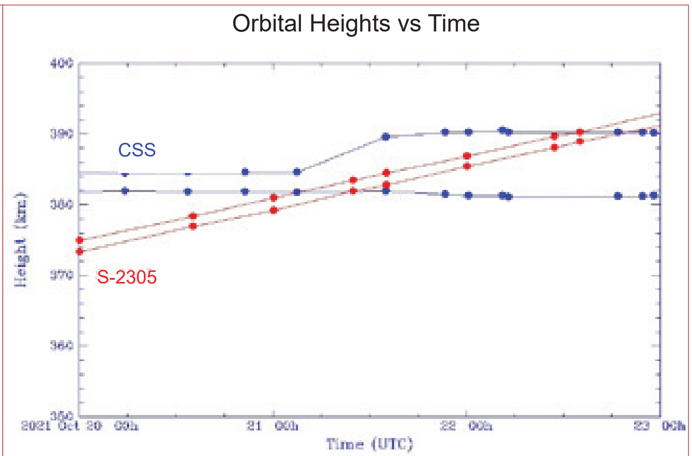


Figure 2: The October encounter. Credit: Jonathan McDowell (https://mobile.twitter.com/planet4589/status/1475631413521178628)

"In the specific instances cited in the note verbale from China to the Secretary-General, the United States Space Command did not estimate a significant probability of collision between the China Space Station and the referenced United States spacecraft:

- *Starlink-1095 (2020-001BK) on 1 July 2021*
- *Starlink-2305 (2021-024N) on 21 October 2021*
  - *Because the activities did not meet the threshold of established emergency collision criteria, emergency notifications were not warranted in either case.*
  - *If there had been a significant probability of collision involving the China Space Station, the United States would have provided a close approach notification directly to the designated Chinese point of contact.*
  - *The United States is unaware of any contact or attempted contact by China with the United States Space Command, the operators of Starlink-1095 and Starlink-2305 or any other United States entity to share information or concerns about the stated incidents prior to the note verbale from China to the Secretary General."*

SpaceX Actions

According to the abovementioned 15 February SpaceNews report, SpaceX has worked with the State Department and other U.S. government agencies on getting notifications to China. Bill Gerstenmaier, Vice President of Build and Flight Reliability at SpaceX, said during a panel at the AIAA ASCEND conference in November 2021 that SpaceX checks for close approaches of its Starlink satellites with the International Space Station and China's Space Station. "We provide information to the State Department, but I don't know what happens after," he said.

On 6 August 2021, SpaceX had a teleconference call with the Federal Communication Committee, discussing Starlink's safety issues. According to the presentation of the meeting this author obtained, Starlink utilises an automated collision avoidance system, ingesting data (of space debris etc.) from the 18th Space Control Squadron, and the satellites can autonomously evaluate risks and plan avoidance manoeuvres, without human input. While humans are still present in an oversight role, as an added measure of safety. Starlink satellites currently default to taking manoeuvre responsibility for conjunction events with other operators. And, avoiding the ISS by a wide margin makes it so that no additional NASA operational actions or dedicated monitoring is necessary.

"Pizza Box"

Based on above information, it can be confirmed that the two encounters did happen and the CSS did perform avoidance manoeuvres in both events. But how close were they, after the avoidance manoeuvre and without manoeuvre? Both China and U.S. did not provide details. Nor did SpaceX. While from the U.S.'s statement, it seems that the distance did not meet its criteria.

This raises a new question: how close is considered "established emergency collision criteria" as mentioned in the U.S. note verbale? I did some research on this topic. In the book Protecting the Space Station from Meteoroids and Orbital Debris (1997) written by the Committee on International Space Station Meteoroid/Debris Risk Management, it is stated (Page 46):

"the SSN [Space Surveillance Network] routinely screens the catalog for objects predicted to approach the orbiter within a defined "warning box" approximately 25 km along the track of the orbit (either leading or trailing), 5 km across the track of the orbit, and 5 km out of the plane of the orbit. The estimated 10 to 30 objects per day that come within the warning box are reassessed using a more accurate algorithm to determine whether any come within a "maneuver box" of 5 km along track x 2 km across track x 2 km in the radial direction. If an object does, the ISS may initiate a maneuver to avoid impact."

Also, in a similar book on Space Shuttle meteoroids and orbital debris protection published in the same year by the same author, there is an identical definition of these two "boxes". And there is also a picture showing their size of 50 km x 10 km x 10 km and 10 km x 4 km x 4 km respectively.

However, NASA now uses a new, single-level criteria for ISS. The following text is quoted from the NASA web site (https://www.nasa.gov/mission_pages/station/news/orbital_debris.html):

"These guidelines essentially draw an imaginary box, known as the "pizza box" because of its flat, rectangular shape, around the space vehicle. This box is about 2.5 miles deep by 30 miles across by 30 miles long (4 x 50 x 50 kilometers), with the International Space Station in the center. When predictions indicate that any tracked object will pass close enough for concern and the quality of the tracking data is deemed sufficiently accurate, Mission Control centers in Houston and Moscow work together to develop a prudent course of action."

There is no illustration of the "pizza box" on the web page, but we could retrieve a NASA document which describes the imaginary box. It was in the book *The International Space Station - Operating an Outpost in the New Frontier* (NASA-SP-2017-634, page 145), published in 2017. However, the height of this box is only 1 km, much less than what was described by the official web page. Considering the book was published about 5 years ago, I have to assume that 4 km is the updated threshold currently in use.

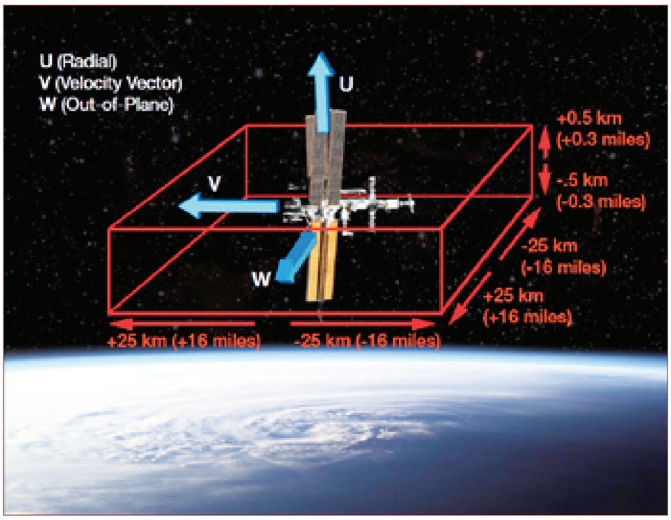


Figure 3: Illustration of this "pizza box" in the NASA publication

If Jonathan McDowell's calculation is correct, the predicted position within 1 km from the CSS (before CSS's avoidance manoeuvre) in October was well inside the warning box and the manoeuvre box used in the past or the "pizza box" used now. But no emergency notifications were triggered. So, either something went wrong in McDowell's calculation (In fact, it is still the only result unverified by other sources), or there was something going on behind the scenes.

