All About The Chinese Space Programme

Go Taikonauts!

龙腾太空

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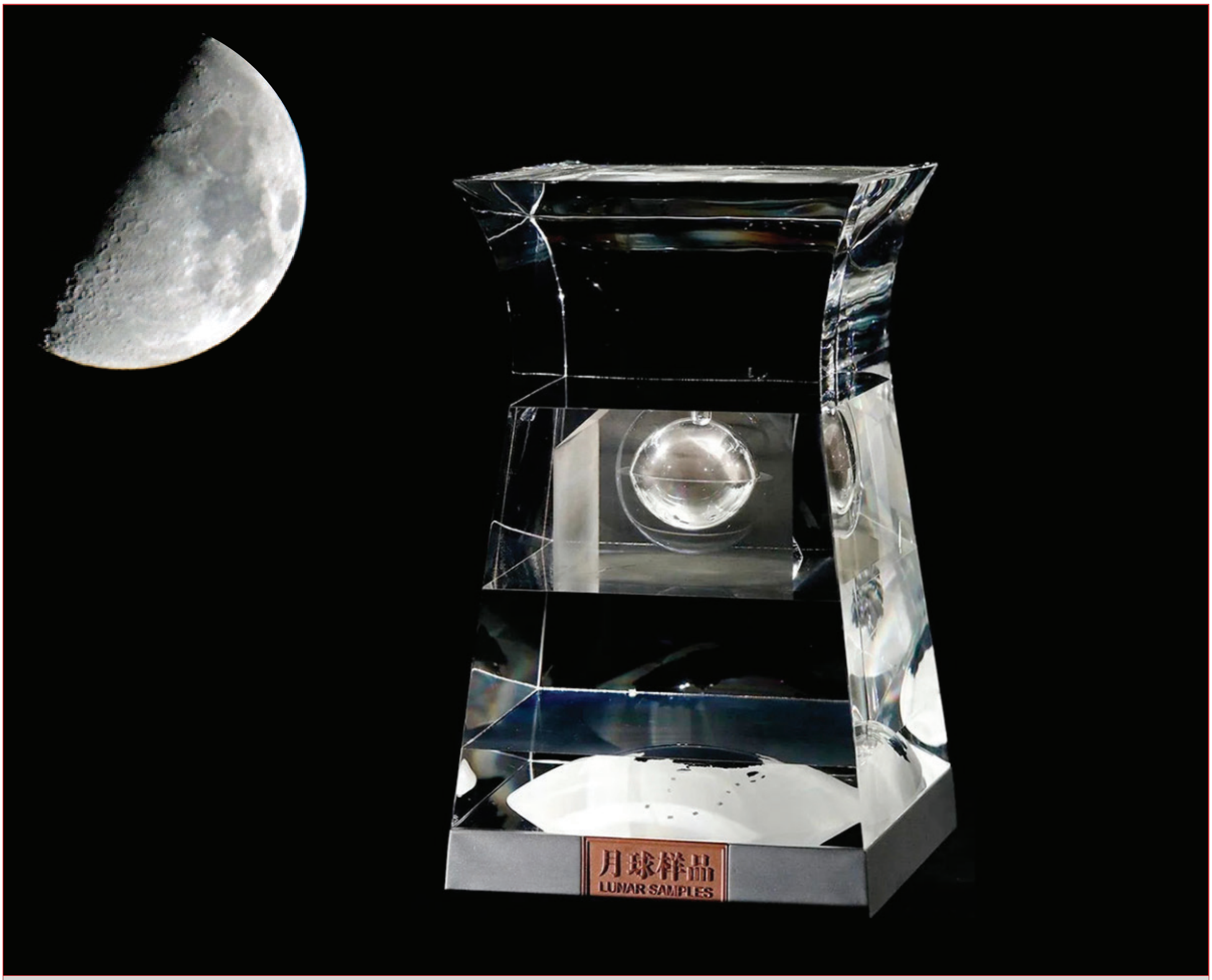


The lunar sample no. 001, which was brought to Earth by the Chang'e 5 mission was inlayed into a transparent vase, shaped like a "zun" - a traditional Chinese bronze ware. Since 27 February 2021, the sample is at display in the National Museum of China in Beijing. Credit: National Museum of China/Xinhua/Jin Liangkuai/Hartmut Sänger

Content

Chinese Space Quarterly Report

January - March 2020

by Jacqueline Myrrhe

SPACE TRANSPORTATION

CZ-3B

During a Beidou satellite launch on 9 March, one of the CZ-3B rocket boosters returned guided by parachutes. Following separation from the rocket, the parachutes opened sequentially, with real-time positioning data relayed back to ground control in Xichang where the drop-point could be calculated.

This new technology is the result of 10 years of research. One of the major difficulties was how to sequence the deployment of the parachutes as each of the 4 t-boosters falls uncontrolled at a speed of around 2 km/s after separation.

The parachuted drop makes it possible to narrow down the landing area that was previously 90 km long and 30 km wide by 85%, and the recovery team could locate the booster within 25 min compared to hours or up to 2 weeks before. More tests are planned to improve the control system. China Academy of Launch Vehicle Technology (CALT) used another technology for the same purpose: in July 2019 it tested for the first time, grid fins on a CZ-2C.

CZ-3B booster after landing by parachute. Credit: CCTV

CZ-5 Y4

On 19 January, the YF-77 high thrust cryogenic engines for the 4th flight of the CZ-5 (CZ-5 Y4) completed a 100 s test hot fire at China Aerospace Science and Technology Corporation's (CASC) test facility in Beijing. The test went smoothly. Once the data were analysed and provided no problems are detected, the engine would be sent for final assembly to the rocket factory in Tianjin. The CZ-5 Y4 is prepared for the launch of the Mars mission Tianwen 1 in July 2020. During the launch, the full duration of the engine burn is 500 s.

For the 3 missions on the CZ-5 manifest in 2020 (new-generation manned spacecraft on the 1st flight of the CZ-5B, Tianwen 1 and Chang'e 5) a total of 24 high thrust hydrogen-oxygen rocket engine tests will be conducted. The development team will also test randomly, engines of the same batch for up to over 500 s to check the overall performance of the engine series.

Unconfirmed reports by a Weibo blogger gave the 23 July as launch date for the Tianwen 1 mission. Arrival on Mars would follow in February 2021 and landing in April 2021.

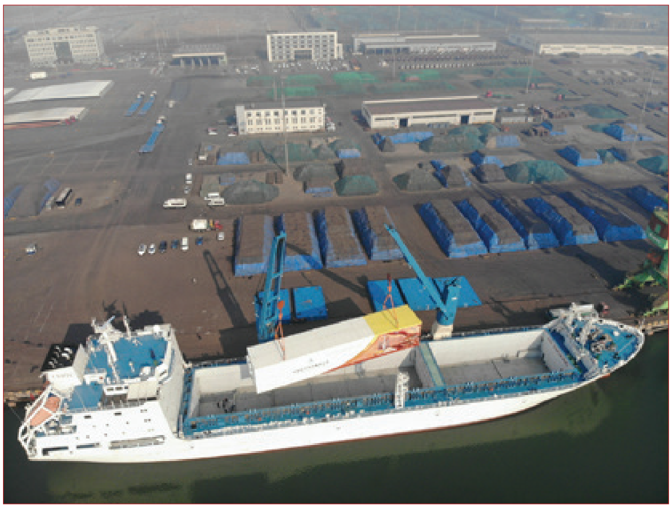
CZ-5B

The 1st CZ-5B carrier rocket - including its 5 m-diameter core stage and 4 side boosters - passed a quality examination on 19 January at CASC's factory in Tianjin. The CZ-5B with its extended payload fairing of 20.5 m by 5.2 m has the largest carrying capacity to LEO.

The rocket's components were carried by two specially designed rocket transportation ships, the Yuanwang 21 and Yuanwang 22, which left Tianjin port close to the rocket manufacturing facility on 26 January. They sailed through the Bohai Sea, the Huanghai Sea, the East China Sea, the Taiwan Strait and the South China Sea, arriving at the Qinglan Port in Wenchang City on Hainan Island on 1 February.

Rendering of the CZ-5. Credit: CGTN

The rocket parts were loaded onto special trucks and arrived via road at the Wenchang Space Launch Centre on 5 February for further checks and preparations, which included a series of dry runs with the prototype of the space station's core module to verify the pre-launch procedures for the space station missions and train the team on the launch site. After that, the prototype space station module will be shipped back to Tianjin for more testing. Following these training activities at Wenchang, the CZ-5B was prepared for its debut flight in the 1st half of 2020 to launch the test version of the new-generation manned spaceship. The test flight will be unmanned. The CZ-5B is the first variant of the CZ-5.



The parts of the CZ-5 are loaded on board the Yuanwang ship at the port in Tianjin. Credit: ChinaDaily.com.cn

The CZ-5 rocket parts are offloaded in Wenchang. Credit: ChinaDaily.com.cn

Yuanwang rocket transport ships in action
CGTN footage of the arrival of the CZ-5B rocket parts at Qinglan Port in Wenchang. It took the Yuanwang ships roughly 1 week to transport the rocket from Tianjin (South of Beijing) to Hainan Island.

CZ-7A

The rocket parts for the newly developed medium-sized carrier rocket CZ-7A arrived in early January on board the Yuanwang 21 cargo ship at the Qinglan port on Hainan island. By mid-February, the CZ-7A rocket was rolled out at the Wenchang Space Launch Centre launch pad in preparation for lifting a technology verification satellite into GTO.

The CZ-7A finally took-off on 16 March 2020, at 13:34 UTC (21:34 BJT) from Wenchang Space Launch Centre.

The launch resulted in a failure shortly after take-off. Xinhua news agency reported a malfunction without providing any further details. The cause of the failure was investigated. The CZ-7A is capable of sending satellites into GEO or can be used for deep-space exploration. It was used before for launching the Tianzhou 1 cargo spacecraft to the Tiangong 2 space lab.

CZ-11

During a news conference at CASC in Beijing on 17 January, Jin Xin, the CZ-11 Deputy Project Manager announced that it is planned to conduct 3 seaborne launches of the CZ-11 from a sea going self-propelled platform in the East China Sea in 2020. Compared with the 1st sea launch in June 2019 in the Yellow Sea, off the coast of Shandong province which used a modified submersible platform without propulsion system, the coming missions will use better ships and streamlined tracking and support systems. Additionally, the CZ-11 launch manifest for 2020 lists 2 land-based missions.

Sea launch on the pier. Credit: CCTV

Yuanwang 3, Yuanwang 7

On 20 January, the Yuanwang 3 (YW-3) and Yuanwang 7 (YW-7) space-tracking ships returned to the port of the China Satellite Maritime Tracking and Controlling Department after completing 3 monitoring missions. The ships met the week before in the Pacific Ocean, on their way back home. By the end of January, all 4 space-tracking ships in service had returned to port or were in a shipyard for maintenance (YW-6).

Because of increased demand for space tracking, the Yuanwang ships often stay at sea for more than 200 days a year.

Yuanwang 5

YW-5 returned to the dock of the China Satellite Maritime Tracking and Control Department on 2 January, after successfully concluding a series of maritime monitoring missions during the last months of 2019. In total, YW-5 spent 204 days at sea, participating in 3 missions: for 2 dual-MEO satellite launches for the Beidou Navigation Satellite System (BDS)-3, and the launch of the CZ-5 Y3 heavy-lift rocket on 27 December 2019.

At the end of February 2020, YW-5 left its home port for the first mission of the year to sail to the Pacific Ocean. Before the end of the Spring Festival, all crew members self-quarantined on the ship to ensure nobody had a Coronavirus infection. The crew stored medical supplies, examined facilities and conducted rehearsals in preparation for the upcoming mission.

Yuanwang 6

On 17 January, YW-6 concluded with test excursions its 9 month-long general overhaul at Jiangnan Shipyard in Shanghai which started in April 2019. It was the vessel's first major maintenance after commissioning in 2008. The work improved the ship's power system and enhanced the operability of on-board equipment. The 3rd generation YW-6 was scheduled for space tracking missions in the 1st quarter of 2020.

Yuanwang 7

On 27 February, YW-7 left its port at the China Satellite Maritime Tracking and Controlling Department in Jiangsu Province and headed for its 1st mission to the Atlantic Ocean. So far only YW-3 has conducted missions in the Atlantic. The captain told media that the designated maritime area is remote and the route is new. Before setting sail, crew members self-quarantined on the vessel and cabins were disinfected to prevent any Coronavirus infection. The crew prepared and checked all medical supplies and examined the on-board facilities. YW-7 is the most modern vessel of the space tracking fleet, developed with the latest technologies in shipbuilding, space tracking and control, marine meteorology and engine performance.

For more details on the space tracking ships – see the detailed report by Brian Harvey on pages 29 to 31.

Please note: There are inconsistencies in our reporting about the date of arrival and leaving port most likely because of discrepancies between the AIS (Automatic Identification System) and the information about the Yuanwang ships in the Chinese press. We assume that this reflects time delays between events happening, when they are reported and when AIS signals are relayed, with the possible additional complication of time zones and possibly translation inaccuracy regarding 'leaving', 'left' or 'due to leave' port (However, in Chinese, "leave" is a clear concept and has no other meanings.).

Pandemic Impact on Space Sector

During the 1st quarter of 2020, the outbreak of the Coronavirus impacted the operations in the space industry and the space programmes. Initially, 2020 was supposed to become a busy year with deep-space missions, the start of the CSS (Chinese Space Station) assembly and several commercial flights. Some missions were delayed while others could not wait, since the launch window for a Mars flight will not remain open after the summer. The same applied for international space conferences in China and with Chinese participation in other countries.

It was reported that special prevention and hygiene concepts were implemented in the companies and in particular at the launch sites. Teams were split up in shifts, isolation areas were set-up, regular disinfection of the workplaces done, face masks were obligatory and body temperature measurements introduced.

Desinfection activity in a facility at Xichang launch site. Credit: Jiao Huangxin

MANNED SPACE FLIGHT

Chinese Space Station - CSS

On 20 January 2020 - after about a week of land and sea transport from the factory in Tianjin where the hardware was built - the space station's core module Tianhe (Harmony of the Heavens) and the new-generation crewed test-spacecraft arrived at the Wenchang Space Launch Centre on Hainan Island for 3 month-long rehearsals and tests in mating checks with the CZ-5B carrier rocket. The tests would comprise functional tests of the rocket and module and the simulation of the launch procedures.

The Tianhe module is 16.6 m long, has a max. diameter of 4.2 m, and a launch mass of 22.5 t. It can accommodate 3 taikonauts for long-term stays and more for short-duration missions. Mainly with a command-and-control function, limited science research can be conducted in the module.

Hao Chun, Director of the China Manned Space Engineering Office (CMSEO) told CCTV on 6 February that for the construction of the CSS 12 missions (including the CZ-5B test flight) are planned until 2022.

New-Generation Crewed Spaceship

The test version of the new manned spacecraft arrived along with the CSS' core module Tianhe in Wenchang and was prepared for pre-launch readiness. The new crewed craft has a special modular and highly reliable design for CSS flights and lunar missions. It will be launched with the 1st flight of the CZ-5B in the 1st half of 2020. The CZ-5B, a CZ-5 derived rocket, arrived in Wenchang on 1 February.

The as yet unnamed manned spacecraft is 8.8 m long and has a launch mass of 21.6 t. (see: text box to the right for more details.) The test flight without crew will assess the flight performance, the avionics, the thermal protection, high-speed re-entry from a 8,000 km high orbit, the group-parachute landing system, the lightweight re-entry heat shield, a new airbag impact cushion and other key technologies.

After the test flight, space engineers will evaluate and analyse the state of the spacecraft to verify the whole system for human-rated use.

Once the partly re-usable manned capsule becomes operational it could ferry up to 6 taikonauts or 3 taikonauts plus 500 kg of cargo into LEO. For flights beyond LEO, the craft can be hosted on a stronger launcher.

The prototype of China's new-generation manned spaceship in the test facility. Credit: China Academy of Space Technology

New-generation Reusable Crewed Spaceship

On 20 January, the test crew spacecraft arrived at Wenchang Space Launch Centre for launch preparations.

The new manned spaceship design brings many improvements. Since it is an advanced transport ship capable of LEO and deep-space missions, it paves the way for China's manned missions of the next decades.

The new-generation crewed spacecraft is 8.8 m long, has a diameter of 4.5 m and is partially reusable. For missions to LEO it can accommodate 6 taikonauts or 3 taikonauts plus 500 kg cargo. The Shenzhou manned spacecraft historically adopts a 3-segment design, consisting of a return capsule, a propulsion section and an orbital module. The propulsion section and the orbital module burn up in the atmosphere, with only the return capsule making a landing at the mission's end. China's new generation manned spacecraft has 2 sections: a service module which provides power and energy, propulsion, fuel resources and other subsystems and a return capsule, which is the command centre and the taikonauts' living compartment. The service module is expendable while the return capsule can be paired with another service section for the next flight. The new design supports a high degree of reusability. The light weight thermal protection hull is mounted in layers and segments and can be dismantled and replaced after flight. The heat shield of the Shenzhou spaceships was integrated in the overall capsule's metal structure, making it robust but did not allow disassembly and reuse. The new-generation manned spacecraft has a 2-3 times better thermal resistance than the Shenzhou, coping with temperatures up to 3,000°C but having 1/3 of the density of the Shenzhou heat shield. The new heat shield allows for high-speed re-entry which is a prerequisite for deep-space missions. The new material and structure were developed in China and are of advanced technology.

Star sensors, electronic and other cost intensive components have been moved to the return capsule with the intention to support reuse.

There are also improvements on the return capabilities, supporting a higher landing accuracy. It is equipped with 12 monopropellant-powered engines, burning non-toxic propulsion. Other improvements include a distributed integrated electronic system, an autonomous guidance, navigation and control system, solar cells with high conversion efficiency and multi-terminal human-computer interaction system.

With an overall mass of 21.6 t, the new spacecraft is still double as heavy as the Shenzhou, meaning that for the landing, the single-parachute configuration of the Shenzhou spaceship would not be enough. Therefore, it was replaced with a parachute combination of 3 parachutes.

In addition, the airbags for cushioning the landing impact are also part of the overall reusable design concept. Experts say that the return unit of the new generation spacecraft might be re-used up to 10 times.

The altitude of the test flight is planned to be 8,000 km exceeding the Shenzhou' performance. For that flight, the CZ-5B will be used which is actually the preferred means of transport for the CSS modules. To mimic the weight of the 22 t station modules, the test manned spacecraft will be fuelled with 10 t of propellant and packed with cargo. The test flight will be unmanned but all data from the installed data acquisition system and the flown hardware will be analysed after the return to further verify the technology and design and prepare for the functional verification of the entire system and prepare for manned flight.

Once this new-generation spacecraft becomes operational, the "old" Shenzhou spacecraft will still be used. Depending on mission and destination, the two manned systems will complement each other.

The crew spaceship was developed by the China Academy of Space Technology (CAST), CASC's 5th Academy. The work for building the test version started in January 2017. It has no name yet.