More Questions

There are more questions to be answered. Did SpaceX provide the specific CSS encounter information to the State Department in July and October, as Bill Gerstenmaier said vaguely in November? What is SpaceX's own criteria for a potential collision? Is it the same as the "pizza box" defined by NASA? Did Starlink's collision avoidance system take manoeuvre responsibility and worked as expected during the encounters in July and October? Why was there not any manoeuvre in the October encounter?

On the other side, China hadn't taken any action for 5 months since the July accident until it submitted the note verbale to the

UN. They continued to keep silent afterwards until media found the note verbale's existence in late December. Was China waiting for SpaceX's active notification and did not want to ruin its good relationship with Elon Musk?

The biggest confusion appeared in the communication between the two sides. "After the incidents, China's competent authorities tried multiple times to reach the U.S. side via e-mail, but received no reply," Zhao Lijian, spokesman for China's Ministry of Foreign Affairs, said. While in the U.S.'s note verbale, it states "The United States is unaware of any contact or attempted contact by China with ... any other United States entity." Who is not telling the truth?

We will probably know answers to these questions in the future. But we already know a fact - communications between China and the United States on collision avoidance in the human space programmes has completely failed. It was very unfortunate. One of the reasons for such poor communication, misunderstanding and even hostility is lack of transparency. We saw it clearly from this case.

Solution and Opportunity

The good thing is that both China and the U.S. have expressed a willingness to improve communications and to establish a formal collision avoidance mechanism - a solution that will benefit both sides.

The United States tends to direct communication through bilateral channels, to facilitate efficient and timely sharing of information and coordination of potentially urgent responses. In the note verbale to the UN, it urges all spacefaring nations to work constructively to reduce the risk of collisions between space objects and within human spaceflight activities.

China prefers to discuss and coordinate space related affairs through the United Nations, as shown in this case. But now it is also open to more formal lines of communication with the U.S. on space safety, Zhao Lijian said: "The Chinese side stands ready to establish a long-term communication mechanism with the U.S. side."

Transparency is the basis for international cooperation on space collision avoidance. China was often accused of lack of transparency in its space programme. While in this case, it released more information than the U.S. side did. Elon Musk and the U.S. government agencies need to provide more details about the events that happened last July and October to clarify the questions I asked above.

On 12 February, the China Manned Space Engineering Office announced that it has started to publish TLE (Two Line Element) data of the CSS orbit on daily basis for collision avoidance analysis by other parties all over the world. It was probably a precaution taken in wake of the two accidents last year. In any case, it was an encouraging step towards a formal mechanism on space collision avoidance through international cooperation.

To establish such a mechanism, there is a lot of work for spacefaring countries to do. Consensus on manoeuvre responsibility and working procedures, and the size of the warning box ("pizza box", or whatever box) must be reached. Maybe an enlarged second warning box for heavier, larger and thus more energetic and dangerous spacecraft is also required. As electric propelled spacecraft like Starlink's changes orbit all the time during ascent and descent and their orbits are difficult to predict using traditional TLEs, to share their orbit status easily to other parties, a new way to describe such an orbit has to be taken into account as well.

The risk of orbital collision has been increasing over recent years and now has become a sensitive international political issue. But the Starlink-CSS near collision also attracted the public's attention and prompted an increased awareness of the importance of the risk of collision in space. Thus, it can also be turned into an opportunity if we take actions immediately. I believe that human beings have wisdom enough to capture this opportunity. One has to stay optimistic.

ANNEX to Quarterly Report - List of Abbrevations

AAPT	Academy of Aerospace Solid Propulsion Technology
AIR	Aerospace Information Research Institute
AO	Announcement of Opportunity
APSCO	Asia-Pacific Space Cooperation Organisation
ASEAN	Association of Southeast Asian Nations
BACC	Beijing Aerospace Control Centre
BDS	BeiDou satellite navigation System
BIT	Beijing Institute of Technology
BJT	Beijing Time
BNU	Beijing Normal University
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
CAS	Chinese Astronomical Society
CASC	China Aerospace Science and Technology Corporation
CASIC	China Aerospace Science and Industry Corporation
CAST	China Academy of Space Technology
CCAF	China (International) Commercial Aerospace Forum
CCTV	China Central Television
CE	Chang'e
CGST	Changguang Satellite Technology
CGTN	China Global Television Network
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
CNES	Centre National d'Études Spatiales

CNSA	China National Space Administration
CSES	China Seismo-Electromagnetic Satellite
CSS	Chinese Space Station/China Space Station
CSU	Technology and Engineering Centre for Space Utilisation
CZ	Changzheng, Long March
DBAR	Digital Belt-and-Road Programme
DFH	Dong Fang Hong
EO	Earth Observation
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAST	Five-hundred Metre Aperture Spherical Radio Telescope
FY	Fengyun
FYESM	Fengyun Meteorological Satellites in Disaster Prevention and Mitigation
GECAM	Gravitational-wave high-energy Electromagnetic Counterpart All-sky Monitor
GEO	Geostationary Orbit
GF	Gaofen
GNSS	Global Navigation Satellite System
GRAS	Ground Research Application System
GTO	Geostationary Transfer Orbit
HERD	High-Energy cosmic-Radiation Detection
HXMT	Hard X-ray Modulation Telescope
IAU	International Astronomical Union
IoT	Internet of Things
ITU	International Telecommunication Union
LEO	low Earth orbit
LEOP	launch and early orbit phase
LFRS	Low-frequency Radio Spectrometer
LND	Lunar Lander Neutron and Dosimetry
LOX	liquid oxygen

LRO	Lunar Reconnaissance Orbiter
LROC	Lunar Reconnaissance Orbiter Camera
MEO	medium Earth orbit
NDRC	National Development and Reform Commission
NSSC	National Space Science Center
P/L	payload
PNT	Positioning Navigation and Timing
RLV	reusable launch vehicle
Roscosmos	Russia's State Space Corporation
SAARC	South Asian Association for Regional Cooperation
SAR	Synthetic-Aperture Radar
SAST	Shanghai Academy of Spaceflight Technology
SCO	Space Climate Observatory
SCO	Shanghai Cooperation Organization
SQX	Hyperbola
SSC	Sweden Space Corporation
SSEC	Space Science and Engineering Centre
SSO	Sun-Synchronous Orbit
SZ	Shenzhou
TW	Tianwen
TQ	Tianque
TT&C	Space Telemetry, Tracking and Command Station
UAV	unmanned aerial vehicle
UN	United Nations
UNOOSA	UN Office for Outer Space Affairs
UTC	Coordinated Universal Time
VLBI	Very Long Baseline Interferometry
VTVL	vertical takeoff, vertical landing
WMO	World Meteorological Organisation
YT	Yutu
YW	Yuanwang

The Chinese Lunar Goddess on a Night Mission (part 2)

by Jacqueline Myrrhe

Arriving at a destination is not always the end of one's journey. It might happen that returning home can be as challenging as the initial voyage towards new locations. Chang'e 5's arrival at the Moon was a crucial accomplishment but the most difficult mission phases were still ahead. The 2nd part of the lunar sample return mission report focuses on the landing, the sample fetching and the flight back to Earth. And last but not least: Where will the lunar samples end up? But the Chang'e 5 mission had also some other interesting items on board. And not to forget: until today, the extended mission is ongoing. (Part 1 was published in GoTaikonauts! 31, pp. 24 - 28)

Much in Chang'e 5's (CE-5) lunar landing sequence was a reminder of previous Chinese lunar landings. Chang'e 3 and 4 went through the same process. For CE-5, the descent started on 1 December at 20:57 BJT (12:57 UTC) at a height of 15 km above the lunar surface. The landing-ascent unit fired its 7,500 N high-thrust engine to decelerate step-wise the horizontal speed from 1.7 km/s to zero.

This was followed by an attitude adjustment at a height of 2.5 km. The on-board cameras took pictures of the landing area, transmitting the data to the ascent stage's computer for analysis. The image processing and analysis system would identify possible hazards or obstacles and feed the result into the guidance and control system which would then adjust the position if needed. After that, the lander continued approaching the lunar surface.

The final checkpoint was at the height of 100 m above the ground, where the lander-ascent module hovered to operate the 3D imaging, high-resolution laser device for scanning the selected area, allocating with high-precision any unwanted obstacles.

This modern hazard avoidance technology was developed by CAST's 502 Research Institute and already used and proven reliable during the CE-3 and CE-4 missions. The computer and star-tracker for position adjustment are integrated into the ascent stage, guiding both mission phases: the descent as well as the later ascent. Since the landing process stirs up a lot of lunar dust there was the concern that the dust would stick onto the star tracker sensor. The engineers decided to apply a dust cover to the design. It was shut over the lens before the final landing sequence and uncovered once the dust had settled again.

The sophisticated ascent stage design led to a more passive function of the landing unit. Keeping in mind that the lander's lifetime requirement was just one lunar day, equivalent to 14 days on Earth, the construction and equipment was streamlined for the very specific tasks during surface operation: robotic arm, drill, landing legs and a minimum instrument suit for the characterisation of the lunar surroundings.

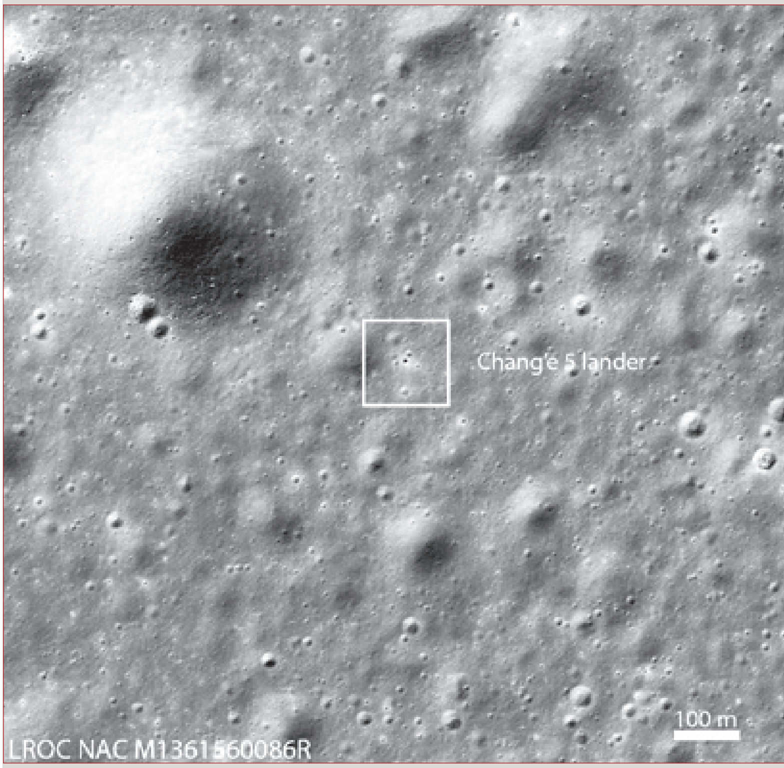
Different from its CE-3 and CE-4 predecessors, CE-5 required unprecedented location accuracy and the autonomous ability to choose a flat landing site with favourable light and temperature conditions. But as important was to select a spot with few irregularities and no high-inclination slopes to ensure the landing site is as good for landing as for taking-off. At the same time, it was important that the environment is scientifically interesting but also easy for collecting the samples. Mission planners had a big job to balance scientific requirements and technical considerations and to come up with a good decision on the suitable landing region and touchdown point.

After the surface scan 100 m above the ground was completed, the CE-5 lander descended vertically at a slower, steady speed before the probe reached a few meters above the landing spot and the engines were switched off. The 4 lander legs cushioned the final free-fall. Compared with the CE-3 landing leg design, the buffer capacity for the CE-5 lander was increased by 30 % while at the same time the weight was reduced by 5%.