LUNAR AND DEEP-SPACE EXPLORATION

CHANG'E 4
See pages: 19 to 23

CHANG'E 5
Peng Jing, Deputy Chief Designer of the Chang'e 5 (CE-5) lunar probe at the China Academy of Space Technology confirmed at the end of January that the mission will land in the region of Mons Rümker on the north-western part of the Oceanus Procellarum. This particular location was selected because it has never been reached by man or rover and because scientists are interested in the geological history of that place. Compared with the lunar samples brought back by the U.S.-American Apollo missions and the Soviet Luna robotic probes, the material in the Mons Rümker territory is believed to be 1-2 billion years younger than in the regions known so far. The aim is to bring at least 1 kg of lunar sample back to Earth, hopefully 2 kg or even more.
Peng said about the future ambitions that 2 or 3 missions could support the set-up of a simple scientific outpost on the Moon, which would be able to accommodate crews for short-term stays, to carry out experiments and explore the feasibility of long-term visits.
At the beginning of March, Peng Jing pointed out in his INSIDE OUTER SPACE-blog that Chinese lunar experts were scheduled to talk at the cancelled 51st Lunar and Planetary Science Conference (LPSC2020), 16-20 March 2020, The Woodlands, Texas. The papers give an introduction to China's readiness to handle samples from the Moon. It outlines which steps need to be taken for storage, processing and preparation of the specimens which the next Chinese lunar mission, Chang'e 5, will return to Earth. Another paper describes the follow-up missions after CE-5. *see text boxes:* "CHANG'E 5" and "CHANG'E 7".

CHANG'E 5 – LUNAR SAMPLE HANDLING
Drawing from the experience from NASA's Apollo programme and the Soviet Union's Luna project, the Chinese researchers defined their specific requirements and processes for handling the lunar material to be expected returned to Earth by the CE-5 mission, later in 2020. These findings were prepared for a presentation during the 51st Lunar and Planetary Science Conference - LPSC2020, 16-20 March 2020, The Woodlands, Texas. Due to the Corona pandemic, the conference did not go through but the abstract of the paper was published and can be found online.

"Storage, processing and preparation methods for China's returned lunar samples"

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For the purpose of handling the lunar samples, China decided to establish the Ground Research Application System (GRAS) within the Lunar Exploration Programme (CLEP). GRAS is hosted at the premises of the National Astronomical Observatory of the Chinese Academy of Sciences in Beijing.
GRAS defined the planning and the processing steps required to receive, pre-process, store and document the lunar material returned by the Chang'e 5 lunar sample return mission. Also, GRAS is managing the new Lunar Sample Laboratory equipped with highly-sophisticated instruments and staffed by specialists. The returned samples are divided into 2 categories and will be handled separately:

- scooped regolith and
- drill cores

Both types of samples will be categorised according to their purpose, what specifically means:

- for permanent storage
- for back-up permanent storage,
- for scientific research and
- samples for exhibition.

The handling sequence includes 4 main steps.

1. Handover and transfer
2. Unsealing
3. Drilled samples separation
4. Scooped samples separation

1. GRAS receives the sealed package (containing the sealed samples) straight from the spacecraft, places it in a nitrogen gas-filled transfer box and transports it to the Lunar Samples Laboratory. Here, the sealed package will be brought to the Sample Storage and Unsealing Laboratory, dedicated to unsealing, pre-processing and storing.
2. In the Lunar Samples Laboratory, the sealed package is processed in an un-sealing glove box. The glove box hosts an 'operation compartment' and an 'un-sealing compartment'. First, the unsealed package is sent to the specially prepared 'operation compartment' where the un-sealing tool is attached. **(Figure 1) [2]**. After that, the package is put into the 'un-sealing compartment' where it is un-sealed and any released gases are collected (for subsequent gas component analysis). The now un-sealed package, containing the two still sealed containers - one with 'scooped regolith' and one with 'drill core' samples - is then returned to the 'operation cabin'. At this stage, the drilled and scooped samples will be treated separately, for which they are taken out of their sealed containers.
3. The 'drill core' samples are then removed from their soft bag, cut into 15 cm sections, and divided into 2 sets, one for subsequent research analysis and one for permanent storage, the latter set being returned to the soft bag container. Any left-over material will be kept in the transfer package and kept for permanent storage.
4. The 'scooped regolith' samples, following un-sealing by the unblocking (un-sealing) tool, are then filled into a square-shaped container where the material is divided into equal portions by using the 16 equal division method (a commonly-used sampling methodology in geology). After that, the material will be divided into research samples, permanent storage and back-up permanent storage samples and stored according to their category.

The final step is to transfer the permanent storage samples to the permanent storage glovebox in the long-term storage room, and the research and back-up permanent samples are to be transferred to the temporary glovebox, **(Figure 2) [1, 2]** waiting for further utilisation.
Those samples, intended for research will be taken out from the temporary glovebox and positioned in a nitrogen-filled glovebox with a stereo microscope. A selection is then made to identify required single particle samples, including minerals/glass particles, and lithic fragments.
The samples will be first analysed non-destructively to understand the samples' elementary composition and structure. For that, the wavelength and intensity of the characteristic fluorescence X-rays generated by the different elements in the samples is studied. The scientists will use microscopic amounts to ensure that as little as possible material is needed.
Thin section samples will also be prepared for structural and compositional analysis in an oxygen-filled glovebox.
All the tools that will come in contact with lunar sample are made of stainless steel, teflon, quartz glass or materials

of known composition to strictly control the factors that will affect the scientific analysis. The water and oxygen content in the glovebox will be strictly monitored to prevent terrestrial contamination.

The procedures will make it possible to compare the Chang'e 5 samples directly with the Apollo and Luna samples.

[1] *Sun L. Z. et al. (2017) Chinese Journal of Vacuum Science and Technology, 37 (8)*

[2] *Wu Q. P. et al. (2017) Chinese Journal of Vacuum Science and Technology, 37 (9): 851-856*

Figure 1: Un-sealing Glovebox. This photo, taken on 27 November 2020 shows the operation area in the Lunar Sample Laboratory for Moon samples at the National Astronomical Observatories of the Chinese Academy of Sciences in Beijing. The Chang'e 5 samples will be unsealed in this glovebox. Credit: National Astronomical Observatories, CAS/Handout via Xinhua

Figure 2: Lunar Sample Storage Glovebox. This photo taken on 27 November 2020 shows the temporary storage device for subsurface samples collected by drilling underground in the Lunar Sample Laboratory at the National Astronomical Observatories of the Chinese Academy of Sciences in Beijing. Credit: National Astronomical Observatories, CAS/Handout via Xinhua

Figure 3: This photo taken on 22 April 2020 shows the Lunar Sample Laboratory at the National Astronomical Observatories of the Chinese Academy of Sciences in Beijing. The Chang'e 5 lunar samples will be unsealed, processed and stored at this laboratory. Credit: National Astronomical Observatories, CAS/Handout via Xinhua

CHANG'E 7

Leonard David mentioned in his INSIDE OUTER SPACE-blog the Chang'e 7 paper for the 51st Lunar and Planetary Science Conference - LPSC2020. The CE-7 mission, scheduled for 2024, is the 1st of the follow-up missions after CE-1 to CE-5. It will launch before CE-6. See text box below for details

CHANG'E 7

51st Lunar and Planetary Science Conference, 16-20 March 2020, The Woodlands, Texas

abstract no 1755: "Overview of China's Upcoming Chang'e series and the Scientific Objectives and Payloads for Chang'e 7 Mission", Yongliao Zou, Yang Liu, Yingzhuo Jia, National Space Science Centre, Chinese Academy of Sciences, Beijing, China.

Within CLEP a series of follow-up missions will be implemented: CE-6, CE-7, and CE-8. **[1]**

Through these 3 missions, China will have the ability to reach the full lunar surface and achieve the goals for in-situ scientific research, resource exploration and application verification. Finally, a robotic scientific research station prototype will be built on the south pole of the Moon by 2035.

The overall scientific objectives include:

- investigating the composition and structure of the Moon's interior;
- investigating the global distribution, content, and source of water and volatile components;
- measuring the age of the South Pole-Aitken (SPA) Basin;
- investigating the space environment above the lunar south pole;
- in-situ lunar resource utilisation experiments;
- Moon-based observation and research of Earth;
- lunar orbit Very Long Baseline Interferometry system (VLBI) for astronomical research;
- scientific experiments related to the lunar surface ecosystem.

The Chang'e 7 mission

The launch of CE-7 is scheduled for 2024, becoming the 1st of the 3 follow-up missions of CLEP.

The scientific objective of the mission include:

1. obtaining information of the lunar inner ring structure, mineral and element components, the characteristics of the electric and magnetic fields, heat flow and gravitational field;
2. obtaining the distribution and source of lunar water and volatiles, directly confirming the presence and source of water-ice on the Moon;
3. imaging the energetic neutral atoms with high space-time and energy resolution of the Earth's magnetotail and understanding the dynamics of the Earth's magnetotail;
4. researching the space environment, such as lunar surface magnetic field, lunar dust and particle radiation, revealing the mechanism of solar wind causing the magnetic anomalies in the vortex region of the lunar surface **[2]**.

CE-7 will consist of a relay satellite, an orbiter, a lander, a rover and a mini-flyer. The total weight will be 8,200 kg. The mission will host 23 scientific payloads - accounting for 415 kg out of the 8.2 t. The relay satellite will accommodate 2 science payloads, the orbiter 5, the lander 7, the rover 4, and the mini-flyer 1 **[4]**. For details on the payloads, see: Table 1. Note that these scientific objectives and payloads are proposals by Chinese scientists and the list is not yet finalised.

CE-7 will establish a relay communication link from the lunar south polar region to the Earth and will conduct a detailed survey of the environment and resources in the lunar polar region. In-situ science and resource exploration of the lunar south pole will be completed through the lander, rover and mini-flyer. The

CE-7 probe will make breakthroughs in key technologies such as high-precision lunar survey, fixed-point landing, airborne surface feature detection, and intelligent robots operating in the harsh environment of the lunar polar region and will test new space technology **[3]**.

Next to serving as the communication transmitter the relay satellite supports deep-space VLBI measurements and radio observation research. The orbiter will host the lander and the rover.

The mission profile consists of Earth-Moon transfer and near-Moon deceleration, the release of the relay satellite and the lander according to the flight procedures, and high-precision remote-sensing of the Moon. The lander carrying the rover and the mini-flyer, will make a soft landing on the south pole of the Moon to conduct scientific exploration of the lunar surface. After the landing, the rover will be deployed and start lunar surface and in-situ exploration. The mini-flyer, carries a science payload named Water Molecule and Hydrogen Isotope Analyser. The flyer is supposed to take off from outside the crater, land in the permanently shadowed area for a short period of time, go around and land in the illuminated area of the crater rim to perform motion detection **[3]**.

China is open to cooperate with other countries on lunar exploration and encourages the participation of planetary scientists from all over the world to establish a lunar science platform for communication **[5]**.

The configuration relationships of each of the science payloads and the scientific exploration missions

__Relay-satellite__

1. Grid-based Energetic Neural Atom Imager
Obtain the global imaging data of neutral atoms in the Earth's magnetosphere energy

2. lunar orbit Very Long Baseline Interferometry system
Earth-Moon VLBI measurement and radio astronomy observation

__Orbiter__

1. High Resolution Stereo Mapping Camera
High precision topography of the lunar surface

2. Miniature Synthetic Aperture Radar
High precision topography of lunar surface and permanent shadow

3. Wide Band Infrared Spectrum Mineral Imaging Analyser
High precision mineral composition and surface thermal environment

4. Lunar Neutron Gamma Spectrometer
High precision characteristic gamma ray and neutron flow data for lunar surface

5. Lunar Orbit Magnetometer
Combined with the rover magnetometer to obtain data on the lunar micro-magnetosphere

__Lander__

1. Landing Camera
Landing area topography data

2. Topography Camera
Topography data of landing area and surface terrain

3. In-situ Measuring System of Volatiles and Isotopes on Lunar Surface
In-situ exploration of volatiles in the landing area

4. Lunar Soil Section Thermal Current Measuring Instrument
Measuring the lunar soil heat flow

5. Lunar Surface Thermometer
Measure the temperature of lunar surface

6. Extreme Ultraviolet Camera
Obtain the imaging data of the Earth plasma layer

7. Lunar Seismograph
Obtain the lunar seismic data on the south pole

__Rover__

1. Panoramic Camera
Obtain the topographic data on the rover area

2. Rover Magnetometer
Obtain the magnetic field and its gradient change on the rover area

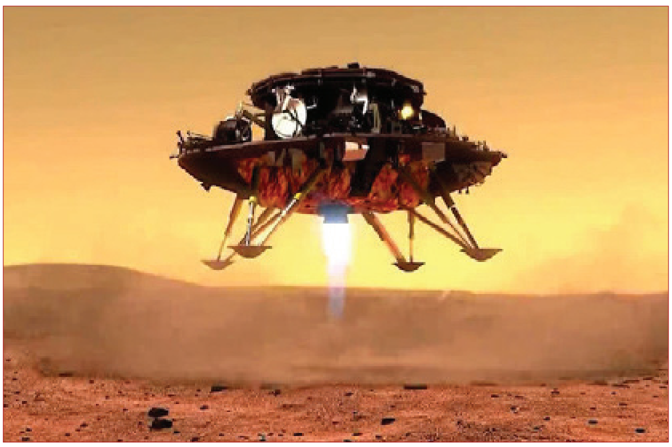
3. Lunar Penetrating Radar
Obtain the data of shallow structure of lunar soil on the rover area

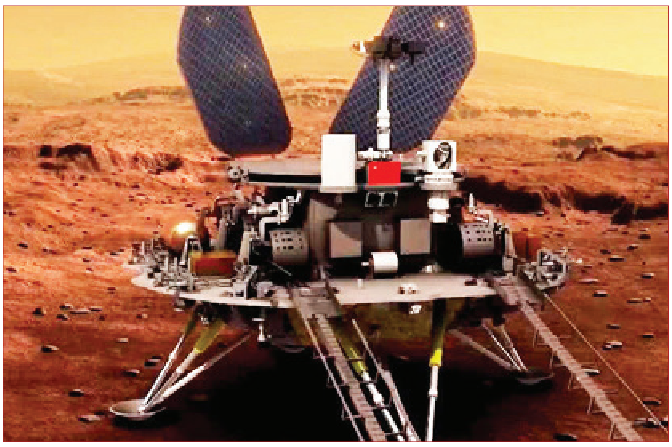
4. Lunar Raman Spectrometer
Obtain the data of mineral composition on the rover area

__Mini-Flyer__

Water Molecule and Hydrogen Isotope Analyser
Water molecule and hydrogen isotope measurement on the lunar permanently shadowed area

[1] CNSA, "Chang'e-4 press conference" (2019). http://www.youtube.com/watch?v=v7FiaHwv-BI.
[2] CNSA. "Report on the Science Objectives and Application Objectives for the Fourth Phase of Lunar Exploration Project" (2019).
[3] CNSA. "Report on the System Implementation Plan of CE-7 for the Fourth Phase of Lunar Exploration Project" (2019).
[4] CNSA. "Report on the Science Payloads Configuration Plan for the Fourth Phase of Lunar Exploration Project" (2019).
[5] CNSA, "United Nations/China Forum on Space Solutions: Realizing the Sustainable Development Goals" (2019).

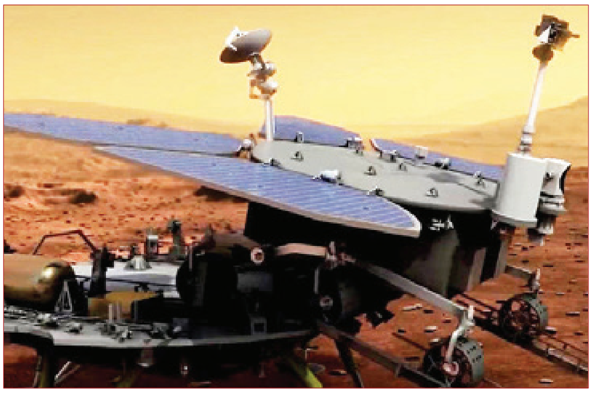




left: Artist's impression of Mars landing.
right: Artist's impression of Mars lander with Mars rover on top. The rover is about to unfold its solar panels. Credit: CNSA

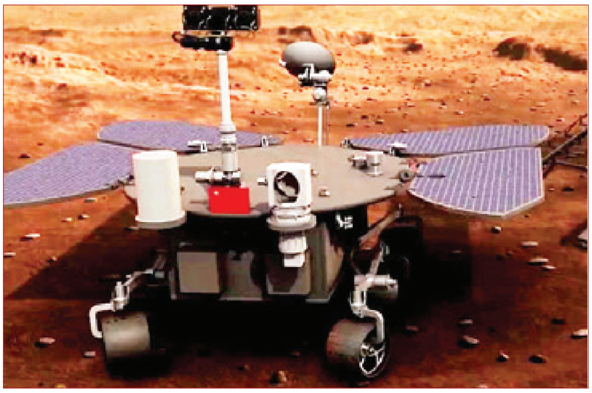
MARS

At the beginning of January, artist's impressions of the upcoming Mars mission were posted on Weibo.

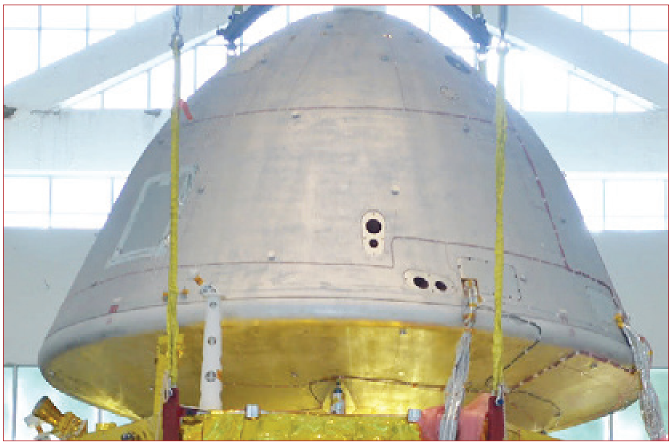


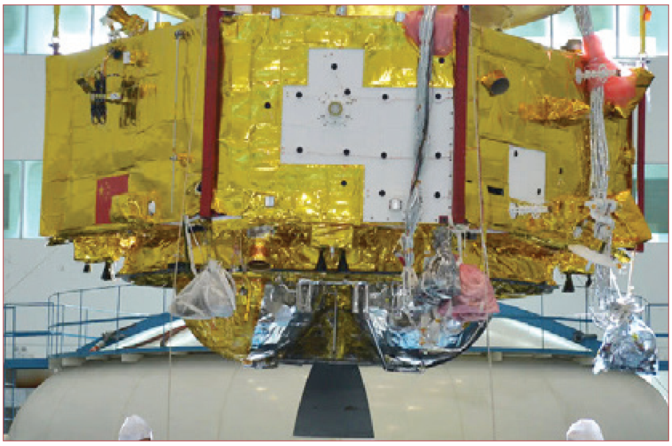
left: Artist's impression of the rover being deployed to the Mars surface by driving down the ramp.

right: Artist's impression of the Mars rover - ready for operations on the Martian terrain. Credit: CNSA



In January, the Mars rover was undergoing thermal testing which was the final large-scale environment test at CAST. The staff was aiming at the completion of the tests during the Spring Festival. Since the start of the development of the Mars probe 5 years ago, the space experts had to overcome many difficulties but always ensured timely delivery.





from top to bottom: Close-up of the Mars probe's re-entry capsule. The whole Mars spacecraft. Close-up of the Mars Orbiter. Credit: CASC/CAST

China Youth Daily reported on 23 January that China's first Mars mission is planned to be launched in July with the 4th launch of the CZ-5, adding that this is the first time the country disclosed the launch month of its Mars exploration programme. There has been unofficial reporting about the mission on a Weibo blog.

Chinese scientists and engineers at the Beijing Aerospace Control Centre (BACC) finished a major test on 10 March in Beijing to verify compatibility between ground control and the Mars probe. The wireless network test is the only joint ground rehearsal between the mission centre and the spacecraft.

While the space environment and distance during the flight to Mars is continuously changing, command and control will be very difficult and challenging for the Chinese space flight operators.

The test exercise comprehensively covered all of the mission's profile, technical conditions, software and hardware systems. The test, the first of its kind in the country, successfully examined signal transmissions and interfaces between ground systems and the robotic probe. Technical plans and statuses, as well as related hardware and software, were put through comprehensive trial runs, and all procedures were the same as those to be used in the upcoming mission.

The outcome of the test will be evaluated and used to optimise the planning.

The teams involved in the preparation for the launch of the Mars mission did their utmost to ensure that everything remained on track for a launch in July. The engineers and space scientists managed to continue the work during the peak time of the Coronavirus outbreak in the first 2 months of 2020. Shift work, telework, online meetings, and on-site accommodation during test campaigns were applied. Nature magazine reported that at the beginning of March the team had to deliver 6 of the scientific payloads for the orbiter from Beijing to Shanghai for integration onto the probe. To avoid infection, 3 team members used a car for the 12-hour long transport. 20 research teams with approx. 70 scientists each across China were involved in the development of the craft's instruments and scientific investigations.

SCIENCE

GRAVITATIONAL WAVES

CASC confirmed the successful verification of the drag-free control technology for satellites with the Tianqin 1 probe. Drag-free means that all external forces that can affect a satellite, apart from gravity, but including solar radiation and atmospheric drag, are compensated so that the probe remains static and stable – a precondition for gravitational wave detection. Tianqin 1 is China's 1st satellite for technology demonstration of space-based gravitational wave detection. Data showed that the external forces acting on Tianqin 1 were reduced to less than 1/400 millionth of the gravitational acceleration or in other words: the displacement caused by external forces was reduced to 30 nanometres. There is still further research needed to practically apply this technology for gravitational wave detection.

The Tianqin 1 satellite (launched 20 December) was used to test the variable thrust propulsion at the micro-Newton (μN) level with an accuracy of up to 0.1 μN. Experts said that the thrust of 1 μN is equivalent to the weight of a 1 cm-long hair. The weak thrust is generated to continuously offset the interference of solar pressure and the residual atmosphere affecting the satellite in order to become a super static and super stable platform and make the space-based detection of gravitational waves possible. The Tianqin programme was initiated by Sun Yat-sen University in Guangdong Province in 2015. The name means “harp in the sky” because it will consist of 3 satellites forming an equilateral triangle around the Earth. The detection of a gravitational wave is imagined as if one side of the harp is plucked. The 4 phases-project costs 15 billion RMB (2.3 billion USD).

Also see: Ziren Luo, ZongKuan Guo, Gang Jin, Yueliang Wu, Wenrui Hu, 2020, *A brief analysis to Taiji: Science and technology*, Results in Physics, 16, 102918, DOI: 10.1016/j.rinp.2019.102918.

FAST

The 3-year-long commissioning of the FAST (Five-hundred metre Aperture Spherical Telescope) telescope was completed on 11 January and the antenna was declared operational after a productive test phase where scientists have identified 114 new pulsars. All technical indicators of the telescope have reached or exceeded the planned level. It can now be used for observation at full capacity. FAST will gradually open to the international science community. It was revealed that the construction costs were nearly 1.2 billion RMB (around 170 million USD). FAST was completed in September 2016, 20 years after it was proposed by Chinese astronomers. International cooperation is expected in areas such as gravitational wave detection and very-long-baseline interferometry (VLBI). Scientists from the United States, Britain and Pakistan have already worked at FAST.

From 1 January to 23 March 2020, FAST was used for nearly 1,000 hours of observation.

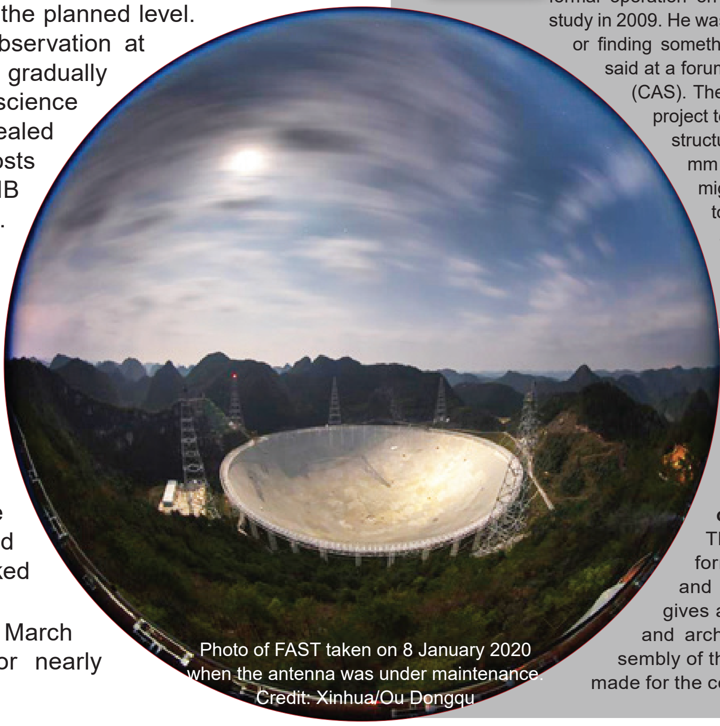


Photo of FAST taken on 8 January 2020 when the antenna was under maintenance. Credit: Xinhua/Ou Dongqu

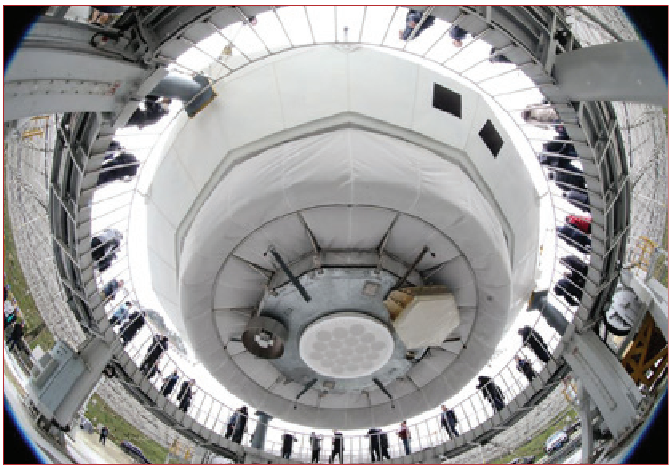
Taking advantage of the neighbourhood of the FAST telescope, the Guizhou Normal University established a Department of Astronomy in December 2019 and announced cooperation with the National Astronomical Observatories of the Chinese Academy of Sciences. Guizhou Normal University has signed an agreement with the operators of FAST to use the radio telescope as a training base for students. In the recent past, the university has already conducted a number of research programmes on astronomy based on FAST data which were provided to the university almost daily. Currently, there are 11 graduate students and more than 30 undergraduate students in the astronomy department of Guizhou Normal University.

Gigantic telescope helps nurture future astronomers
Xinhua news agency tells the story of graduate student **Lin Quanwei** of Guizhou Normal University, who had the chance to work with the data, received by FAST.

The man behind China’s signature project explains how it was to build FAST
Jiang Peng is the Chief Engineer of the Five-hundred metre Aperture Spherical Telescope (FAST) in China’s Guizhou Province. Also known as "China's Eye in the Skye", it started formal operation on 11 January. Jiang completed his doctoral study in 2009. He was faced with choices of continuing his studies or finding something challenging and intriguing to do, Jiang said at a forum held by the Chinese Academy of Sciences (CAS). Then he saw a job advertisement for FAST - a project to design and build a transformable cable net structure - 500 m diameter and an accuracy on the mm scale. Jiang firstly thought the vacancy note might be a fraud since it seemed impossible to design such a structure at that time. But an attached official document released by the National Reform and Development Commission told him it is a real and significant science and technology project.

FAST telescope in numbers: FAST & Advanced - Unveiling the secrets behind the world’s largest single-dish radio telescope, in the mountains of China’s Guizhou
This video explains the key facts, the performance indicators for the FAST telescope and the science behind the research. It also gives an interesting insight into the engineering and architectural challenges involved in the assembly of the dish. Many materials had to be custom made for the construction.

Experts and scholars visit FAST in Guizhou Province on 11 January 2020 while it was under maintenance. Credit: Xinhua/Liu Xu



Scientists and experts and scholars visit FAST in Guizhou Province on 11 January 2020 while it was under maintenance. This made it possible to have a close-up look at the feed cabin. Credit: Xinhua/Liu Xu

SMILE

Preliminary Design Review

From 14-17 January 2020, the SMILE (Solar Wind Magnetosphere Ionosphere Link Explorer) ESA-CAS Joint Mission Preliminary Design Review (M-PDR) Meeting was held at the European Space Research and Technology Centre (ESTEC) in The Netherlands. The Board Panel of Experts reviewed the Data Package and generated RIDs. After 3 days of discussion and consultation, the review committee concluded that all review objectives were achieved, and the M-PDR was successfully concluded.

GRANULOGY science project

The annual conference of the joint project GRANULOGY (Granular media in low-gravity environment) under the Europe (ESA) and China (CMSA/CSU) Space Science and Utilization Cooperation Programme was held on 13 and 14 January 2020 at the Chinese Academy of Sciences (CAS), Beijing with Chinese and European members of Space Grains.

SATELLITES

BNU-1

Ice Pathfinder (BNU-1) - China's 1st polar-observing satellite has completed 6 months of Antarctic observation operations. Since its launch on 12 September 2019, it has sent back more than 1,000 images of the South Pole region, showing the collapse of the Amery Ice Shelf on 25 September 2019 and the Pine Island Glacier in February 2020.

The Ice Pathfinder project team coordinated remote sensing with China's 36th Antarctic expedition for synchronous satellite and drone-ground observations of the region around Zhongshan Research Station, China's Antarctic research base. The recorded data will complement those collected in the past by vessels and mobile stations and are useful for studying climate change and developing new arctic shipping routes.

With its designed lifetime of 1 year, the satellite will continue with the observation of the Arctic region during the next 6 months.

The satellite data of the Antarctic data collection will be released soon to the Chinese and international scientific community.

CFOSat

On 21 February, the French and Chinese space agencies gave the go-ahead on the recommendation of representatives of the scientific community to grant open access to the CFOSat - China-France Oceanography Satellite's science data. More than 40 science teams in France, China and around the globe - in Europe, the United States, Russia, India, Australia and Korea - have proposed projects using CFOSat observations to support research work and operational weather forecasting applications. These teams were given (in late July 2019) access to the 20 TB of the first high-accuracy remote sensing dataset, collected through the scatterometer and wave spectrometer instruments. With the CFOSat data now freely accessible, they will be joined by other teams to exploit the original observations of this 1st French-Chinese scientific satellite.

In France, the CFOSat data can be accessed through CNES's AVISO+ ocean altimetry science portal at: *https://www.aviso.altimetry.fr/fr/missions/missions-en-cours/cfosat.html*.

The relevant ground stations in China have met the requirements of data processing and distributed the data to 40 users in China. CFOSat was launched on 29 October 2018.

CNES's CFO mission website

ETRSS-1

At the beginning of January, ETRSS-1 (Ethiopian Remote Sensing Satellite-1) has captured its first test images of surface features near China and they were published by the Ethiopian Space Science and Technology Institute. Once fully operational, ETRSS-1 is expected to save Ethiopia around 350 million BIRR (about 11 million USD) annually, money it currently spends to receive information from foreign satellites.

The SpaceinAfrica webportal reported that Ethiopia and China reached an agreement on the development of a communication satellite; however, details of the contract were not provided. China is also supporting Ethiopia in building a satellite ground station near Addis Ababa within the next 3 years. The data receiver would be useful for the dissemination of spatial information to various African countries, since Addis Ababa is hosting the African Union (AU) Headquarters.

Ethiopia and China are interested in a long-term partnership ranging from training programmes for Ethiopian space engineers to assisting Ethiopia with launching space satellites and setting up a continental satellite data receiver station.

FENGYUN (FY) DATA

Florence Rabier, Director General of the European Centre for Medium-Range Weather Forecasts (ECMWF) sent a letter to Liu Yaming, Administrator of China Meteorological Administration (CMA) and expressed gratitude to CMA for providing ECMWF with Fengyun 4A data and constantly improving with new instruments the data quality.

F. Rabier also appreciated the fruitful cooperation between CMA, ECMWF, and the Space Science and Engineering Centre (SSEC) of the University of Wisconsin-Madison, USA in 2019. During the cooperation, expert teams carried out independent comparisons of observation data collected by the FY-4 instrument GIIRS (Geostationary Interferometric Infrared Sounder), SSEC infrared observation data, and ECMWF model simulation, and diagnosed the problem of spectral shift's influence on data flow, and finally the CMA team successfully resolved the problem.

FENGYUN INTERNATIONAL COOPERATION

On 2 January, the Chinese ambassador to Mozambique handed over a FY-2 satellite direct data reception station to the Vice Minister of the Mozambican Ministry of Transport and Communication at the Mozambique National Institute of Meteorology (INAM) in Maputo. Mozambique is the 1st African country to apply this system and will obtain 24/7 back-to-back meteorological satellite monitoring services.

In 2019, Mozambique has activated the Fengyun Emergency Support Mechanism (FYESM) 3 times and requested CMA to provide FY satellite data products for the affected region. The new donated system will fill the gap in space-based meteorological data of Mozambique's territory.

Prior to the inauguration of the satellite ground station, CMA has sent experts to install the FY-2 Satellite Data Direct Broadcasting Receiving System and SWAP. They have also carried out technical training tailored to the application of FY satellites in weather, environment, and emergency response as well as disaster mitigation.

During the 18th World Meteorological Congress held in June 2019, CMA and INAM signed a FY satellite application cooperative agreement.

Ziyuan 3-01

The civilian high-definition mapping satellite Ziyuan 3-01 has exceeded its designed operational lifetime of 5 years by 3 years and has continued to deliver data. By the end of 2019, the satellite has collected 3D data of 79 million km^2 of global surface, which were provided to more than 40 countries and regions.

APPLICATIONS

AIS DATA

A cooperation project led by Spire Maritime and China's HiFleet increased the visibility of ship signals in the South China Sea by more than 200 %. Dynamic automatic identification systems (AIS) for ships are helping to close data gaps in one of the busiest regions for maritime traffic. Dynamic AIS combine ground data from identification system receivers in the port with those from AIS satellites in orbit. Further improvements of the system will make it possible to look into the history of vessel movements.

COMBINED REMOTE SENSING of LOCUSTS

Researchers from the Aerospace Information Research Institute of the CAS analysed combined Earth observation satellite data from China's Gaofen satellites, the United States' Landsat, and the European Sentinel satellites. These remote sensing data were enriched with global meteorological data and plant protection survey data and were processed with the data from pest prediction models and big data analysis on the digital Earth science platform. This enabled the scientists to investigate the temporal and spatial distribution of desert locusts' reproduction and migration in Africa in February and predict their migration to China. Results showed that considering the influence of the Northeast Monsoon and the barriers of Qinghai-Tibet Plateau, the possibility of desert locusts swarming into China was by the end of February relatively small. But if the desert locusts in Pakistan and India were not effectively controlled and expand to Nepal and Myanmar, there will be a risk of desert locusts invading southwest China's Yunnan and Tibet from around May to June.

WeChat APPLICATION

The National Satellite Ocean Application Service developed a WeChat application to make marine satellite data from multiple satellites such as the China-France Oceanography Satellite CFOSat and the HY-2 satellites accessible to individual users, enterprises and government departments. The app allows for customized services, providing remote sensing data for scientific ocean expeditions in polar regions and disaster monitoring and forecasting. Users can search for the distribution of typhoons or cyclones in a certain sea area and check the trend over the past 5 days. More similar products and services on marine satellite data will be developed.

NAVIGATION

BEIDOU INFRASTRUCTURE

In the last 4 months of 2019, 112 maritime buoys and 6 beacons in the Qiongzhou Strait (north of Hainan Island) were maintained and updated. Staff of the Haikou Navigation Mark Office of the Navigation Guarantee Centre of South China Sea (NGCS) of the Ministry of Transport installed telemetry and telecontrol units based on the Beidou Navigation Satellite System and Beidou AIS (Automatic Identification System) navigation device which receives AIS signals from nearby ships and re-sends them to the control centre through Beidou short messaging system.

BEIDOU JOURNAL

The English language, open-access, peer-reviewed academic journal "Satellite Navigation" was online by the end of January. The publication is issued in cooperation between the Chinese Academy of Sciences (CAS) and the publisher Springer Nature. It is sponsored by the Aerospace Information Research Institute of the CAS. The journal aims to report new results or progress on the theoretical techniques and applications of satellite navigation. Yang Yuanxi, the Deputy Chief Designer of the Beidou Satellite Navigation System (BDS) is the Chief Editor, and the editorial board is composed of 40 international experts.

journal website:
https://satellite-navigation.springeropen.com/articles

IN-ORBIT TESTING

The 41^{st}, 49^{th}, 50^{th} and 51^{st} satellites of the BDS family have completed in-orbit testing and started operation within the network. Beidou 41 works in GEO, Beidou 49 in inclined geosynchronous Earth and Beidou 50 and 51 are positioned in in medium Earth orbit (MEO).

Link to the presentation of the Chinese delegation during the 14^{th} Meeting of the International Committee on Global Navigation Satellite Systems (ICG) of the United Nations, held in December 2019 in Bangalore, India

BEIDOU – launch preparation

Despite the challenges brought about by the Corona pandemic, the CZ-3B rocket for the launch of the Beidou satellite in March was transported to Xichang on 14 February. Around 200 engineers and technicians were working at the launch centre. The BDS-3 Beidou satellite had arrived already earlier. The plan is that the launch of the CZ-3B in May will bring the final Beidou navigation satellite into space.

BEIDOU INDUSTRY

The Beijing municipal government has released a 3-year plan to promote the innovation and development of industries related to the Beidou Navigation Satellite System. This plan comprises the

The aerial photo, taken on 8 January 2020, shows the crew of the sea patrol ship "Haixun 172" deploying a buoy installed with a telemetry and telecontrol unit based on Beidou Navigation Satellite System and Beidou AIS (Automatic Identification System) physical navigation mark in Qiongzhou Strait, south China. The AIS was mounted by technicians of the Haikou Navigation Mark Office of the Navigation Guarantee Centre of South China Sea (NGCS) of the Ministry of Transport during the overhaul in Xiuying Port of Haikou Credit: Xinhua/Yang Guanyu

Technicians of the Haikou Navigation Mark Office of the Navigation Guarantee Centre of South China Sea (NGCS) of the Ministry of Transport are installing a telemetry and telecontrol unit based on Beidou Navigation Satellite System and Beidou AIS (Automatic Identification System) at buoy no 1 during the overhaul in Xiuying Port of Haikou Credit: Xinhua/Yang Guanyu set-up of an innovation centre for Beidou-related industries and 7 major demonstration projects to promote the application of the Beidou system in smart transportation, environment protection and intelligent logistics. The aim is to promote key technologies and the creation of a Beidou-related industry ecosystem.