On 1 December, at 23:11 BJT (15:11 UTC), CE-5 successfully landed on the near side of the Moon. The lander came to a halt at the preselected site at 51.8° West longitude and 43.1° North latitude, near Mons Rümker in the Ocean of Storms (Oceanus Procellarum), ready to fulfil the mission objective of sampling the planned 2 kg of lunar material.

After CE-3 and CE-4, CE-5 was the 3rd Chinese lunar lander mission. Not considering the impact missions, China's Chang'e flights are the only lunar surface explorations in the 21st century to date. Interestingly, the Chinese Chang'e missions have been the only successful missions since the Soviet Luna 24 sample return mission left the Moon on 19 August 1976.

On the day after landing, NASA's Lunar Reconnaissance Orbiter (LRO) passed over CE-5's landing site. LRO's camera (LROC) was able to take an off-nadir (13° slew) image showing the lander within a triangle of craters. The LROC team calculated the coordinates of the lander to be 43.0576°N, 308.0839°E, -2,570 m elevation, with an estimated accuracy of +/- 20 m.
The announcement of the photo came with the information of the local geology of the landing site which consists of a broad, flat mare basalt unit. Similar to flood basalts on Earth, this deposit was the result of a massive outpouring of highly fluid basaltic lavas. On the Moon, scientists concluded, this massive eruption occurred somewhere between 1-2 billion years ago. The sample collected by CE-5 should help scientists to precisely determine its age and chemistry. Credit for text and image: LROC/NASA/http://lroc.sese.asu.edu/posts/1172



The box indicates Chang'e 5 lander on the basaltic plains of Oceanus Procellarum (Ocean of Storms) on 02 December 2020, at 09:54 EST (14:53:55 UTC). The lander is the bright spot in the centre of the outline. The image is 1,210 m wide; North is up. LROC NAC M1361560086R. Credit for text and image: NASA/GSFC/Arizona State University

Image taken by CE-5 descent camera after the landing. Credit: CNSA/ CLEP

View of the Beijing Aerospace Control Centre (BACC) on 1 December 2020 after the successful landing of CE-5. Credit: CNSA/CLEP/ BACC

After the successful landing, the Beijing Aerospace Control Centre (BACC) carried out a series of status checks and inspections along with the deployment of the solar panels and the directional antenna. Additionally, the lunar penetrating radar started analysing the sub-surface structure in the vicinity of the lander, collecting reference data for the 2 imminent sampling procedures. The intention was to get 2 types of samples: a drilled sample from under the surface and a scooped surface material. To make this happen, CAST's engineers installed 2 collection devices on the landing unit. Having 2 independent sampling instruments also reduced the risk of total failure.

The data sent back by the probe, were relayed to researchers in a lunar test-bed landscape in a Beijing laboratory. During the entire collection process on the Moon, the engineers synchronised a full-scale simulation with mock lunar soil based on the provided data from the real landing site's environment.

Less is more

Then, everything happened relatively quickly. Instead of the previously announced 2 days for the drilling, scooping and storage of the lunar samples, the automatic systems were ready after 19 hours of operations.

The drill finished in the morning of 2 December at 4:53 BJT. China's lunar experts had hoped to drill up to 2 m deep into the sub-surface. But at a depth of 1 m, the drill encountered hard regions and the data from the sub-surface radar showed that more dense layers existed beneath. At this moment, it was not clear whether the depth of 2 m would be reached without risking the mission's success. It was decided to play safe and not to push the drilling further, ending at 1 m depth. That might have been the hardest decision of the mission…

Without any further problems, the craft then used a mechanical arm to scoop up lunar surface samples from different spots on the landing site. The samples were packed and stowed into a vacuum container inside the ascender. All processes finished on 2 December at 22:00 h, which was much earlier than anticipated.

Chang'e 5 collects lunar samples. Credit: CNSA/CLEP

Lunar scientists expected to get 2 kg lunar material returned with CE-5: 1.5 kg of surface regolith and 0.5 kg from the drill. Soon it became evident, that the total mass was 1,731 g.

The CE-5's Surface Sampling and Packing System (SSPS) for lunar surface sampling, packaging and sealing was developed by a research team of the Hong Kong Polytechnic University (PolyU), led by Yung Kai-leung, Chair Professor of Precision Engineering and Associate Head of the Department of Industrial and Systems Engineering of PolyU. Consisting of 2 samplers for collecting loose and sticky type of lunar regolith, 2 heat-resistant near-field cameras for vision guidance during sample acquisition, as well as a packaging and sealing system, the SSPS has more than 400 components made of different light-weight but durable materials withstanding the extreme space environment. Upon completion of the sample acquisition, the robot arm supported through vision guidance, lifted the container and placed it into the ascender.

Prof. Yung Kai-leung told Chinese media that the research team has simulated the sample collection with the SSPS more than 1,000 times.

PolyU has been involved in previous national and international space exploration missions, among them the CE-3, CE-4, and TW-1 missions and on the international level ESA's 2003 Mars Express and the Sino-Russian exploration mission in 2011. The team has a strong expertise and leading knowledge in sampling as well as high-precision high-resolution 3D mapping and geomorphologic analysis of the landing region. PolyU's SSPS is already booked for the CE-6 mission.

With a big relief over the successful sampling task, mission control then executed the planned bonus activity. A 1 kg pyrotechnical deployment mechanism on the lunar lander released a mini-flagpole hoisting a wrinkle-free and spotless Chinese national flag. A good 51 years after the Apollo landings,

Hong Kong Polytechnic University's tools for Chang'e 5 include (clockwise from bottom left) a packaging and sealing system, a sampler for loose material, and another for sticky material – while Xinhua news agency's illustration (bottom right) shows how the samplers work with the probe's robotic arm. Photo: PolyU/Xinhua

Xu Weilin (2nd from left), Professor at the Wuhan Textile University, talks with his team about the fabric technology for the CE-5 flag. Credit: Wuhan Textile University

Engineers test the un-rolling mechanism at CAST. Credit: CAST/Wuhan Textile University

which left 6 U.S. national flags planted into the lunar soil, China demonstrated how serious the nation is about catching-up with the United States. The seriousness of the flag ceremony was underlined by the effort and the many details Chinese media reported about this small event with no relevance for the scientific success. Lengthy reports also covered the research which went into finding the right material used for the 12 g flag. The Wuhan Textile University spent one year to investigate the best suitable and long-lasting material and the right procedure for dying the aramid fibre, making the national symbol survive the harsh space environment for many years even if the lander might not.

The flag hoisting ceremony concluded the lunar surface operation. On 3 December at 23:10 BJT, the 400 kg ascent stage took-off, entering an elliptical lunar orbit in preparation for the rendezvous and docking with the 2.3 t orbiter-re-entry combination. The 3,000 N engine worked for 6 min and accelerated to 6,011 km/h (1.67 km/s). The lander unit with its 3 sampling instruments and flag, remained on the lunar surface. Apart from the sample collection, the lander was also equipped with instruments for the analysis of loose surface material as well as subsurface layers.

The instruments continued to provide data until the lunar night set in: the panoramic camera was transmitting photos of the landing area, the infra-red spectrometer still investigated the composition of the rocks and the regolith, and the ground-penetrating radar was still sounding the sub-surface around the drilling location.

There were reports that the lander was damaged during the take-off of the ascent stage. A camera on the lander recorded the moment of take-off and sent the data back to Earth. Nevertheless, the lander was anyhow not designed for surviving the extreme cold lunar night with temperatures dropping to -190°C.

The possible damage might have led to the loss of data about electrically charged dust detected at the landing site because no details were secured on the lunar dust thrown up during landing or ascending.

Within the next 2 days and with support from the mission control centre in Beijing, the ascent stage conducted 4 orbital correction manoeuvres to gradually close in on the orbiter.

Two instruments, developed by CASIC, played a crucial part in the automated final phase of rendezvous and docking: a pair of microwave radars mounted on both, the ascent stage and orbiter and high-precision accelerometers.

The high-precision accelerometers helped to measure velocity changes, so that the relative velocity between the ascender and orbiter-return combination could be controlled as precisely as possible, a key technology for automatic rendezvous and docking.

The microwave radar, CE-5's only instrument for long-distance measurement in lunar orbit, consisted of a host unit installed on the orbiter and a responding unit on the ascent stage. The radar started to work at a distance of 100 km, measuring the rapidly changing distance between the 2 units with an accuracy of around 5 cm and facilitated the communications between the components for high-precision position adjustment before docking.

The significant difference in the mass between the two spacecraft added to the difficulty of docking. The docking mechanism uses holding claws to weaken the impact. This design requires high precision angle measurement by the microwave radar to enable accurate alignment. The CASIC engineers developed a fault tolerant algorithm to get the angle-measurement accuracy correct. Designers also opted for dust covers on sensitive parts of the radar to guarantee that the ascender sensors would work flawlessly and were not even disturbed by micro-dust.

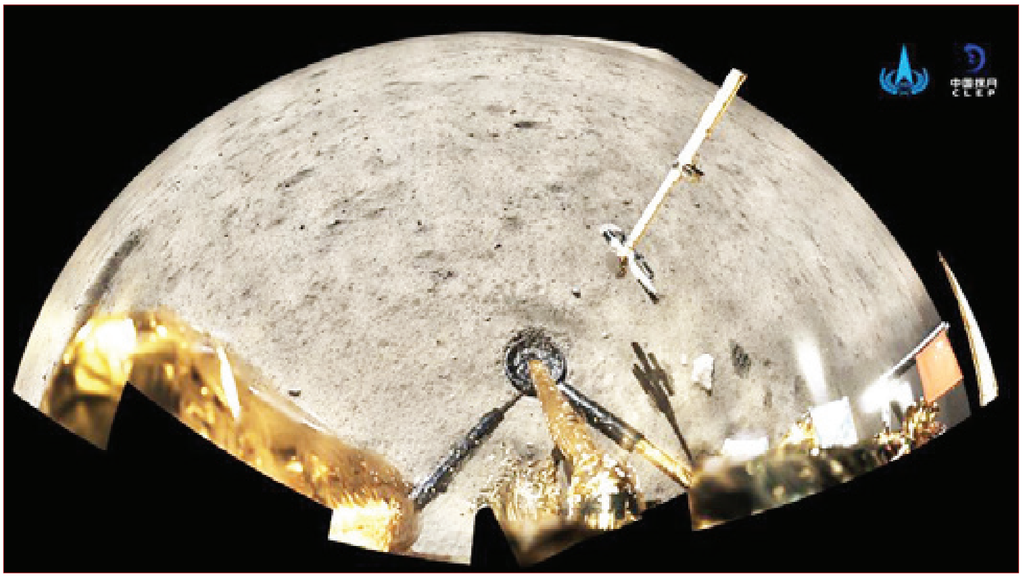


Image taken by the panoramic camera installed on the lander-ascender combination of the probe, before the ascent stage blasted off from the Moon with lunar samples. It shows the flag at the far right. Credit: CNSA/CLEP/Xinhua

The two spacecraft continued adjusting their flight attitudes according to the radar signals until the docking mechanism on the orbiter captured and locked the ascender. The whole docking sequence took 3.5 h.

On 6 December at 05:42 BJT (5 December, 21:42 UTC) the first robotic docking in lunar orbit was accomplished

The Chinese mission planners decided for the complicated and complex version of rendezvous and docking in lunar orbit including the transfer of the samples from one unit to another. This multiple-step approach holds several risks and points of failure but laid a technical foundation for future projects of deep-space exploration and will serve as a blue-print for later human missions to the Moon.

Equally important was that this approach made it possible to apply a modular spacecraft design. While the orbiter-re-entry combination was waiting in lunar orbit, the lander-ascent stage combination conducted the surface operations. This split of functions and consequently split of spacecraft mass allowed for less fuel consumption and enabled the transport of a larger lunar sample mass. The Soviet Luna missions did not include a lunar orbit docking instead launched directly from the lunar surface for a trajectory back to Earth. Such a process asked for a fully integrated lunar probe with all systems taking part in any step of the flight - a solution which compromised on the payload capacity for the samples brought back to Earth. In total, the Soviet Union brought back lunar samples in the range of hundreds of grams only.

30 min after docking, at 6:12 BJT, the sample container had been transferred from the ascent stage to the return capsule. Short video sequences of this process were published on Chinese media.