Next to Beijing, 4 other BDS clusters are in 1) Guangzhou, Shenzhen and Zhongshan along the Pearl River; 2) in Shanghai and the Yangtze River Delta region; 3) in Central China of Hubei and Hunan province, and to a certain degree, 4) Western China around the Sichuan, Chongqing and Shanxi provinces.

It is estimated that the total output value of the Beidou navigation and location service industry in Beijing will exceed 100 billion RMB (about 14.4 billion USD) by 2022.

U2: Beidou Is My Co-pilot

In March, the webportal insidegnss.com had a story about the use of Beidou signals within the U.S. Air Force. According to a statement by the head of U.S. Air Force Air Combat Command, pilots of the elite U-2 spy plane wear watches that receive foreign GNSS signals and provide back-up navigation when GPS is jammed. “My U-2 guys fly with a watch now that ties into GPS, but also Beidou and the Russian [GLONASS] system and the European [Galileo] system so that if somebody jams GPS, they still get the others,” said Gen. **James “Mike” Holmes** on 4 March at the McAleese Defense Programs Conference in Washington.

GNSS Addressing Coronavirus

Inside GNSS webportal spoke with Zheng Yao, Associate Professor with the Department of Electronic Engineering, Tsinghua University about the use of Beidou to mitigate the Corona virus pandemic.

Beidou and other GNSS (Global Navigation Satellite System) supported the fight against the Corona pandemic by providing reliable positioning data used for decision making and guiding the traffic of persons and goods. The most emblematic effort was the construction of the 2 makeshift hospitals in Wuhan, but also other medical facilities needed to be set-up.

Logistics companies were and are using Beidou terminals to distinguish the trucks with relief materials from other cargo. In contrast to other navigation systems, Beidou broadcasts RDSS (Radio Determination Satellite Service) as well as RNSS (Radio Navigation Satellite Service) signals. RDSS carries short messages which were instrumental in pushing the latest information to the 6 million transport vehicles connected to the National Public Supervision and Service Platform for Road Freight Vehicles, and recommended road driving and transportation service information.

Beidou-guided, high-precision UAVs (unmanned aerial vehicle) have been spraying disinfectant in particular in locations difficult to reach by man or surface robots. One drone could carry 10 kg of disinfectant, enough for covering an area of 5,000 m^2, a move which was seen critical in other countries because the environmental impact is not clear.

CGTN was asking **Blaine Curcio**, the Affiliate Senior Consultant for Euroconsult, to explain the significance of the Beidou Navigation Satellite System.

He points out the importance of the short message service and the potential of exporting Beidou services to other countries. Blaine Curcio also explains the high number of satellites and the accuracy of Beidou signals, an achievement which gives China independency and a new dimension for international outreach.

Beidou APPLICATION in precision farming

Beidou navigation system-based drones are helping farmers to apply fertilizers and pesticides more precisely. An intelligent fertilizer-pesticide distributor, assisted by the Beidou Navigation Satellite System and big data technology, has been working in the wheat fields in Hancun village in Jiangdu county, in east China’s Jiangsu Province. Through the remote network technology service platform, high precision fertilizer distribution can be applied with little manual interference.

TELECOM

APSTAR-6D

On 25 March, the APSTAR-6D high-throughput communication satellite passed the manufacturing tests and design review at CAST. The 5.55 t satellite is based on the enhanced Dongfanghong 4 platform. It has 1,220 transponders in the Ku- and Ka-band with 99 beams and nearly 1,000 waveguide components.

Prepared for launch into GEO at 134°East longitude later this year, APSTAR-6D will become part of China’s first global, high-throughput, broadband, satellite communication system providing high-quality broadband network and data communication services for users in the Asia-Pacific region.

The joint establishment of the Asia Pacific Satellite Broadband Communication (Shenzhen) Co., Ltd. by the Aerospace Science and Technology Group and the Shenzhen Municipal Government in 2016 was the start of China’s first global high-throughput broadband satellite communication system.

MOBILE SATELLITE COMMUNICATION

China officially launched its new domestically developed satellite-based mobile communications services to the public on 10 January, bringing wider coverage to serve various needs. Featuring full coverage over China’s territory and its territorial waters, the services provided by the Tiantong satellite communications system can be used in a wide range of scenarios including in marine fishery, emergency response programs and in search and rescue operations.

The system provides users with voicemail, short message, data transmission and positioning services in its coverage areas, while it is also capable of supporting multiple types of communications devices such as satellite mobile phone, sat-nav, and the system’s own Tiantong modem.

At present, users can subscribe to the service online or at outlets of the exclusive provider China Telecom. The annual fee is 1.000 RMB (144 USD) and includes 750 min of phone calls.

Launched in 2016, Tiantong 1, the satellite backing the Tiantong system, was China’s first self-developed mobile communications satellite.

SHIJIAN 20

Shijian 20 reached its position in geostationary orbit by 5 January (some reports said: on 6 January). See LAUNCH section in GoTaikonauts! issue no 30.

VeneSat-1

The Venezuelan telecommunications satellite, VeneSat-1, contracted via the China Great Wall Industry Corporation (CGWIC) and launched on 29 October 2008 from the Xichang Satellite Launch Centre, interrupted service on 13 March 2020. There were several reports in the media, that the satellite was drifting away from its designated position at 78°West and was tumbling in an elliptical orbit which keeps the satellite not perfectly but sufficiently away from GEO. VeneSat-1 is a DFH-4-based satellite with a projected lifetime of 15 years. The satellite is operated by Venezuela’s space agency ABAE.

In January 2020, ABAE reported that it is planned to build in cooperation with China the VeneSat-2 satellite to continue the operations after VeneSat-1's planned end-of-life around 2024.

On 25 March, Venezuela’s Ministry of Science and Technology confirmed the loss of VeneSat-1 but did not give details.

On request by SpaceNews, Fu Zhiheng, Executive Vice President of China Great Wall Industry Corp., which built VeneSat-1 for the Venezuelan government, said the satellite suffered a solar array drive assembly problem that resulted in VeneSat-1’s failure and emergency relocation effort. Drive assemblies point a satellite’s solar arrays at the sun to generate the maximum energy.

ADVANCED TECHNOLOGY

DRONES FOR MOBILE QUANTUM NETWORK

Researchers from the National Laboratory of Solid-State Microstructures of the Nanjing University developed drones which in the future could be used in a mobile quantum network for the purpose of on-demand and real-time coverage at different time and space scales, from a local-area network to a wide-area network with a reach of hundreds of km or more. During a first test, the experts realised a mobile entanglement distribution to connect 2 ground locations in up to 200 m distance. In the future, such a mobile network can interconnect with the satellites and fibre networks for further extension, which will finally form a practical, multifunctional global quantum network.

Link to paper in National Science Review:
Hua-Ying Liu, Xiao-Hui Tian, Changsheng Gu, Pengfei Fan, Xin Ni, Ran Yang, Ji-Ning Zhang, Mingzhe Hu, Jian Guo, Xun Cao, Xiaopeng Hu, Gang Zhao, Yan-Qing Lu, Yan-Xiao Gong, Zhenda Xie, Shi-Ning Zhu, 2020, Drone-based entanglement distribution towards mobile quantum networks, National Science Review, 7, 5, 921-928, DOI: 10.1093/nsr/nwz227

Satellite Assembly Integration & Test Centre – AIT Centre

The China National Space Administration (CNSA) Satellite Assembly Integration & Test Centre (AIT Centre) is not only responsible for testing the space hardware for most of China's national space programmes, but it also offers its services to UNOOSA Member States (United Nations Office for Outer Space Affairs).

In May 2017, CNSA decided to share the AIT Centre, which is a subsidiary of China Academy of Space Technology located in Huairou District Beijing China, with the international community. During the 57th session of UNOOSA's Scientific and Technical Subcommittee (STSC) in February 2020, the Chinese representative gave a technical presentation with the title: Access to Satellite AIT Centre CNSA. Already on 6 February 2018, China presented its AIT capacities for spacecraft testing during the 55th session of the Scientific and Technical Subcommittee of COPUOS (United Nations Committee on the Peaceful Uses of Outer Space).

As a shared resource, the Satellite AIT centre CNSA covers:

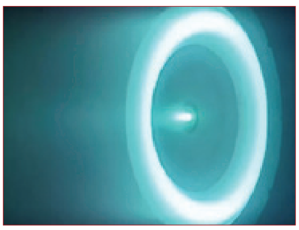
- Space education & seminars.
- Technical training.
- Satellite AIT activities.
- Building ground facilities.

Access to Satellite AIT Center CNSA - presentation given during the 57th STSC in February 2020
https://www.unoosa.org/documents/pdf/copuos/stsc/2020/tech-62E.pdf

Chinese Industry Practice for Space Capacity Building - presentation given during the 55th STSC in February 2018
https://www.unoosa.org/documents/pdf/copuos/stsc/2018/symp-02E.pdf

Hall-effect thruster

Researchers from CASC have developed the country's first Hall-effect thruster (HET) with an input power of 20 kilowatts that can produce a thrust of 1 Newton, marking a leap for China's HETs from milli-Newton level to Newton level. During a test, the thruster showed stable operation, with a specific impulse of 3,068 seconds and working efficiency above 70%. HETs could have wide applications in the attitude control of satellites and the use as a main propulsion engine for medium-size robotic space vehicles.



The 20-kW Hall thruster in operation at a laboratory of CASC. Credit: CASC

COMMERCIAL SPACE

SOLAR POWER

The Shanghai Institute of Space Power-Sources has signed a Memorandum of Understanding (MoU) with solar module developer JinkoSolar to develop high-efficiency solar cells for space and terrestrial applications. The innovation is based on a silicon wafer as the supporting bottom substrate and bottom cell.

Assessing China's commercial space industry
Jeff Foust of TheSpaceReview took a look at the current status of commercial space activities in China. He thinks that "the closest competitor to the United States in entrepreneurial space might be China. Dozens of start-ups have emerged in just the last few years, pursuing everything from launch vehicles to constellations of communications or remote sensing satellites, much like their American counterparts. The rise of China's overall economy to one of the largest in the world has prompted questions about whether these Chinese space start-ups could pose serious competition to American companies."

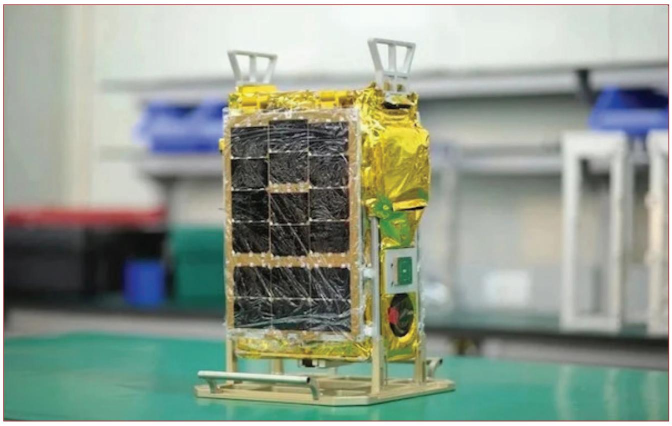
COMMERCIAL - Satellites

MiniSAR

Starting with MiniSAR, a miniature synthetic-aperture radar (SAR) satellite that weighs 150 kg and provides a resolution of 1 m per pixel, SpaceTY has started to develop its own payloads for its satellites. SpaceTY has implemented many innovative new designs in this satellite.

So far, SpaceTY has been involved in 10 launches that have sent 18 satellites to orbit.

SpaceTY developers working on the Xiaoxiang verification satellite. Credit: SpaceTY



Xinghe, a remote-sensing technology verification satellite jointly developed by SpaceTY and ADASpace. Credit: SpaceTY

Geely - GeeSpace

GeeSpace, a subsidiary of the Geely Technology Group, plans to invest 2.27 billion RMB (326 million USD) in a satellite manufacturing, testing and research facility in Taizhou, Zhejiang Province, with an annual production capacity of 500 satellites by 2025 and a workforce of 300 engineers. Construction of the facility officially started on 3 March. It is planned to launch still in 2020 a pair of satellites for the validation of relevant

Geely Satellite Manufacturing and Test Centre. The cutting-edge facility will include a modular satellite manufacturing centre, satellite testing centre, satellite R&D centre, and cloud computing centre. Taking full advantage of Geely's experience in modular intelligent manufacturing, the facility will be able to develop and produce a variety of different satellite models. Credit: GeeSpace

technologies and communications systems for the planned commercial LEO satellite constellation which has not yet a name. The first 2 Geespace satellites will undergo final validation testing in June.

The constellation was advertised as a "smart three-dimensional mobility ecosystem," that would offer high speed internet connectivity, precise navigation, and cloud computing capabilities to cars with autonomous driving technology as well as to any type of automated system. The PNT (Positioning Navigation and Timing) payloads will provide an accuracy in the range of centimetres. Each satellite is supposed to have an operational life of 10 years. Geely, one of China's most prominent car brands, got involved in various high-tech fields beyond automobiles.

The Chairman of Geely Holding Group, Li Shufu, said in Geely's press release from 3 March: "The pace at which science and technology is developing has reached an unprecedented level, changing human society at its core. Today, the automotive industry faces huge challenges and equally huge opportunities. Geely must take the initiative to embrace change, develop through innovation, find new synergies online and offline, and cooperate with global partners to become a global technology leader, drive change in mobility, and create new value for users."

Geely's entry into the field of satellites is part of its transformation into a global mobility technology group.

Also, in November 2018, Zhejiang Geely Holding Group (Geely Holding) signed a strategic cooperation agreement with CASIC (China Aerospace Science and Industry Corporation) that focuses on the development of supersonic train technology and industrial Internet. Geely also invested in the VoloCity air taxi. This is a strategic move, which implies that the travel in the future will be done in driverless vehicles. Car manufacturers might have an incentive to turn into autonomous fleet operators as well.

Founded in 2018, GeeSpace focuses on the R&D of satellite communications systems, electronic products, and technologies about communications and data processing.

Geely has also invested into Daimler, Volvo and Proton and among its many car factories is also one in Taizhou.

MinoSpace

MinoSpace has secured a Series A2 round funding of nearly 100 million RMB (14.2 million USD) provided by investment firm Billionhome Capital.

The company's CEO stated that the finances will be used for the development of satellites in the 200 kg-class and bigger, tapping into the market of state-owned-companies. So far, MinoSpace's core business was the development of satellite busses and payloads and ground station hardware such as an Intelsat ground terminal, also used in national defence.

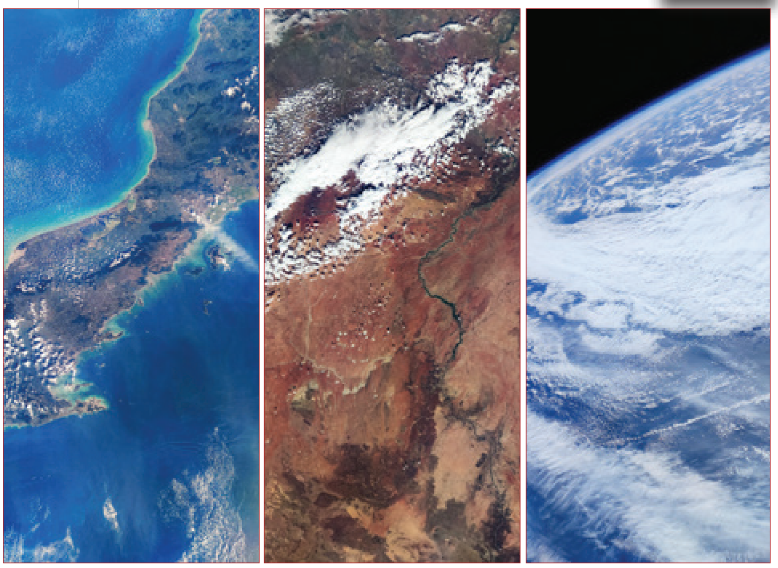
Since 2017, MinoSpace has completed 4 rounds of financing. In September 2019, it secured tens of millions of dollars in Series A+ round funding from state-owned Shenzhen Capital Group, Yongxin Group's investment arm Kexin Capital and existing investors Yonghua Capital, Casstar, and NXROBO. Prior to this, it had also collected money from CASIC's subsidiary, Essential Capital, Amphora Capital, Feng Yang Capital, and CPG Capital Partners.

SpaceTY - Xiaomi

In 2019, Xiaomi asked SpaceTY to install its #Mi10Pro's 108MP camera hardware module onto the SpaceTY-built cubesat, Xiaoxiang 1-08 (Dianfeng, TY 1-08, XX-1 08, XX1-08, Tianyi-15, TY-15, COSPAR: 2019-072D) and make it ready for taking photos from space. The cubesat launched on 3 November 2019. The release of the photos during a press conference on 13 February for the regular introduction of Xiaomi 10/Mi 10 Pro, show a resolution of 60 m per pixel, area coverage of 720 x 540 km and a high image clarity. Xiaomi published an advertisement video on YouTube: See Our Mother Earth from a Different Angle.

For the future, Xiaomi and SpaceTY are considering more cooperation in the area of remote sensing, fitting into SpaceTY's philosophy of "making space as easy as possible".

more video / photos taken from space with the Xiaomi 10/Mi 10 Pro



Expace

Since the space industry is built on strong planning with longer term procedures in place, this sector seems to be less impacted by the short-term Coronavirus lockdown.

That has been the case for most of the commercial space companies but not for CASIC's commercial spin-off Expace in Wuhan which was hit by the Coronavirus outbreak. Its first launch on 16 January from the Jiuquan Satellite Launch Centre went through, but all other planned missions - 4 to 5 for the first half of the year - were put on hold as a consequence of the interruption of the Kuaizhou rocket production and missing transport options due to the lockdown of Wuhan. Expace combined the original Kuaizhou 11 rocket test team, Kuaizhou-1A rocket test team and the Xingyun satellite test team into one team. Online tools were used to communicate between teams and colleagues. Normal work resumed slowly only by the end of March.

Also, the construction work on CASIC's satellite park in the Wuhan National Space Industry Base came to a halt.

iSpace

iSpace told Chinese media that the Coronavirus epidemic had less effect on the company but still impacting efficiency and smoothness of operation, such as the delivery of components. iSpace resumed work at full capacity in its Beijing headquarters while following measures against the spread of the virus. iSpace's research and development branch in Xi'an achieved a 90 % resumption rate at the beginning of March. iSpace hopes to continue its launch plan for a June 2020 launch from Jiuquan, sending 6-7 satellites into space. As a novel feature, the company is cooperating with a renowned artist to play piano on the launch pad.

Landspace

Landspace reported that the Corona epidemic has not impacted its business activities. The company continued its testing series of the TQ-11 rocket engine in March, achieving at its Huzhou test stand incremental full-system hot fire tests of 10 s, 100 s, 750 s, and in March, of 1,500 s duration.
However, the launch timetable for 2020 had not been confirmed due to the epidemic. While staff at its Beijing HQ still telework, the Huzhou production facility has resumed work.

TQ-11 methalox test fire in March 2020. Credit: Landspace

INTERNATIONAL COOPERATION

CNSA-ESA Workshop on EO Data Cooperation

On 14 January 2020, representatives of CNSA's Earth Observation and Data Centre and ESA's Directorate for Earth Observation held a special workshop on China-EU Earth Observation Cooperation. The meeting was co-chaired by Tong Xudong, Director of CNSA's Earth Observation and Data Centre, and Josef Aschbacher, ESA's Director for Earth Observation.
The two parties reviewed the status of China-ESA Earth Observation Projects and exchanged technical details on the application areas of EO data from the Gaofen 5 and Sentinel 5P satellites. Both sides agreed that there is big potential for more cooperation.

RUSSIA

In a first joint concept, Russian scientists from the Institute of Astronomy at the Russian Academy of Sciences and Chinese experts from the Changchun Institute of Optics, Fine Mechanics and Physics have worked out a space-based telescope concept, assembled in space by robots: On-orbit Assembling Space Telescope (OAST).
Mikhail Sachkov, the Deputy Director of the Institute of Astronomy told media that his team was asked by his Chinese colleagues to develop the scientific requirements. Russia would contribute the spectrometer and China would take care of the hardware development. Currently, no funding was assigned to the project which would not be realised before 2030.

UKRAINE

Vice Prime Minister for European and Euro-Atlantic Integration of Ukraine Dmytro Kuleba said at a meeting of the Ukrainian experts involved in the Ukraine-China Commission on Cooperation on 31 January that China is a strategic partner for the European country. Apart from trade and economy, the key fields of Ukraine-China cooperation are research and technology, space, agriculture, culture, education and medicine. In each of these areas, subcommittee work, and joint projects are implemented. Among those projects, 34 Ukrainian research projects are on the way in cooperation with Chinese counterparts. Space cooperation is part of the 5-year plan, Ukrainians participate in the Chinese Lunar Exploration Programme. The areas of scientific exchange and space industry are key priorities of Ukraine-China cooperation.

PAKISTAN

All Weather Friends: China and Pakistan Space Cooperation

Preethi Amaresh for: The Diplomat

Pakistan's space program is set to benefit greatly from China's advanced technology. Pakistan's first satellite Badr 1 was launched in 1990 by China. In 1991, the Chinese Ministry of Aerospace Industry and SUPARCO (Pakistan Space and Upper Atmosphere Research Commission) signed an agreement on space cooperation, but for decades they had little to show for it. Space cooperation between China and Pakistan focused mainly on "personnel training and infrastructure development" for the next 20 years.
In 2005 China started the Asia-Pacific Space Cooperation Organization (APSCO) and Pakistan became one of its founding members.
In 2011, as part of Pakistan's Space Program 2040, the Chinese-manufactured PAKSAT-1R, was launched.
The two countries also signed a 2012-2020 roadmap for space cooperation between SUPARCO and the China National Space Administration (CNSA) in 2012. Part of this agreement is to send a Pakistani astronaut into space.
In April 2019, China and Pakistan signed an agreement on space exploration, which marks a new phase in space science cooperation between the all-weather allies. Pakistan also requested China's participation in the development of the Pakistan Remote Sensing Satellite (PRSS). PRSS-1, launched in 2018.
With the inclusion of India and Pakistan in both the Shanghai Cooperation Organization (SCO) and SAARC (South Asian Association for Regional Cooperation), these South Asian countries have a major positive role to play in space rather than countering each other. If India and Pakistan follow a path of confrontation on future space projects, it will only deepen the cooperation between Pakistan and China.

US-China Space Dialogue

U.S. and Chinese officials were trying to prepare for a bilateral Civil Space Dialogue around March in the first such discussion since 2017. "The U.S. and China were not able to schedule a Civil Space Dialogue in 2019 but are in the planning stage for the U.S. to host the Dialogue during the first half of 2020," a State Department official told SpaceNews. Topics of mutual interest such as space exploration and space science should be on the agenda. No details became known as to why the expected meeting in autumn 2019 did not go through. The 3rd and most recent U.S.-China Civil Space Dialogue took place in Beijing in late 2017, the 1st one in Beijing in 2015 and the 2nd in Washington in 2016.

MISCELLANEOUS

KIRIBATI

At the beginning of January, Chinese President Xi Jinping met the President of the Pacific state of Kiribati, Taneti Maamau, in Beijing. Until 2003, China had used the space tracking station on the island state. The ground station was supporting China's first manned space mission. However, diplomatic relations were discontinued in 2003 and only re-established in 2019. There are no official confirmations on the reopening of the tracking station, but a former Kiribati diplomat confirmed that the station could easily become operational again. Compare GoTaikonauts! issue no 29, p. 14.

TOP SPACE NEWS in 2019

Lists of China's and the world's top 10 sci-tech news reports, jointly selected by the Chinese Academy of Sciences and Chinese Academy of Engineering, were announced on 11 January in Beijing. The 10 major Chinese scientific and technological news events included the first-ever soft landing on the Moon's far side by the Chang'e 4 lunar probe, the discovery of the largest ever stellar black hole by Chinese astronomers, as well as the successful in-orbit tests of the country's first space-based gravitational wave detection experiment satellite Taiji 1.

Racing to where/what/when/why?
Dwayne A. Day is analysing why there is so much talk about a space race and what does it mean. Is China in a space race with the US? What would be the indicators for that? And if there is no race, what is the current state of affairs in reaching for the Moon and other exploration destinations?

LAUNCHES

2020-002A
07 January 2020 - 15:20 UTC (23:20 BJT)

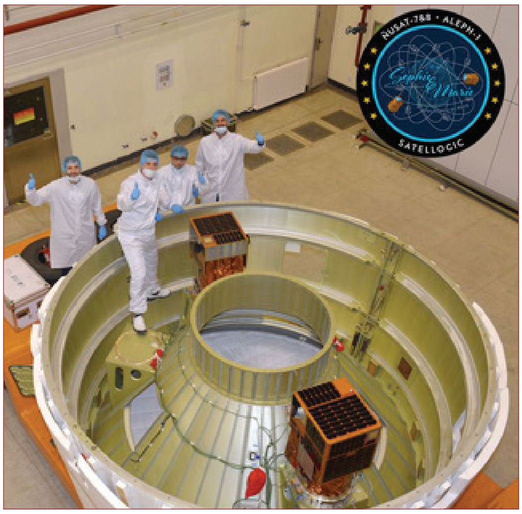
launch site: Xichang Satellite Launch Centre - XSLC, LC2
launcher: Chang Zheng 3B/G2 - CZ-3B/G2
payload: Tongxin Jishu Shiyan Weixing 5 - TJSW-5 (TJS 5)

Official Chinese media reported that the launch put a new communication technology experiment satellite into space. The satellite, developed by the Shanghai Academy of Spaceflight Technology (SAST), will be used in communication, radio, television and data transmission, as well as for high throughput technology testing. The oblong-shaped satellite with 2 solar panels is based on the SAST 5000 bus. There was very limited information available on this launch.

2020-003A
2020-003B
2020-003C
2020-003D
15 January 2020 - 02:53 UTC (10:53 BJT)

launch site: Taiyuan Satellite Launch Centre - TSLC, LC9
launcher: Chang Zheng 2D - CZ-2D
payloads:
Jilin 1-Gaofen 2B (Red Flag 1-H9, Kuanfu 1, Jilin-1KF01)
ÑuSat 7 (NewSat-7, Aleph 1-7, Sophie)
ÑuSat 8 (NewSat-8, Aleph 1-8, Marie)
Tianqi 5 (Tianqi 2-03, Xinzhou, Yunjiang)

The main payload on this launch was the Jilin 1 - an optical remote-sensing satellite for commercial use, developed by the Changguang Satellite Technology Co., Ltd. The 230 kg satellite has the shape of a flat box and is equipped with 2 solar panels. The 3 sensors, integrated into a 1.2 m telescope, provide a super-wide coverage of around 40 km and a full-colour resolution of 0.76 m and a multi-spectral resolution better than 3.1 m. From an 535 km orbit, it is also capable of high-speed data storage and transmission at a rate of 1.8 Gbps. It will work with the 15 satellites of the Jilin 1 family already in orbit to form a constellation that will provide remote-sensing data and services for governmental and industrial users. The project is part of efforts by the Jilin Province to develop its satellite industry as a new economic driver.
The CZ-2D also lifted 3 other small satellites into space, including ÑuSat 7 and ÑuSat 8 developed by the Argentinian company Satellogic S.A. which will become part of a commercial LEO Earth observation constellation operating in 500 km SSO orbit with an inclination of 97.5°. The panchromatic camera has a resolution of 1 m, the hyperspectral camera of 30 m, and the infrared sensor of 90 m. The 2 almost identical 37 kg satellites of 450 x 450 x 800 mm dimension were named after French mathematician Sophie Germain and Polish-French physicist Marie Curie. They are the 1^{st} satellites of a launch service contract signed in January 2019 by Satellogic and China Great Wall Industry (CGWIC). The agreement comprises multiple launches from Taiyuan to place 90 of Satellogic's Earth observation satellites into orbit. Upon completion, the Satellogic constellation Aleph 1 will provide weekly updated Earth observation data with 1 m resolution, useful for a very wide range of applications for industrial, administrative and agricultural purposes. CGWIC confirmed that the deal is one of the largest international commercial launch contracts. Within the last four years CGWIC launched 7 ÑuSats for the Satellogic constellation.
The other P/L was the 6U cubesat Tianqi 5 for Internet of Things (IoT) communications tests for commercial small satellite company Guodian Gaoke Tech. Ltd. Tianqi 5 has a mass of 8 kg and is equipped with 4 solar arrays. It also carries a camera for educational purposes. The cubesat is part of the "Apocalypse Constellation" that provides users with data collection and transmission services for blind areas in terrestrial network coverage, as used in marine, environmental protection, meteorological, forestry, geological, emergency, rescue and smart city industries.



Satellogic prepared its two small Earth observation satellites ÑuSat 7 and 8 (Sophie and Marie) for launch on a Long March 2D rocket. Credit: Satellogic

2020-004A
16 January 2020 - 03:02 UTC (11:02 BJT)

launch site: Jiuquan Satellite Launch Centre, mobile platform
launcher: Kuaizhou-1A - KZ-1A
payload: Yinhe 1, GalaxySpace 1, GS-SparkSat-03

The 227 kg broadband communication technology test satellite was designed and built by the start-up GalaxySpace which will also operate the satellite. The box-shaped satellite is equipped with 2 solar panels of 1.8 x 1.0 m. The research team creatively used the 3D printing in the key components manufacturing, which has reduced the space usage by 2/3 and greatly reduced the payload weight. It is the biggest and highest performance LEO comsat, so far developed by a private company. Also, it is China's first 5G-capable satellite, with a data transmission capacity of 10 GB/sec, which ensures a 600 megabits per second network speed. Another first is the use of extremely high-frequency Q/V-band (millimetre wave band) and Ka-band. The power amplifier needed to support those bands demanded techniques, used for the first time in China.
The satellite will be able to cover an area of 300,000 km^2, roughly 50 times the size of Shanghai. GalaxySpace aims to build a LEO broadband satellite constellation and create a global 5G communication network, accessible from all regions and by all individuals on a cost-efficient base. For that, GalaxySpace cooperates with China Aerospace Science and Technology

Corporation (CASC), with the China Aerospace Science and Industry Corporation (CASIC) and with the China Electronics Technology Group Corporation (CETC).
The constellation will comprise 1,000 satellites in 500 km to 1,000 km orbits, of which 144 will be launched within the next 3 years. All satellites will have a deorbit function for the end of lifetime. Future users of the constellation will connect via a small, intelligent, low-cost and easy-to-install terminal, allowing for high-speed and flexible connectivity in schools, homes, automobiles, aircrafts and in other scenarios. Users will be able to switch between satellite and ground 5G networks in a seamless manner. GalaxySpace will develop more low-cost, high-performance 5G satellites for space internet and bridging digital gaps, aiming for a 1,000 satellite constellation.

2020-014A
2020-014B
2020-014C
2020-014D
19 February 2020 - 21:07 UTC (20 February - 05:07 BJT)

launch site: Xichang Satellite Launch Centre - XJSC
launcher: Chang Zheng 2D - CZ-2D
payload: XJS-C, XJS-D, XJS-E, XJS-F

The 4 test satellites (Xin Jishu Shiyan) will test new technologies for inter-satellite communications, including high-speed telecommunications and cutting-edge sensors for next-generation Earth observation satellites. They continue initial research with XJS-A from June 2018.
XJS-C and -D were built by SAST, XJS-E by Harbin Institute of Technology (HIT), and XJS-F by DFH Satellite Co. Ltd./China Academy of Space Technology.
CASC said on the occasion of this launch that despite the Coronavirus outbreak, engineers were preparing upcoming missions, noting measures have been taken to ensure those people's health and missions' implementation. For each team member a health record was kept and meetings were done through online tools. Also, the launch site was divided into several sections with limited cross over permissions. The meals were delivered to the workers. And before launch the area was disinfected. All members of the team volunteered to cut short their holiday and stayed under quarantine in the base to ensure the success of the launch. Optimistic forecasting confirms that the planned 40+ launches for 2020 could be achievable.
The CZ-2D carrier rocket used for this launch adopted a new technology to improve launch injection accuracy. The satellites were integrated into a special payload dispenser built by DFH Satellite. It was the 1st time that a CZ-2 rocket took off from the Xichang Satellite Launch Centre.

The CZ-2D carrier rocket at the Xichang Satellite Launch Centre on the day before launch. Credit: China News Service/Sun Gongming

2020-017A
09 March 2020 - 11:55 UTC (19:55 BJT)

launch site: Xichang Satellite Launch Centre - XSLC
launcher: Chang Zheng 3B - CZ-3B/G2
payload: Beidou DW 54 (Beidou-3 GEO-2/C60)

The CZ-3B/G2 sent the 54th satellite of the BeiDou family into a geostationary orbit. One of the rocket's side boosters was equipped with a parachute, testing a controlled fall back. Beidou 54 is the 2nd GEO satellite of the BDS-3 system. The last one is expected to be launched in May which will complete the construction of the BDS constellation providing global high-precision, reliable positioning, navigation and timing services.
The satellite with integrated functions for navigation and communication was developed by CAST. It has the most functions and signals, the largest size and the longest designed life span among all the BDS-3 satellites. It is based on the Dongfanghong-3B platform, currently one of the largest satellite platforms being used in China, and can carry more fuel to ensure its long life. Beidou 54 is a 4,600 kg box shaped satellite, equipped with 2 solar panels and laser retroreflectors for orbit determination. Its lifetime is 8 years. The navigation payload sends signals in the S/L-band at 1.20714 GHz (B2) und 1.26852 GHz (B3). The communication payload sends in C-band.
The accuracy of the dynamic positioning can reach the decimetre level, providing services for driverless vehicles, accurate berthing of ships, as well as take-off and landing of airplanes. It will be widely used in the fields of communication, electric power, finance, mapping, transportation, fishery, agriculture and forestry.
The ability of short message communication has been improved by 10 times on this satellite. Users can send a message of over 1,000 Chinese characters at once as well as pictures via the satellite, quite useful in emergencies. The satellite's ability to receive signals has also been greatly improved, which could help miniaturize users' terminals.
Engineers at the China Xi'an Satellite Control Centre in northwest Chin's Shaanxi Province have been monitoring the


The launch team on site. Credit: China Academy of Space Technology

status of the satellite in real time, conducting daily in-depth analysis of the satellite's telemetry parameters, and analysing the parameters to ensure safe satellite operation. Next, the control centre will carry out platform in-orbit testing, inter-satellite link testing and satellite node access to ensure that the satellite will be connected to the network as soon as possible to provide continuous, stable and reliable navigation services.

2020-F02
16 March 2020 - 13:34 UTC (21:34 BJT)

launch site: Wenchang Satellite Launch Centre, LC201
launcher: Chang Zheng 7A - CZ-7A
payload: XJS-6 (Xinjishu Yanzheng 6, New Technology Validation Satellite 6)

The first launch of the CZ-7A failed to reach orbit, sometime after 2nd stage ignition. The planned parking orbit was at 195 x 195 km with 20° inclination. A 2nd burn of the 3rd stage, 30 min after launch, would have delivered the XJS-6 to geotransfer orbit. The improved 3-staged CZ-7A is designed mainly for geostationary orbit transport and can lift 6.8 t to 7.0 t payload into GTO, intended for replacing the "old" CZ-3. CZ-7A can be launched from Xichang or Wenchang.
The cause of the problem is unknown. Experts are investigating the issue and analysis would follow. Unknown was also the impact on other rockets within the CZ family. For example, the 2-stage CZ-7, uses YF-100 and YF-115 engines for its 1st and 2nd stages, respectively, just like the CZ-7A. The YF-100 kerosene/oxygen engine is also used in the CZ-5 rocket. The CZ-5's 2nd-stage YF-75D engine is a modification of the YF-75 hydrogen/oxygen engine used in the CZ-7A's 3rd stage.
The experimental satellite XJY-6 is CAST-built, based on the DFH-5 bus. The launch mass was estimated at 5 t. More details were not revealed.

2020-021A
2020-021B
2020-021C
24 March 2020 03:43 UTC (11:43 BJT)

launch site: Xichang Satellite Launch Centre - XSLC, LC 3
launcher: Chang Zheng 2C - CZ-2C
payloads:
Yaogan 30-06 Group 01 (CX-5-16)
Yaogan 30-06 Group 02 (CX-5-17)
Yaogan 30-06 Group 03 (CX-5-18)

A group of 3 Yaogan 30 remote sensing satellites for electromagnetic environment detection and related technological tests was sent to space. They successfully entered orbit and will be added as the 6th group to the Chuangxin 5 (CX-5) constellation. The satellites were developed by the Innovation Academy for Microsatellites of the Chinese Academy of Sciences. There was no further information available.

Beidou launch on 9 March. Credit: Guo Wenbin/Xinhua.

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

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

ABAE	Bolivarian Agency for Space Activities of Venezuela
AIS	Automatic Identification System
AIT	Assembly, Integration & Test
AO	Announcement of Opportunity
APSCO	Asia-Pacific Space Cooperation Organisation
BACC	Beijing Aerospace Control Centre
BDS	BeiDou satellite navigation System
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
CASC	China Aerospace Science and Technology Corporation
CASIC	China Aerospace Science and Industry Corporation
CAST	China Academy of Space Technology
CBERS	China-Brazil Earth Resources Satellite
CCTV	China Central Television
CE	Chang'e
CFOSat	China-France Oceanography Satellite
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
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space

COSPAR	Committee on Space Research
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
ECMWF	European Centre for Medium-Range Weather Forecasts
EO	Earth Observation
ETRSS	Ethiopian Remote Sensing Satellite
FAST	Five-Hundred Metre Aperture Spherical Radio Telescope
FY	Fengyun
FYESM	Fengyun Meteorological Satellites in Disaster Prevention and Mitigation
GEO	Geostationary Orbit
GF	Gaofen
GNSS	Global Navigation Satellite System
GRAS	Ground Research Application System
GTO	Geostationary Transfer Orbit
HIT	Harbin Institute of Technology
HY	Hongyun
ICG	International Committee on Global Navigation Satellite Systems
IoT	Internet of Things
ISRO	Indian Space Research Organisation
LEO	low Earth orbit
LEOP	launch and early orbit phase
LND	Lunar Lander Dosimetry and Neutron
LOX	liquid oxygen
LRO	Lunar Reconnaissance Orbiter

MEO	medium Earth orbit
MoU	Memorandum of Understanding
NSMC	National Satellite Meteorological Centre
NSSC	National Space Science Center
P/L	payload
PNT	Positioning Navigation and Timing
QUESS	Quantum Experiments at Space Scale
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
SBSP	Space Based Solar Power
SCO	Space Climate Observatory
SCO	Shanghai Cooperation Organization
SSEC	Space Science and Engineering Centre
SMILE	Solar wind Magnetosphere Ionosphere Link Explorer
SSO	Sun-Synchronous Orbit
STSC	Scientific and Technical Subcommittee
SUPARCO	Space and Upper Atmosphere Research Commission
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
YW	Yuanwang
ZQ	Zhuque

Chang'e 4 – Behind the Moon (part 5)

Operations of lunar days 13 to 16 on the far side of the Moon

by Jacqueline Myrrhe

13th lunar day – from approx. 19 December 2019 - 02 January 2020

The scientific instruments on the Chang'e 4 (CE-4) lander and Yutu 2 (YT-2) rover continued to collect data. YT-2 explored several sites and photographed and analysed with the Visible and Near-infrared Imaging Spectrometer (VNIS) a lunar rock with a lighter colour. Closer inspection showed that compared to the material studied so far the rock has less lunar erosion caused by the impact of micrometeoroids or thermal stress. The lighter colour and lesser erosion might give clues about its origin. CE-4 landed in an area with predominantly volcanic material which tends to be darker. The science ground team made calculations for adapting Yutu's route for the investigation of this particular rock what might explain the relatively short distance of 12.6 m Yutu travelled during lunar day 13.