Almost 7 hours after docking, at 12:35 BJT, the spacecraft combination of orbiter and return section separated again from the ascent stage. Both separated segments continued orbiting the Moon.

On 8 December at 6:59 BJT, BACC commanded the ascent stage for final impact on the Moon. 31 min later, at 7:30 BJT, it landed hard in the planned location at 0° longitude and 30° southern altitude.

By that moment, the combination of orbiter and return unit remained in lunar orbit, waiting for around one week to hit a narrow window to fire its engines and head for Earth.

On the last leg of the journey

After 6 days in circular lunar orbit, the orbiter-return combination prepared with 2 transfer injection manoeuvres for entering the Moon-Earth transfer trajectory. The 1st manoeuvre on 12 December at 9:54 BJT adjusted CE-5's circular to an elliptical orbit. On 13 December at 9:51 BJT, when CE-5 was 230 km above the lunar surface, the orbiter's four 150 N engines fired for 22 minutes. This 2nd impulse injected CE-5 into the required transfer trajectory, initiating its 112-hour long journey back to Earth.

The 1st orbital correction on the Earth-bound trajectory was conducted with both 25 N engines which started working for 28 seconds on 14 December at 11:13 BJT. Meanwhile, the search-and-retrieval team of the Jiuquan Satellite Launch Centre reported readiness for the recovery operations expected for Siziwang Banner in the Inner Mongolia Autonomous Region. 3 days later, CE-5 closed in on the end of its mission.

In the very early morning of the 17 December BJT when CE-5 was 5,000 km over the South Atlantic, the orbiter separated from the return capsule. While the orbiter continued its flight, the capsule started its critical and complicated skip-re-entry manoeuvre, once tested during the CE-5-T1 mission back in 2014. As in October 2014, ESA's Deep-Space Tracking Network supported the mission phase with its 15 m antenna in Kourou, French Guyana and the 15 m Maspalomas antenna on Gran Canaria. Already at the beginning of the CE-5 mission, the Kourou dish had been receiving the first signals after launch and helped-out for several hours in the early mission phase. ESA's 35 m receiver in Malargüe, Argentina, served as back-up for the lunar landing and lunar take-off. With the involvement in the CE-5 flight, ESA continued its support from earlier Chang'e missions but also used the opportunity to learn and gain valuable experience of its own.

In the middle of the night, on 17 December 2020 at 01:59 BJT (16 December 2020, 17:59 UTC) CE-5's lunar roundtrip ended with the touchdown of the return capsule as planned in Siziwang Banner. The night landing was accompanied by a spectacular search-and-recovery operation for which the recovery team deployed from Jiuquan trained long and hard before because the CE-5 recovery posed more challenges than previous operations. The re-entry capsule's volume was about 14 % of that of the Shenzhou spaceships, but because of the skip-re-entry the landing polygon was 16 times bigger. Bian

Video of docking sequence and probe handling

photo gallery

Video of the moment of separation at 12:35 BJT

A camera on the lunar lander captures the moment the CE-5 ascent stage takes-off from the Moon. credit: Xinhua/CLEP

Photo taken on 3 December 2020 shows a view of the control room of the Beijing Aerospace Control Centre (BACC).

Hancheng, the head of the recovery team put this into context when he compared the process of finding an item of the size of a standard dining table in an area similar to the size of Belgium.

Also, the winter weather situation in the landing region was marked by a more than usual snow coverage and low temperatures, as well as the fact that the vehicle was scheduled to touch down at night.

For a precise meteorological forecasting, the Meteorological Service of Inner Mongolia established a special task force to support the return operations with an accurate prediction for high-altitude wind, frost index and turbulences along the altitude profile from 0 to 20 km, as well as visibility, cloud coverage, precipitation, and temperature - among other data.

The recovery team had performed 5 full-scale night-time exercises at -20°C and had extensively studied and mapped the landing area. Bian Hancheng said the mission team had looked into 3,000 potential hazards and was hoping the spacecraft managed to avoid them all – some of which were out of control to the rescue team, such as high-voltage power lines or communication towers. 6 military helicopters would used infrared devices to allocate and track the capsule during descent above Dorbod Banner, close to the region's border with Mongolia. Once the helicopters' infrared imaging sensors had a confirmed sighting, a ground team was alerted and approached the touchdown site.

There, a special CASC team set up a communication tent to connect the field team with CASC's headquarters in Beijing. The experts wore unpowered exoskeletons to manage the walk through the snow and uneven terrain while at the same time carrying the heavy equipment.

The Chang'e Moon goddess is not only fond of her pet rabbit, in the case of its landing, the mission was also supported by horses. A 23-man-strong militia cavalry team of Siziwang Banner supported the search operations. Only founded in April 2020, the cavalrymen team trained around the landing site for more than 10 days before the landing. The main task was to patrol the landing area and support the search for the capsule, making sure the ground support personnel and the recovery team could focus on their work.

But the first living being to meet the capsule from close was not a horse, nor a rabbit but a wild animal living in the wasteness of the Gobi Desert. It was most likely a fox which was hopping from the right to the left of the view of the infrared cameras on the search helicopters. The animal showed in the same way as the hot re-entry capsule as a bright shape in the thermal camera footage, clearly distinguishable from the cold snow which was projected as a black background on the images.

The significance of the mission success for China as a nation was revealed by the congratulatory note which President Xi Jinping directed to all persons involved in the mission. He stressed in his letter that the mission is as much a success of the project teams as it is of the Chinese system which makes it possible to mobilise all resources to overcome difficulties and achieve the set goals.

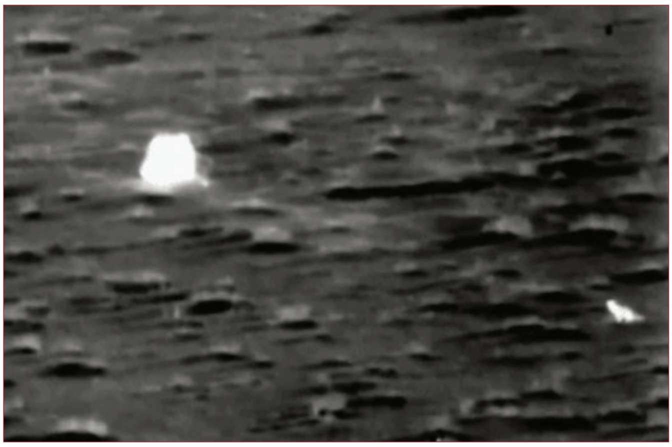
After landing, the return capsule was readied for further transport. In the afternoon of the same day, it arrived by plane in Beijing. There it was initially handled by experts at the China Academy of Space Technology. CAST was responsible for the capsule transport, retrieving the sample container and to prepare it for handover.