13th lunar night – from approx. 03 to 17 January 2020

By the end of lunar day 13, YT-2 has driven 357.695 m. The lander and the rover switched to dormant mode for the 13th lunar night on 2 January.

03 January 2021

One Year Anniversary on the Far Side of the Moon

3 January 2020 marked the 1st anniversary of the CE-4 mission on the far side of the Moon. On that occasion, the main milestone achievements of the past 12 months were highlighted:

- Data obtained by VNIS installed on YT-2 show that the lunar soil in the landing area contains olivine and pyroxene originating from the lunar mantle.
- YT-2 exceeded it designed life time of 3 months. Its relatively slow speed is due to the rugged terrain, which requires careful route planning.
- Queqiao is expected to work as long as possible, with a goal of another 10 years. China is open to offer Queqiao to other nation's lunar missions.
- 210 GB of data were released to the project scientists and the science teams. (while 1.7 TB of data were received).

03 January 2021 - 20.9 GB of scientific data released

On 3 January 2020 (and updated on 3 March 2020), the Ground Research and Application System (GRAS) of the Chinese Lunar Exploration Project published CE-4 scientific data acquired by 6 scientific payloads on-board the CE-4 lander and rover during the 1st and 2nd lunar day. A total of 12,542 data files, with a total data volume of 14.97 GB were released. The Landing Camera (LCAM), on the bottom of the lander, imaged the lunar surface around the landing site during the lander's descent from a height of 2 km to 4 m. Each file of these Level 2A camera data is accompanied by a descriptive file.

Lander: **LCAM-Landing Camera:** Level 2A Scientific Data / **TCAM-Terrain Camera:** Level 2C Scientific Data / **Low Frequency Spectrometer:** Level 2C Scientific Data

Rover: **PCAM-Panoramic Camera:** Level 2B Scientific Data / **LPR-Lunar Ground Penetrating Radar:** Level 2B Scientific Data / **VNIS-Visible and Near-Infrared Spectrometer:** Level 2B Scientific Data

Access to CE-4 data on the website of the Ground Research and Application System (GRAS) of the Chinese Lunar Exploration Project

The data from the Chang'e 4 cameras are popular among space fans and even space professionals from the U.S. One of them is Doug Ellison who is the lead engineer for cameras on NASA's Curiosity Mars Rover. He converted a range of data into imagery as well as very impressive panorama views.

Philip Stooke works as a cartographer at the Western University in Ontario, Centre for Planetary Science and Exploration. He issues regularly updated maps of the route Yutu 2 is driving on the Moon.

Techniques Spatiales - a French space enthusiast published an extensive gallery of imagery of the TCAM on the CE-4 lander.

Yutu 2's Sleep and Wake-up Routine

Approximately 24 hours before the lunar night sets in, Yutu 2 will drive to the pre-planned location for overnight hibernation. The front of the rover will be directed into the Southern direction so that the fixed solar panel (in driving direction the left one – means: the one which is hanging a bit lower - similar to a floppy bunny ear ;-) will face East. As the Sun moves closer to the horizon and the temperature gradually decreases, mission control turns on the coin-sized radio-nucleoid heating element providing 120 W performance. The heating unit can last for 5,000 days.

When the night is about to start, the rover's mast with the parabolic antenna and the 3D panoramic camera is folded backwards along the rover's body and the foldable solar panel will be closed over it to cover and protect the electronics and other instruments from the cold. After 14 terrestrial days, when the lunar day is about to start and the Sun gradually shines on Yutu 2's fixed side solar wing facing East (the floppy one) the rover will wake up autonomously once the power generation has reached a certain threshold. This will trigger the central computer to turn on, unfold the movable solar wing again and deploy the camera-antenna mast. With that is done, Yutu 2 and Queqiao well establish its communication link autonomously. Once mission control gets the signal, it does a status check and configures the systems for the upcoming lunar day. The ground team will turn the rover in the desired direction and work can start.

Not only the low temperature of up to -180°C during the lunar night is an issue for the rover, also the high temperature during mid-lunar day is. Yutu's solar panel can adjust the angle to prevent the rover from overheating. But at noon, the rover will again go into hibernation. The consequence is that all tasks have to be scheduled for the lunar mornings and lunar afternoons – approx. 3 - 4 days each.

Working Mode: Spot Environmental Sensing

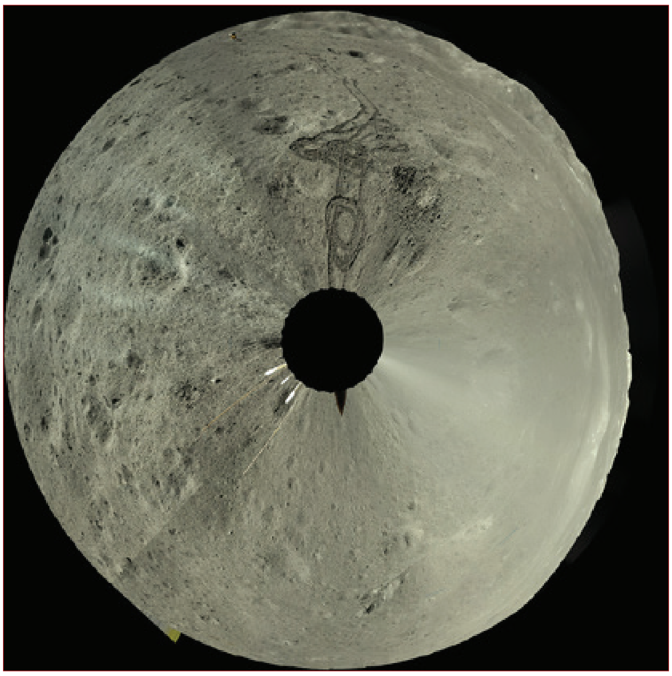
At certain points, YT-2 stops and is rotating on the spot in a 360° circle. The Visible and Near-Infrared Imaging Spectrometer (VNIS) and the Advanced Small Analyzer for Neutrals (ASAN) are conducting in-depth analysis of the location. VNIS takes measurements every 2 hours. Additionally, the Terrain Camera is taking photos.

Yutu 2 was turning in a circle for detailed analysis of the spot. Credit: CLEP/CNSA

Working Mode: Track Sensing

When the rover stops at certain points along its route, Yutu 2 is commanded to turn around by 180° and investigate the tracks it creates in the lunar soil with the VNIS instrument.

Track detection Credit: CLEP/CNSA



Data processed from Chang'e 4-Yutu 2. Credit: CLEP/DOUGELLISON.SMUGMUG.COM/https://dougellison.smugmug.com/Change-4-Yutu-2/i-sx98dM9/A

14th lunar day – from approx. 17 January to 02 February 2020

CE-4 lander and rover resumed work for the 14th lunar day after waking up from hibernation during the lunar night. Both craft were in a good state. The CE-4 lander woke up at 22:00 BJT on 18 January and YT-2 at 17:55 BJT on 19 January. The telemetry signal and the energy balance were nominal, and the scientific instruments started collecting data.

14th lunar night – from approx. 02 to 17 February 2020

At the end of the 14th lunar day, YT-2 had accumulated 367.25 m of traversing the far side of the Moon. On 01 February, the lander and rover switched to dormant mode for the 14th lunar night.

15th lunar day – from approx. 17 February to 03 March 2020

The CE-4 lander woke up on 18 February at 6:57 BJT and the YT-2 rover at 17:55 BJT on 17 February to resume work for the 15th lunar day. Both were in normal working conditions. It was planned that YT-2 would drive northwest and then southwest to continue its scientific exploration.

15th lunar night – from approx. 03 to 17 March 2020

CE-4 lander and YT-2 rover switched to dormant mode for the 15th lunar night on 2 March. By the end of the 15th lunar day Yutu 2 had driven 399.788 m.

16th lunar day – from approx. 17 March to 01 April 2020

On 18 March, the CE-4 lander and YT-2 rover switched back to operational mode for the 16th lunar day. Both the lander and rover were in nominal working conditions. The lander woke up at 23:38 BJT and the rover at 7:30 BJT. YT-2 continued to move to the northwest of the landing area and conducted measurements with its instruments.

Double 400 milestone

By the end of the 16th lunar day, YT-2 had survived more than 400 Earth days and travelled 405.44 m on the far side of the Moon.

16th lunar night - from approx. 01 April to 15 April 2020

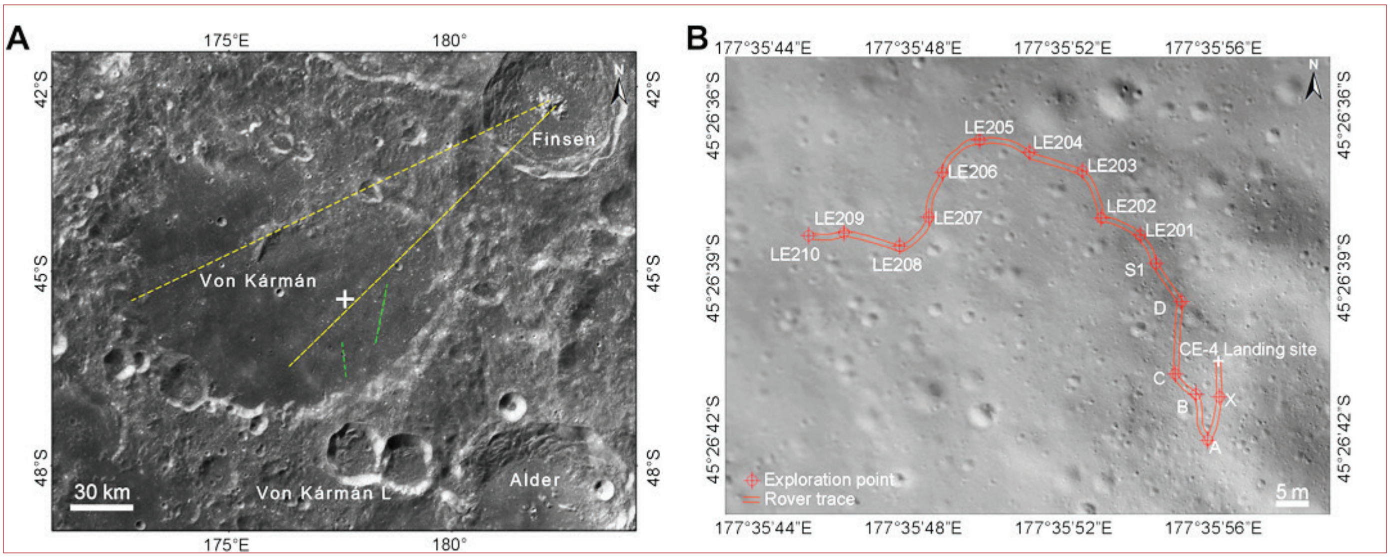
CE-4 lander and rover ended operation for the 16th lunar day and entered the stand-by mode for the 16th lunar night at 17:30 BJT and 8:25 BJT on 31 March. By the end of the 16th lunar day, YT-2 had driven 424.455 m. All systems operated nominally. The ground team analysed the data from the lunar crafts.

Lunar Penetrating Radar on Yutu 2 provides insight into the subsurface structure of the far side of the Moon

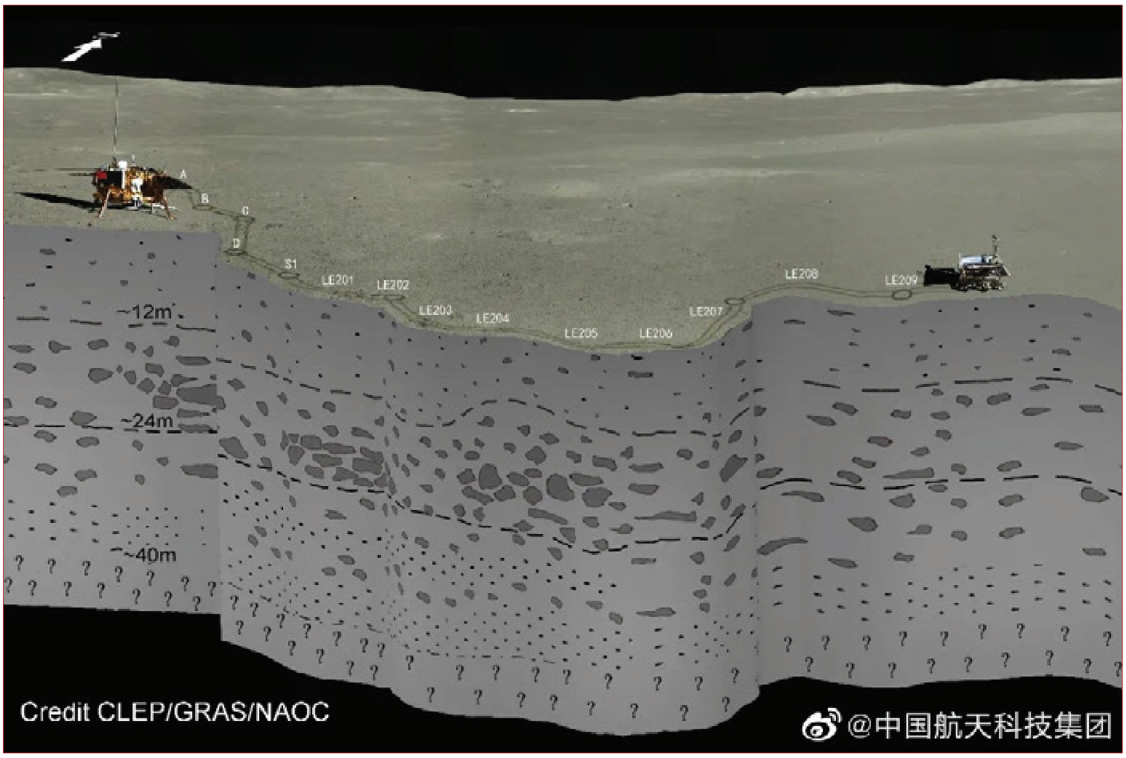
A study conducted by a research team led by Li Chunlai and Su Yan at the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) analysed the data from the Lunar Penetrating Radar (LPR) on the YT-2 rover. The 500 MHz signals of the LRP's high-frequency channel can reach a depth of 40 m under the lunar surface. Data, gained along a 106 m route driven by the rover during the first 2 lunar days, revealed a subsurface stratigraphy of the far side of the Moon which is more complex than what the data of CE-3 show for the near side. The upper layer reaches 12 m deep and is fine soil. Under that, the 2nd layer with embedded rocks is stretching from 12 m to 24 m. The strong radar echo from that region means that there is a layer of rock and stacks of loose stones. At a depth of 24 m to 40 m, granules and scattered stones were detected. Also, compared with the LPR on CE-3, the YT-2 radar is penetrating 3 times deeper. The scientists analysed the radar image with tomographic technique, and the result shows that the subsurface is essentially made by highly porous granular materials embedding boulders of different sizes. The results illustrate the spatial distribution of the different materials that contribute to form the ejecta sequence and their geometrical characteristics. As YT-2 has traversed more territory, more data will become available. The project scientists would like to drive YT-2 into a basalt zone, to better understand distribution and structure of ejecta from meteorite impacts. However, those regions are at a distance of 1.8 km from the current site. A directed drive would take around one year. The study was published on 26 February in *Science Advances*.

QR Code: https://advances.sciencemag.org/content/6/9/eaay6898

Li, C.; Su, Y.; Pettinelli, E.; Xing, S.; Ding, C.; Liu, J.; Ren, X.; Lauro, S. E.; Soldovieri, F.; Zeng, X.; Gao, X.; Chen, W.; Dai, S..; Liu, D.; Zhang, G.; Zuo, W.; Wen, W.; Zhang, Z. ; Zhang, X.; Zhang, H., (2020) "The Moon's farside shallow subsurface structure unveiled by Chang'E-4 Lunar Penetrating Radar", *Science Advances*, 6, 9, eaay6898, DOI: 10.1126/sciadv.aay6898



The CE-4 landing region and the YT-2 rover route. (A) CE-4 landed in the eastern floor of Von Kármán crater (44.45°S, 176.3°E; diameter ~186.3 km), as indicated by the white cross (177.5991°E, 45.4446°S) on a bright ejecta blanket. The yellow and green lines show the ejecta direction from Finsen (12) and Von Kármán L, respectively. The image is a CE-2 7-m resolution Digital Orthophoto Map (DOM). (B) YT-2 rover route during the first 2 lunar days. Two red lines show the tracks of the left and right wheels on the Yutu-2 rover. The LPR performed observation along the ~106-m route from exploration points A to LE210. The background image is stitched from images obtained during the landing process, where the spatial resolution is 5 cm.



Schematic representation of the subsurface geological structure at the CE-4 landing site inferred from LPR observations. The subsurface can be divided into three units: Unit 1 (up to 12 m) consists of lunar regolith, unit 2 (depth range, 12 m to 24 m) consists of coarser materials with embedded rocks, and unit 3 (depth range, 24 m to 40 m) contains alternating layers of coarse and fine materials.

Credit: Li, C., Su, Y., et.al., (2020) "The Moon's farside shallow subsurface structure unveiled by Chang'E-4 Lunar Penetrating Radar", *Science Advances*, 6, 9, eaay6898, DOI: 10.1126/sciadv.aay6898

Addendum to Chang'e 4 – Behind the Moon (part 4) in GoTaikonauts! issue no 30:

At the end of 2019, the Chang'e 4 mission was awarded several science and public prizes.

- **Best Fusion Innovation Award**

On 23 December 2019, the Rongmedia Works Contest "Hello New Age!" awarded the prize in the category for the Best Fusion Innovation Award to the Yutu 2 Weibo blog.

- **Best Innovation Award**

At the end of 2019, the U.S. "Popular Science" magazine selected the "100 Greatest Innovations of 2019", and the Chang'e 4 mission was honoured with the "Best Innovation Award" in the aerospace category.

- **Science and Technology Achievement Award**

In November 2019, Wu Weiren, the Chief Designer of China's Lunar Exploration Project, together with other 56 scientists from different science areas was awarded the "Science and Technology Achievement Award 2019". Academician Wu Weiren was responsible for the development of China's 1st S-band computer telemetry and remote control system which supported the development and construction of China's deep-space network. Wu Weiren proposed and implemented the "1 mission - 3 technical projects" approach during the CE-2 mission which made China the 3rd country to reach the Lagrange L2 point and an asteroid. By doing so, China could gain new experience in the field of deep-space exploration. Wu Weiren continued to be responsible for the CE-3, CE-4, and CE-5 missions and the conceptualisation of the future lunar south pole research station, among which the CE-4 landing on the far side of the Moon achieved a first in the history of astronautics.

Chang'e 4 Scientific Achievement Exchange Meeting

On 23 November 2019, the Lunar Exploration and Aerospace Engineering Centre of the National Space Administration and the General Department of Lunar and Deep-Space Exploration of the Chinese Academy of Sciences jointly organised in Beijing a workshop to report on the mission progress and to exchange on the scientific achievements of the CE-4 mission. The mission has produced 1.7 TB of scientific data from all its 13 instruments.

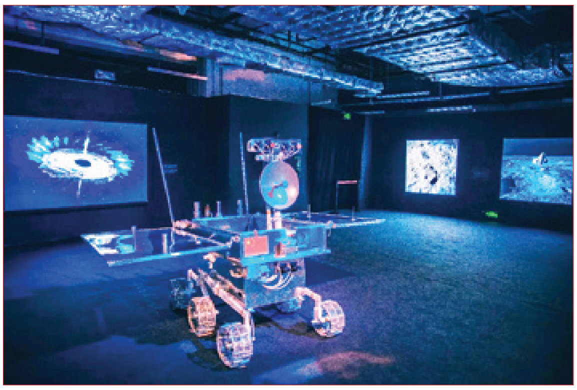
Moon and Beyond Space Art Exhibition

On 18 December 2019, the "Moon and Beyond Space Art Exhibition" opened in the Tianhe District in Guangzhou and run through to 2 April 2020. The 3,000 m² immersive virtual reality exhibition featured multimedia items, a 360° high-definition 3D landscape, and other interactive features to let the audience experience the interstellar world with the help of virtual reality. Next to the highlight exhibits of Dongfanghong 1, Shenzhou 5, and Chang'e 1 representing the milestones of Chinese space exploration achievements, expert scientists gave lectures, a design competition for university students was held, and space-related music concerts conducted. The 1st science lecture was given by Academician Ouyang Ziyuan.

The fact that the exhibition was located in Guangzhou's Tianhe District and the landing site of Chang'e 4 was named "Statio Tianhe" made a nice coincident.

Addendum to 11th lunar night in: Chang'e 4 – Behind the Moon (part 4) in GoTaikonauts! issue no 30:

The CE-4 lander switched to stand-by on 4 November at 6:15 BJT and the YT-2 rover at 5:16 BJT the same day.



left: Liu Yang at the Guanzhou lunar art exhibition. right: A Yutu 2 model at the Moon and Beyond Space Art Exhibition in Guangzhou. Credit: Xinhua

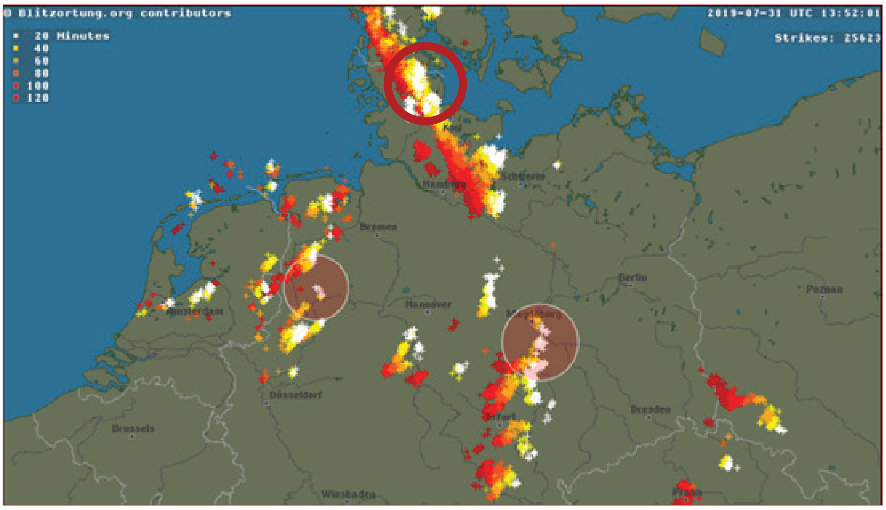
All dates and times: BJT
CE-4 - Chang'e 4
YT-2 - Yutu 2
CE-3 - Chang'e 3

to be continued in the next issue of GoTaikonauts!

The dramatic last day of Longjiang 2 (DSLWP-B) - a thrilling finale

by Jacqueline Myrrhe

The 31 July 2019 was the last day of the Longjiang 2 mission. Radio amateurs and scientists from China, Germany and The Netherlands joined together to accompany the microsatellite up to the last minutes of its flight, until impact on the Moon would be confirmed. The team consisted of Wei Mingchuan (BG2BHC) from Harbin in China, André Offringa; Cees Bassa; Paul Boven (PE1NUT) from Dwingeloo Radioteleskop CAMRAS and via Internet Tammo Jan Dijkema - all from the Netherlands, and Reinhard Kühn (DK5LA) from Sörup in Germany.



The screen shot shows the strong and long stretch of the thunderstorm front over Central Europe, including the North of Germany, during the mid-day of the 31 July 2019. The red circle marks the region around Sörup. Credit: Blitzortung.org CC BY-SA 4.0

That day, a heavy thunderstorm crossed over Sörup. This resulted in some nervous excitement to all involved and in particular in an eventful situation for Reinhard Kühn (DK5LA), the radio amateur in North Germany who provided up-link capacity for the mission via his private ground station in Sörup. (We reported in GoTaikonauts! no 30, pp. 29-32 how Reinhard supported the complete Longjiang 2 mission.)

With thick clouds, thunder and lightning in the sky over him, Reinhard was very concerned that lightning would hit the antenna which would not only cause enormous damage to the construction but would also pose a danger to the operator of the equipment.

At 13:29 UTC, in the middle of the thunderstorm, Reinhard was asked to send a command to the lunar micro-satellite for downloading the last image, taken at 13:24 UTC when the amateur payload was powered on and was ready for download. Reinhard succeeded in sending the command at 13:31 UTC and download started at 13:32 UTC. At 13:36 UTC, lightning struck a spot approx. 100 m from Reinhard's location. Normally, he would immediately disconnect his equipment from the power supply. But he realised that several radio antenna stations were busy receiving data and waiting for the result of the last command. Not being sure whether the download was complete, Reinhard hesitated and stayed active – but took the minimum caution he could: step away from the equipment. Finally, he got confirmation from the other radio amateurs in the Netherlands and China that the picture was received – completely received. What a relief!

The final picture taken by the satellite, shows the overexposed Earth. The quality of the photo is poor, but it was not the purpose to get a nice image – those last commands were important to keep the connection with Longjiang 2.

In the meanwhile, the thunderstorm got worse. Reinhard disconnected his equipment at 13:39 UTC. Also, from that moment on, he did not have contact with the Longjiang 2 team in The Netherlands and in China. Everybody was waiting for the thunderstorm front to pass by and hoping that Reinhard could power on his station soon again. But the thunderstorm did not want to go away - thunder and lightning was still very close.

At 14:04 UTC, Reinhard decided to power up his equipment again. Under normal circumstances, Reinhard would never have done this, bearing in mind that lightning can be life-threatening or destroy the station. Facing this unique situation, Reinhard proceeded, for if he would not have done this, this crucial opportunity would have been lost. In fact, as it would turn out - it was a matter of only a very few minutes – actually seconds.

One minute later, at 14:05 UTC, amateur radio fellow Wei Mingchuan at Harbin University of Technology, asked Reinhard to send the very last command to keep the payload activated so that ground stations could follow Longjiang 2 until loss-of-signal which was expected for around 14:10 UTC.

Reinhard sent the command “download picture” at 14:06 UTC. The transmission took 70 seconds – 70 nerve wrecking seconds. Everybody was wondering whether the signal was too late or whether Longjiang 2 had already left the range of visibility. This tense moment was interrupted, at 14:08 UTC when Longjiang 2 started transmitting again only to stop again after a few seconds. As short as the signal was, it was important for the mission planner to know the exact time when Longjiang 2 was leaving the line of sight. With this last command, sent by Reinhard, the connection was activated and a signal available. By knowing the moment of loss-of-signal the mission experts could calculate the impact location of Liangjiang 2 on the far side of the Moon. Finally, contact with Longjiang 2 was lost at 14:08 UTC because the micro-satellite had disappeared behind the Moon. At 14:20 UTC Longjiang 2 impacted the Moon's far side.

Not only Reinhard, but the whole team was relieved when it became evident, that everything had worked.

Already in May 2019, Daniel Estévez (EA4GPZ / M0HXM) was able to estimate when Longjiang 2 would hit the lunar surface. In August 2019, he determined very precisely the impact location. He predicted an impact near Van Gent crater (16.69°N, 159.52°E) what was just 328 m off the actual point what is an incredible accuracy. (compare: GoTaikonauts! issue no 29, p. 20)

Later on, NASA's engineers responsible for the suites of cameras on the agency's LRO (Lunar Reconnaissance Orbiter) confirmed the impact location. Based on the calculated coordinates an image was taken on 5 October 2019 and a new 4 x 5 m crater with a depth of approx. 10 m was identified which could be assigned with certainty as a result of the Longjiang 2 impact. Longjiang 2 (DSLWP-B) caused the 7th crater on the far side of the Moon, caused by a man-made object. The radio amateurs were honoured to have been part of this event.

All involved experts, from all over the world, have stressed over-and-over again, that the success of the Longjiang 2 mission was a strong and well-coordinated team effort. Every team member was proud of the success. The fact that all those amateur experts have invested their time, their equipment and knowledge on a voluntary and non-compensated basis cannot be overestimated. It is an emblematic result and successful example of the beauty of global space cooperation.

Full list of participating amateur operators:
http://lilacsat.hit.edu.cn/wp/?page_id=844

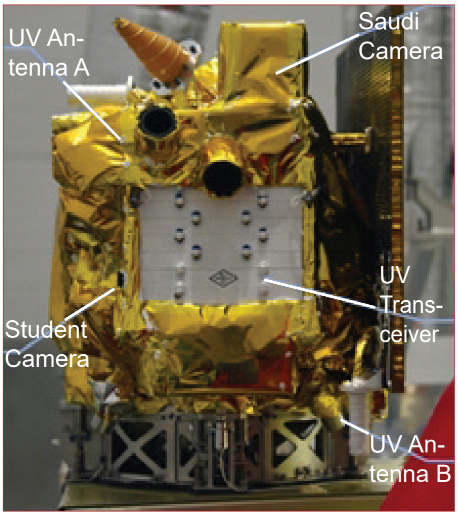


Photo of the Longjiang-2 microsatellite at the launch site, getting prepared for integration with the Queqiao lunar relay satellite. The Longjiang-1 and -2 microsatellites were launched on 20 May 2018 together with Queqiao as part of the Chang' e 4 mission. The lander and rover for lunar far side operations followed on 7 December 2018. Credit: Harbin Institute of Technology

Resources:

- https://www.universetoday.com/144047/the-impact-site-of-chinas-longjiang-2-spacecraft-has-been-found-on-the-moon/
- https://schostar.com/2019/08/10/the-crash-of-a-chinese-moon-earth-photographer/
- https://destevez.net/2019/07/dslwp-b-last-activities-and-end-of-mission/
- http://lroc.sese.asu.edu/posts/1132
- online presentation by Reinhard Kühn for Volkshochschule Sörup, 12.03.2021

The author wishes to thank Reinhard Kühn for providing the information and explaining the details of the last day of the Longjiang 2 mission. Thanks go also to the Volkshochschule Sörup and the Kepler Sternwarte Linz who organised online-presentations by Reinhard about his engagement in the Longjiang 2 mission.

Image 0x24, taken on 2019-07-31 13:24, partially downloaded on 2019-07-31 13:32 to 14:0. Daniel Estévez commented this photo by saying: "Before the satellite hid behind the Moon, it was possible to download a last image. This was image 0x24, which was taken at 13:24, as the Amateur payload powered on. It shows an over-exposed Earth. As DSLWP-B hid behind the far side of the Moon, it was looking back to the Earth, the place where we all live, and we managed to grab this last view of our planet.

The Longjiang 2 (DSLWP-B) microsatellite impacted the lunar far-side on 31 July 2019 after completing its orbital mission. This new crater was most likely the result of that impact. Image width 330 m, North is up, image enlarged by 4x, LROC NAC M1324916226L. Credit: NASA/GSFC/Arizona State University.

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The Chinese Lunar Goddess on a Night Mission (part 1)

by Jacqueline Myrrhe

After more than 40 years, lunar material was once again returned to Earth. China's Chang'e 5 mission accomplished what was abandoned by the U.S. and the Soviet Union in the 1970s. By doing so, China manifests its reputation as a serious space nation.

1 multiplied by 1.731

Until today, no other space project has been more successful than NASA's Apollo missions of the last century. The returned lunar material, consisting of 2.200 samples from 6 different locations totalling 382 kg, helped lunar researchers to achieve a great moment for science giving an unprecedented boost of knowledge about our neighbour in space. But the effects went even further.

In 1978, one gramme of those Apollo samples was given as a good-will present to China by Zbigniew Brzezinski, the National Security Adviser of U.S. President Jimmy Carter. Half of the material ended up in the museum and the other half served Chinese scientists for research. One of the scientists who got hold of the tiny amount of lunar dust was the young geologist Ouyang Ziyuan. The work with the substance fascinated him so much that he decided to dedicate his just-beginning professional career to lunar research. He would eventually become the conceptual mastermind and Chief Scientist of China's lunar exploration programme CLEP (Chinese Lunar Exploration Programme) and would define its strategy and objectives.

No matter how rich and versatile the Apollo samples have been – the picture was not complete. The age of the Apollo samples and also of the surface material scoped by the Soviet Luna missions is estimated to be between 3.1 and 4.4 billion years. That led to the conclusion that lunar volcanic activity might have stopped by that time. However, scientists have always wondered whether there are regions on the Moon, harbouring younger magma. Should that be the case, gaps in current theories about the evolution of the Moon could be filled.

It was Ouyang Ziyuan who recommended that China's lunar exploration should follow a methodically increasing complexity where each step builds on the success of the previous mission. The objectives were conceptualised in a way that China would be able to contribute new knowledge to the global lunar research.

Following this approach, the most recent lunar mission, China's Chang'e 5, was realised as a sample return mission, picking up material from the region of Mons Rümker in the Ocean of Storms (Oceanus Procellarum). Mons Rümker is a far reaching volcanic formation in the North-Western part of the near side of the Moon. It covers roughly 70 km from 41-45° North to 49-69° West. The peak of Mons Rümker is up to 1.300 m high, overlooking the surrounding Ocean of Storms – the biggest lunar plains, referred to by scientists as 'mare'. The scientists hypothesised that the basaltic material in the Eastern region of Mons Rümker is approx. 1-2 billion years old. So, this was the location from which Chang'e 5 returned to Earth on 17 December Beijing Time (BJT) with 1,731 grammes of lunar regolith together with pieces from a drill core. Ouyang Ziyuan must be 85 years of age by now, but he is still a frequent guest at mission control in Beijing where he follows each lunar mission. It would be interesting to know whether he will put some of the lunar grains under the microscope to close the loop he started more than 40 years ago.

A milestone for China

Chang'e 5 (CE-5) has been China's most complex and ambitious mission so far. It was the last mission of the 3^{rd} Phase "return" of CLEP (China Lunar Exploration Programme). Chang'e 1 and 2 belong to Phase 1 "orbiting" while Chang'e 3 and 4 were assigned to the 2^{nd} Phase "landing".

There was an intermediate step implemented: In 2014, the Chang'e 5-T1 test mission circumnavigated the Moon (without entering orbit) and tested upon return to Earth the special skip re-entry manoeuvre. Skip re-entry means that the spacecraft enters the atmosphere under a flat angle and almost leaves it again before transferring to a ballistic descent. The challenge is the high-velocity when the return capsule arrives at the vicinity of Earth at the 2^{nd} Cosmic Velocity of 11.2 km/s. CE-5-T1 has been already part of the 3^{rd} CLEP phase, despite it having more of a preparatory character. Taking this into consideration, CE-5 is actually China's 6^{th} lunar mission. Remarkable is that all 6 missions have been successful and that CE-2, 3 and 4 but also the orbiter of CE-5 are still operational. CE-2 is flying an extended mission, the CE-3 lunar lander has still some instruments sending data, regardless of the fact that the Yutu 1 rover got stuck much earlier than planned. In contrast, the CE-4

MISSION OBJECTIVES

Scientific Aims

- Investigating the landing site's geological and topographical features.
- Detailed analysis of the sampled lunar material with respect to structure and physical characteristics.
- Comparison of in-situ data with laboratory analyses, in particular with respect to new insights into the origin and the evolution of the Moon.

Secondary Aims

- Extending knowledge and making progress in the development of technologies and the promotion of talents in order to prepare for future human lunar missions and other deep-space projects.
- Strengthening of the international standing of the Chinese nation and contributing to the global space community.

Engineering Objectives

Testing and verification of the technical maturity of the mission sequence and the hardware for:

- Autonomous lunar sampling, packaging and storage.
- Moon-based launch capability.
- Automated lunar orbital rendezvous and docking.
- Atmospheric re-entry with 2^{nd} Cosmic Velocity (11.2 km/s).
- Development of the technical foundation for future manned lunar missions and other deep-space missions.

The mission's Firsts

- China's 1^{st} lunar sample return mission and at the same time China's 1^{st} sample return mission from any extra-terrestrial celestial object.
- China's 1^{st} space launch from an extra-terrestrial celestial object.
- China's and at the same time the worldwide 1^{st} autonomous rendezvous and docking in lunar orbit *(Note: The Apollo missions implemented manual docking in lunar orbit and the Soviet lunar missions launched directly from the lunar surface back to Earth.)*
- For the 1^{st} time, China has the opportunity to analyse its own lunar samples.
- 1^{st} lunar sample return mission since the Soviet Luna 24 mission in 1976.

Ouyang Ziyuan around the year 2000. Credit: Chinese internet

Chang'e 5 in the clean room. Chang'e 5 is China's heaviest and largest lunar probe. Credit: CASC/CLEP/China Daily

In the early morning of 24 November BJT, the CZ-5 heavy-lift carrier rocket launced from Wenchang Space Launch Centre in South China's Hainan province marking the start of the Chang' e 5 lunar sample return mission. Despite the night time launch, many spectators gathered along the beach to follow the unique spectacle. Credit: Xu Jingxing/China Daily

History of the set-up of China's Moon exploration programme

Already in 1970, after Dongfanghong 1 was launched, Chinese scientists started talking about a national lunar exploration programme. But 1970 was in the middle of the difficult period of the Cultural Revolution. It was Premier Zhou Enlai who was concerned about the technological, technical and financial difficulties of such a bold project and turned down the idea.

It was not until the early 1990s that Chinese scientists came up with the first serious proposal for China's own lunar programme. In 1991, under competitive pressure from the successful Japanese lunar satellite Hiten (MUSES-A - MU Space Engineering Spacecraft A), a group of Chinese Academy of Space Technologies (CAST) researchers, led by Zhu Yiling, drafted a proposal for China's first lunar mission. In 1992, another proposal for crash landing a badge engraved with a map of China dedicated to Hong Kong's return to China in July 1997, was also submitted to the then Ministry of Aerospace. However, China's focus by that time was on the human space programme and the hard landing proposal did not have any scientific value, and Premier Li Peng said, "No go!" to the proposal.