In the morning of the 19 December, the 1.731 kg of Moon samples collected by the CE-5 mission were transferred to the Chinese research institution responsible for storage and analysis of the material. Photos in the Chinese media showed that the lunar sample transport was accompanied by armed guards. A Lunar Samples Handover Ceremony attended by Chinese Vice Premier Liu He and 80 experts from China's space industry and the CE-5 project took place at the National Astronomical Observatory of CAS in Beijing. Zhang Kejian, Head of CNSA, officially assigned ownership to Hou Jianguo, President of the Chinese Academy of Sciences (CAS).

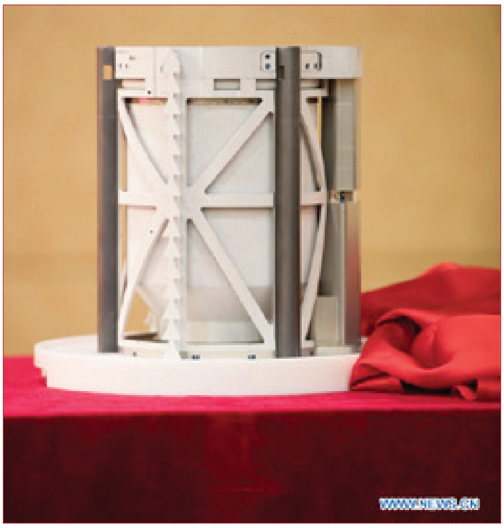
The final destination of the samples are the storage and research facilities of the Moon Sample Laboratory of the National Astronomical Observatory of CAS, also referred to as: Ground Research Application System (GRAS). The laboratory is brand new and was built just for the lunar samples. There are labs and clean rooms for opening, analysing and storing

GRAS staff carry a box containing the CE-5 container with lunar samples at the National Astronomical Observatories under the Chinese Academy of Sciences (CAS) in Beijing, on 19 December 2020. Credit: Xinhua/Jin Liwang

The militia cavalry team, specially trained for the support of the CE-5 landing operations. Credit: Xinhua



A wild animal, most likely a fox, is seen to the right of the just landed and still hot re-entry capsule. Credit: CCTV



Zhang Kejian (r), Head of CNSA, and Hou Jianguo, President of CAS, present the handover certificate after Zhang transferred the lunar samples to Hou, on 19 December 2020. (Xinhua/Jin Liwang)

left: The lunar sample container during the CE-5 Lunar Sample Handover Ceremony at CNSA in Beijing. (Xinhua/ Jin Liwang)

the samples. The material will be divided into 4 categories: for scientific research, for permanent long-term storage, for permanent long-term back up and for exhibitions.
The national and international science community can apply for access to the lunar samples – the CNSA published the guidelines for this process on 18 January 2021.

For photos of the Moon Sample Laboratory at the National Astronomical Observatories of the Chinese Academy of Sciences in Beijing – see GoTaikonauts!, Issue no 31 pages 5-6.

Next steps

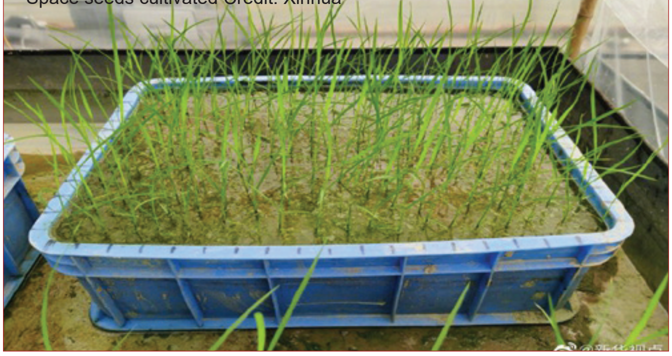
It will take 3-6 months to open the container in the processing laboratory and prepare the lunar material for the correct categorisation. More details in: GoTaikonauts!, no 31, pp. 5-6.

Once the cataloguing is complete, the samples will be distributed to the scientists and institutes which applied for working with the material.

In accordance with international standards, China will make its lunar samples accessible for the global research community. The rules and regulation for that were finally published in January 2021. According to Chinese media reports, China has signed cooperation framework agreements with several international space agencies, including the UN Office for Outer Space Affairs, Russia's state space corporation Roscosmos and the European Space Agency. The fact that the landing site was never sampled before and is geologically younger than the sampling areas of the U.S. and the Soviet missions, is creating significant interest among the international science community. However, it has to be noted that not many laboratories exist that can handle lunar samples. Up to the beginning of 2022, it was not known whether any international research team had received any CE-5 lunar samples.

CE-5 also carried memorabilia of the Beijing Winter Olympics and 30 kinds of seeds from oats, alfalfa and orchid and for the 1^{st} time rice seeds.

Space seeds cultivated Credit: Xinhua



The seeds were selected by experts from national research institutes such as the China Agricultural University, the Beijing Forestry University, the Dalian Maritime University in Liaoning, the South China Agricultural University and the Chinese Academy of Agricultural Sciences. The seeds are part of the space-based mutation breeding programme coordinated by the China High-Tech Industrialisation Association in Beijing. Among the seeds were around 1,500 rice seeds, accounting for 40 g. The rice seeds were handed over on 23 December to the National Engineering Research Centre of Plant Space Breeding of South China Agricultural University (SCAU), in Guangzhou, Guangdong Province. Rice is a model organism in genetic research. By sending rice to deep-space the scientists hope for beneficial mutations caused by the space environment. The institute will also conduct a series of selfing and crossbreeding experiments to cultivate new rice varieties that would show improved properties regarding resistance to diseases and pests, stress tolerance and suitability for mechanised production.

The space breeding institute started the germination of the CE-5 rice seeds in the new year. The green seedlings left the greenhouse for being planted in the fields on 29 March 2021. This 1^{st} batch of rice was expected to be harvested at the end of June 2021 and then sown for a 2^{nd} generation. After 4 to 5 generations, favourable characteristics of the plants are matured and can be selected for new rice varieties.

China is very experienced in using the space environment for initiating gene mutation in seeds. For the 1^{st} time, the deep-space environment could be utilised for a duration of 23 days. Deep-space conditions are extremely unique and are expected to produce even stronger genetic effects than in LEO and in particular compared with terrestrial induced seed mutations achieved by heavy ions radiation.

The photo from 27 November 2020 shows a scanning electron microscope in one of the laboratories at the National Astronomical Observatories of the Chinese Academy of Sciences in Beijing. (National Astronomical Observatories, CAS/ Handout via Xinhua)

Not only scientists are keen to get hold of the fresh lunar material. On 18 May 1788, Carl Rümker who would become later a renowned astronomer, was born in the small town of Burg Stargard in the North-East of Germany. In 1935 Mons Rümker was named after him. On the occasion of the originally planned launch of CE-5 in November 2017, the Major of Burg Stargard and the county of Mecklenburgische Seenplatte invited the Chinese astronaut Chen Dong to Germany. The Major and Chen Dong revealed a commemorative display to honour Carl Rümker. May the lunar sample from Mons Rümker attract world-wide attention and let some glory shine on Rümker's home town of Burg Stargard.

Another handover ceremony was held on 25 December 2021 at the Shaoshan Mao Zedong Memorial Museum in Shaoshan, central China's Hunan Province. The museum was selected as the official and only backup storage of CE-5 lunar samples. Shaoshan is also the home town of the late Chinese leader Mao Zedong. The 10 g of lunar material was handed over by CNSA to Hunan University and will be stored in the newly constructed Shaoshan base. The storage facility was approved to be built in 2014 by Hunan University and passed technical verification tests in July 2021. Among the demanding requirements is for example the protection from natural disasters or the impact or alteration by extreme conditions. The lunar material is stored in a special device filled with nitrogen, with an internal pressure slightly higher than atmospheric pressure, to preserve the samples original state.

The lunar samples represent a significant accomplishment jointly achieved by tens of thousands of sci-tech workers, said Zhang Kejian, head of the CNSA during the 2021 event in Shaoshan. Storing the lunar samples in Chairman Mao's hometown is a profound tribute to his contributions to the Chinese nation and the people of the world, and it honours his long-cherished dream of reaching the Moon, Zhang said.

… and if it is not over – it is not the end

The return capsule landed in Siziwang Banner but the orbiter headed away from Earth after separation from the return capsule on 17 December. With 200 kg of fuel left, the orbiter was assigned to an extended mission. By the moment the re-entry capsule was released, the CE-5 orbiter had a speed of 10 km/s. Mission Control decelerated the orbiter until 19 January 2021 to a speed of 4 km/s. 2 more orbital manoeuvres and 2 trajectory correction led the orbiter to the inner L1 Earth-Sun Lagrange point where it arrived on 15 March 2021. CE-5 carried out observations of the space environment and the sun and was used for operational tests. CE-5 joined the 25-year-old ESA-NASA Solar and Heliospheric Observatory (SOHO) and NASA's Deep Space Climate Observatory (DSCOVR) – both still operating there. By arrival in L1 still with approx. 100 kg of propellant left, mission controllers decided to conduct another orbital manoeuvre on 30 August 2021. The CE-5 orbiter flew back to the Earth-Moon system, and made a lunar flyby on 12 September 2021 (some reports say: 9 September). As of December 2021, the official mission end is unknown.

China has experience in extending its lunar missions. CE-2, launched in 2010, flew to the Earth-Sun L2 Lagrange point after completing its primary mission. After that there was still sufficient fuel available for a flyby of near-Earth asteroid Toutatis in December 2012 and the continuation of the flight. Only in 2014 contact was lost.

Also, the CE-5-T1 mission from 2014 went on after the accomplishment of its primary mission to travel to the Earth-Moon L2 Lagrange Point. China used the opportunity for gaining operational experience for the later Queqiao relay satellite, positioned in Earth-Moon L2.

All future Chinese Moon missions are part of the 4th phase of its national lunar exploration project CLEP (China Lunar Exploration Programme).

According to CNSA mission planners, CE-6 is scheduled to be launched around 2023 and bring rock and soil samples from the lunar South Pole back to Earth. The exact launch date and landing site of the CE-6 mission will be determined based on the results of the CE-5 mission. It might well be that CE-6 will sample the far side of the Moon. That is depending on whether Queqiao is still functioning or not.

CE-6 will consist of 4 components: orbiter, lander, ascender and re-entry module.

In addition to its own mission payloads, CNSA will allocate 20 kg of payload capacity – 10 kg on the orbiter and 10 kg on the lander - for other national and foreign users, as well as Chinese private enterprises.

However, CE-6 will launch after CE-7 because the mission goal of CE-7 is to conduct a thorough investigation of the lunar South Pole in 2024. CE-8 will be tasked with testing and verifying high-technologies that are of interest for future Moon expeditions, including the International Lunar Research Station (ILRS) jointly planned with Russia.

On 9 March 2021, approved by both nations' governments, Zhang Kejian, Director of CNSA, and Dmitry Rogozin, Director General of Roscosmos, signed the "Memorandum of Understanding between the Government of the People's Republic of China and the Government of the Russian Federation on Cooperative Construction of International Lunar Research Stations" via video conference.

The ILRS is a comprehensive experimental research base built on the lunar surface and/or the lunar orbit for multi-disciplinary and multi-objective scientific research activities such as lunar exploration, in-situ resource utilisation, lunar-based observation, fundamental scientific research and technology verification, and long-term autonomous robotic operation.

China and Russia intend to use their accumulated experience in space science, research and development and use of space equipment and space technology to jointly develop a road map for the construction of an ILRS. Close collaboration is carried out in the planning, demonstration, design, development, implementation and operation of the scientific research station project, including the promotion of the project to the international aerospace community.

The CE-5 lunar sample handover ceremony is held in Shaoshan, Central China's Hunan Province on 25 December 2021. Credit: Hunan provincial publicity department

For extensive details on the Chang'e 7 mission, please, consult, GoTaikonauts!, Issue 31, pages 6-7 and for the ILRS in GoTaikonauts!, Issue 33, pages 25-26.

Beijing Time = GMT (UTC) + 8 hours


Thinking
in
visions!
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