Regardless these setbacks, the scientists did not give up on their efforts.

In 1994, Song Jian, a renowned space scientist and former head of China's top science planning body, proposed that China could take advantage of the new-generation rocket under development for human spaceflight and use that carrier also for a robotic lunar mission.

The same year, Ouyang Ziyuan, as an academician of the Chinese Academy of Sciences (CAS), submitted another proposal to the 863 Committee (responsible for China's national high-tech programmes), starting a 10-year long hard study and lobbying process.

Ouyang's 2nd proposal in 1996 conceived of a 3-step plan. It proposed to send a lunar orbiter first, then to conduct a soft landing on the Moon's surface, and to have a sample return mission as the last step. In 1998, he started studies on the mission's scientific objectives and payload configuration. In 2000, he concluded and set the primary objectives for the 1st lunar orbiter – to obtain 3D images of the lunar surface, to analyse the chemical element distribution on the Moon, to determine the depth and characteristics of lunar soil, and to detect the space environment between the Earth and the Moon. All these important works laid the foundation of the later formal programme.

In April 1997, 3 senior and influential scientists, Yang Jiaxi, Wang Dahang and Chen Fangyun submitted a new proposal called "Suggestions to Lunar Exploration Technologies of Our Country" which received wide support within the science community.

In August 2000, a review was held by experts from the CAS, CASC, Ministry of Science and Technology, and various universities. It concluded that the proposal by Ouyang was feasible and reasonable.

In November 2000, the government announced in a Space White Paper that preparatory research about lunar exploration was included in its space plans.

In 2001, the Committee of Science Technology and Industry for National Defence (COSTIND) formed a team to conduct a series of detailed studies covering mission objectives, payloads, spacecraft, launch vehicle, as well as a ground support system, etc. In April 2002, the programme entered the pre-study phase that was to complete system design and key technology development. In December 2003, the spacecraft design was completed, and a preliminary review done. At the same time, breakthroughs had been made on key technologies such as ultraviolet sensors and directional antenna. Based on these outcomes, it finally submitted a report to the government at the end of 2003.

On 23 January 2004, the Chinese government officially approved the Phase 1 project to launch an orbiter around the Moon, and to build necessary facilities for the mission. It allocated a budget of 1.4 billion RMB. Premier Wen Jiabao signed and officially kicked-off China's national lunar exploration programme. The programme was named Chang'e, after the name of the mythical goddess who lives with her white rabbit Yutu on the Moon – a story known to every Chinese. The first lunar orbiter was named Chang'e 1 (CE-1). Ruan Enjie, the China National Space Administration (CNSA) administrator by that time, was named as the Chief Commander. Sun Jiadong was named as the Chief Designer, and Ouyang Ziyuan was named as Chief Scientist.

Chang'e 1	2007, 24 October
Chang'e 2	2010, 1 October
Chang'e 3	2013, 1 December (2 December – BJT)
Chang'e 4	2018, 7 December (8 December – BJT)
Chang'e 5-T1	2014, 23 October (24 October- BJT)
Chang'e 5	2020, 23 November (24 November – BJT)

lander with its Yutu 2 rover on the far side of the Moon are still working flawlessly well beyond their design lifetime.

While China was sleeping

Something else made CE-5 special: the important mission milestones such as launch, Moon landing, ascent from the Moon and return to Earth took place during night-time in China. For European observers and space enthusiasts however, all those events happened during convenient evening hours and for American on-lookers during the day.

CE-5 launched from the new space launch site Wenchang on the island of Hainan on board of a Long March 5 (CZ-5) rocket on 23 November 2020, at 20:30 UTC what was early morning at 04:30 BJT on 24 November in China. The rocket was the 5th of the CZ-5 type, indicated by the addition "Y5": CZ5-Y5. With that, the number 5 made up for the accidental and easy to remember configuration: 5-5-5, meaning the 5th CZ-5 rocket launched Chang'e 5.

Also, it was the 1st time that a lunar mission was launched by a CZ-5 rocket and also the 1st time that China departed for the Moon from Wenchang. All the previous Chang'e missions used the CZ-3 variants, launched from the Xichang Satellite Launch Centre. Only the launch of the Queqiao relay satellite for the Chang'e 4 mission with a CZ-4C was an exception but it also lifted-off from Xichang. And: The CZ-5 is with its height of 57 m, take-off weight of 870 t, and thrust of 1,000 t the biggest and most powerful Chinese launcher. Likewise, CE-5 was the biggest and heaviest of lunar probes China launched so far. All-in-all many superlatives and unique numbers.

The early morning launch time was decided by mission planners and rocket designers based on several considerations: trajectory, sunrise and cloud cover over the launch site, ground-based monitoring and tracking.

The relative position between Earth and the Moon in the early hours of the 24 November (BJT) allowed for beneficial conditions for entering the preferred transfer trajectory. Also, launching before sunrise reduced interference from solar radiation on communications between ground stations and the spacecraft. Similarly, before daylight, the cloud cover is thinner, which avoids any risk to ground-to-space communication. And also important: the pre-dawn conditions enable better ground-based tracking of the launch and 1st stage separation.

Already in late September, the CZ-5 rocket parts were transported by ship from the factory in Tianjin to Qinglan port on Wenchang and then carried by special trucks to the launch site. There, the assembly and testing of the CZ-5 Y5 took around 2 months. The readied CZ-5 was finally moved to the launch pad on 17 November. Fuelling of the rocket started in the early evening of 23 November - at around 18:30 BJT.

Despite the very early morning launch, many spectators inside and around the coastal launch site watched the rocket taking off. The Chinese government had invited diplomatic envoys and officials from international organisations to Wenchang to experience the hopeful beginning of a mission, scheduled to last 23 days.

Initially, the launch of CE-5 had been planned for 30 November 2017. But in July 2017 the just newly-designed heavy-lift CZ-5 carrier rocket had a problem during launch with the turbopump in the 1st stage engine. What followed was a 1 ½ year-long rigorous overhaul of the entire engine. The effort paid off. In December 2019 the CZ-5 became operational again. However,

Chang'e 5 Project Management

OVERALL MANAGEMENT

The management and implementation of the CLEP missions are under the responsibility of the China National Space Administration (CNSA) – the agency for all Chinese scientific space missions. The technical lead was delegated by CNSA to the Lunar Exploration and Aerospace Engineering Centre – a unit under CNSA.

LUNAR PROBE

CAST, the China Academy of Space Technology, was tasked to design and build the 8.2 t CE-5 spacecraft, consisting of 4 modules: service module/orbiter, lander, ascent stage, return unit.

CARRIER ROCKET

The CZ-5 launcher was built by CALT, the China Academy of Launch Vehicle Technology affiliated to China Aerospace Science and Technology Corporation CASC.

GROUND SEGMENT

The Ministry of Satellite Launch, Measurement and Control System of China was responsible for organising the ground segment which included launch, measurement and control and recovery.

SAMPLE RESEARCH and STORAGE

The National Astronomical Observatory of the Chinese Academy of Sciences in Beijing is responsible for the research and development of ground application systems, which are responsible for the reception and processing of scientific data and the storage of samples.

left: Yuanwang 5 on tracking mission. Credit:

left: Yuanwang 6 on its way to port. Credit:

right: Launch site staff celebrates the launch of the Chang'e 5 lunar mission at the Wenchang launch site on Hainan island on 24 November 2020. Credit: Jin Liwang/Xinhua then came the Corona pandemic. The Chinese space industry made multiple and far-reaching efforts to keep the launch sites operational and processes in place. Thanks to consequent hygiene concepts and the commendable willingness by engineers, technician, space experts and all involved personal to make sacrifices, the planned space launches stayed on track. Not only the Mars mission Tianwen 1 launched in July 2020 with the 4th CZ-5 (CZ-5 Y4) but eventually CE-5 was sent on its 112-hour long journey to the Moon.

1st stage separation happened at about T+489 seconds.

At 20:58 UTC, 28 min after launch, the 2nd stage fired for a 7-minute long translunar injection burn which finished at 21:05 UTC. About 2,200 seconds after lift-off, at 21:06 UTC, the Chang'e-5 lunar probe separated from the rocket's 2nd stage and entered directly the Earth-Moon transfer orbit with the perigee at 200 km and the apogee at about 410,000 km.

The early flight phase was supported by 2 of China's space tracking ships: Yuanwang 5 and Yuanwang 6 positioned in the Pacific Ocean. About 6 minutes after the launch, Yuanwang 6 detected the object and followed its flight. At approx. 30 min into flight, Yuanwang 5 continued the task of sending accurate real-time data to the Beijing Aerospace Control Centre BACC and to Wenchang.

Additionally, and like during previous Chang'e missions, ESTRACK - ESA's network of tracking stations - provided communication support. The 15 m-antenna in Kourou, French Guiana, tracked Chang'e 5 for several hours after launch, providing to BACC a data connection from the spacecraft to confirm the mission status and the trajectory.

ESA appreciates those opportunities for cooperation, since it increases the agency's own experience and capabilities. Later during the mission, ESA's Malargüe antenna in Argentina would serve as a back-up emergency antenna support for lander and ascent during lunar surface operation. And again, the Kourou station will support the transfer trajectory back to Earth. During the final phase of the mission, just before Chang'e 5 enters the atmosphere, ESA will receive Chang'e 5 signals with the Maspalomas station on Gran Canaria, operated by the Instituto Nacional de Tecnica Aerospacial (INTA) of Spain.

The 1st trajectory correction manoeuvre, TCM-1, occurred 17 hours into flight at a distance of 160,000 km from Earth. The 3,000 N engine of the lunar probe fired for 2 seconds on 24 November at 14:06 UTC. TCM-2 was conducted exactly one day later, on 25 November at 14:06 UTC. The two 150 N engines worked for 6 seconds. The lunar orbit insertion burn was

Detailed mission sequence of Chang'e 5 lunar mission
Jonathan McDowell compiled in his "Jonathan's Space Report No. 787" the best available sequence of events for the Chang'e 5 mission and gives a useful overview on the space craft components: https://planet4589.org/space/jsr/back/news.787.txt

ESA's 15 m-diameter tracking dish at Kourou, French Guiana.

Credit: ESA/A. Chance

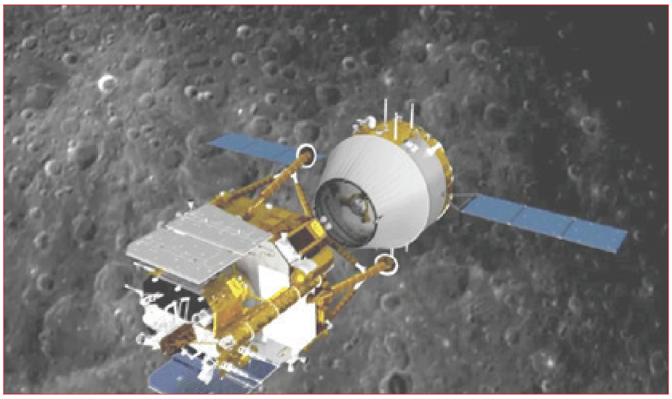
The graphic shows ESA's involvement in the launch and Earth return phases of the Chang'e 5 flight. Credit: ESA conducted on 28 November, starting at 12:58 UTC (20:58 BJT) and was completed 17 minutes later, at 13:15 UTC. CE-5 had entered a 216 x 5,585 km x 42.4° elliptical lunar orbit. Almost exactly 24 hours later, on 29 November at 12:23 UTC (20:23 BJT) the elliptical orbit was lowered to a 217 km circular orbit retaining the inclination of 42.4°.

After that, BACC, prepared for another crucial night shift.

Under BACC's control, the 4-module probe separated into 2 units on 29 November at 20:40 UTC (30 November, 4:40 BJT). The service module and the return unit remained in lunar orbit and the lander with the descent and ascent stage were prepared for landing.

Mission Control in Beijing confirmed that all systems were in good condition and the mission operations went smoothly. BACC remained busy for the next day by manoeuvring the landing unit on 30 November (UTC) in 2 steps into a lower perilune orbit. The 1st step was on 30 November, at 14:23 UTC when the orbit lowered to 19 x 217 km and the 2nd 4 hours later at 18:22 UTC when the lander moved into a pre-descent orbit of approx. 19 x 67 km. The service module unit followed on 30 November short before midnight UTC to enter a lower perilune orbit of approx. 77 x 217 km.

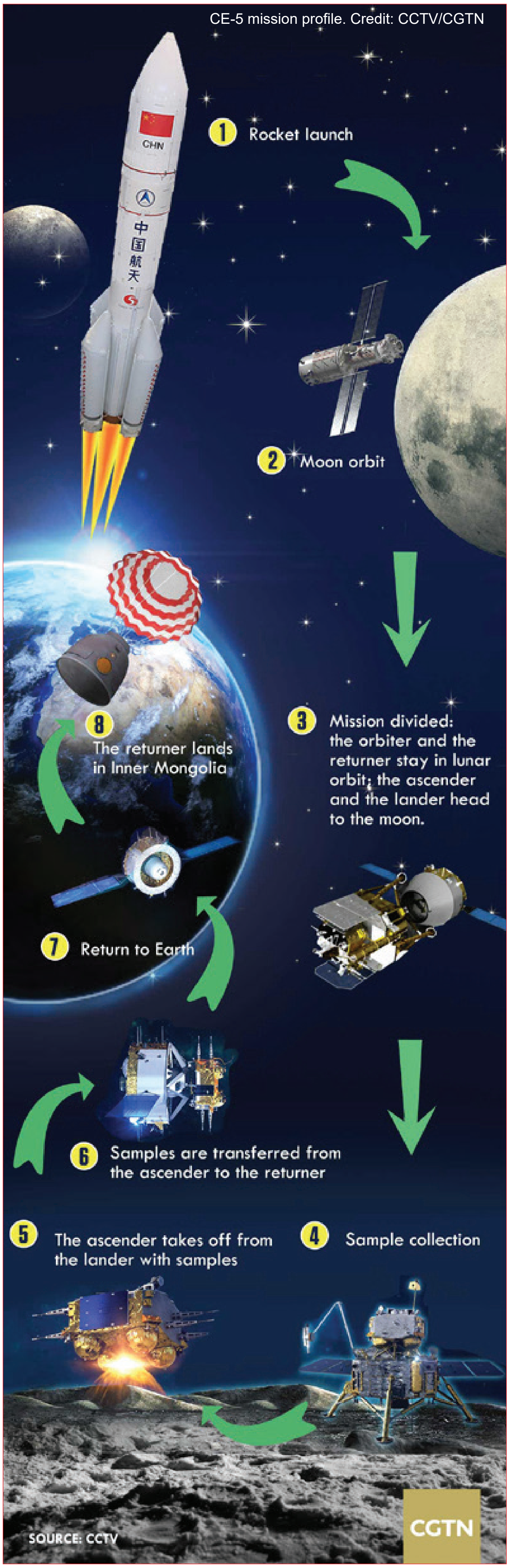
And the next night shift at BACC would shoulder the next challenge of the mission – the landing.



Artist's view of the separation of the Chang'e 5 landing unit from the orbiter in lunar orbit. Credit: CNSA/CLEP

View of the Beijing Aerospace Control Centre (BACC) in Beijing, on 30 November 2020 after successful separation of landing module and orbiter/return unit. Credit: BACC/Xinhua

In the 2nd and final part of our mission report we will reflect on Chang'e 5's landing sequence, the sampling of the lunar material, the hardware used for that operation and the spectacular return of the space craft – which, again, was a night-time operation. We will also talk about where the lunar samples ended up and give details on the extended Chang'e 5 mission.



CE-5 mission profile. Credit: CCTV/CGTN

Following Yuanwang: new destinations?

by Brian Harvey

Two earlier articles in Go Taikonauts! (GT! 26, 27) followed the activities of the Yuanwang fleet of Chinese space tracking ships from summer 2019 to year's end. This, the third article in the series, follows the fleet for January to end July 2020. This was an important period, for it saw two launches of the Long March CZ-5, including China's first mission to Mars; a CZ-7 launch; and the completion of the Beidou network. As we know from earlier articles, the Yuanwang are not used for all space missions, but focus on those going to 24 hr orbit (e.g. communications or navigation satellites); deep-space (e.g. Moon or Mars); and new rocket tests (e.g. CZ-5, 7), where tracking is required for critical manoeuvres and telemetry. Generally, the tracking ships are not used for smaller payloads going to low Earth orbit. To the right is a table of China's missions during this period and the ships involved in tracking their location (right column).

Date	Main mission	Launcher and site	Tracking operations
7 January	TJSW-5 (GEO)	CZ-3B, Xichang	Yuanwang 3, mid-Pacific
15 January	Jilin 1	CZ-2D, Taiyuan	
16 January	Yinhe 1	Kuaizhou 1A, Jiuquan	
20 February	Xin Jishu Shiyan	CZ-2D, Xichang	
9 March	Beidou 54 (GEO)	CZ-3B, Xichang	Yuanwang 5, mid-Pacific
16 March	XJS-6	CZ-7, Wenchang	Yuanwang 5, mid-Pacific
24 March	Yaogan 30-6 group	CZ-2C, Xichang	
9 April	Palapa (GEO) (fail)	CZ-3B, Xichang	Yuanwang 5, mid-Pacific Yuanwang 7, Montevideo
5 May	XZF	CZ-5, Wenchang	Yuanwang 7, Montevideo Yuanwang 5, east Philippines
12 May	Xingyun 2-1, 2-2	Kuaizhou 1A, Jiuquan	
29 May	XJY-G, -H	CZ-11 Sea Launch	
31 May	Gaofen 9-02	CZ-2D, Jiuquan	
10 June	Haiyang 1D	CZ-2D, Taiyuan	
17 June	Gaofen 9-03	CZ-2D, Jiuquan	
23 June	Beidou 55 (GEO)	CZ-3B, Xichang	Yuanwang 5, mid-Pacific Yuanwang 6, Pacific
3 July	Gaofen, multimode	CZ-4B, Taiyuan	
5 July	Shiyan 6-02	CZ-2D, Jiuquan	
9 July	Apstar 6D (GEO)	CZ-3B, Xichang	Yuanwang 7, south Pacific Yuanwang 5, mid-Pacific
10 July	Jilin Gaofen	Kuaizhou 11, Jiuquan	
23 July	Tianwen 1 (Mars)	CZ-5, Wenchang	Yuanwang 5, mid-Pacific Yuanwang 7, south Pacific
25 July	Ziyuan 3-03	CZ-4B, Taiyuan	Yuanwang 6

The current tracking fleet comprises Yuanwang 3, the oldest; Yuanwang 5; and two sister ships, Yuanwang 6 and 7, the most recent additions to the fleet. As noted in the earlier articles, Yuanwang 6 presents us with a particular problem. The earlier articles noted how it spent most of its life on frequent, short journeys up and down the south east coast, normally passing through the straits of Hainan, a pattern which might make sense for a routine cargo carrier but not for a space tracking ship. At the same time, Chinese media reported Yuanwang 6 sailing distant shores, which leads us to the conclusion that the beacon identifying Yuanwang 6 was supplied erroneously, corrected by Marine Traffic after the summer. This is not to suggest anything sinister, but it is a problem of incorrect beacon information being transmitted. Accordingly, this report will focus on Yuanwang 3, 5 and 7 and published non-beacon information on Yuanwang 6. Before describing their journeys, it should be cautioned that there can be long periods when no beacon report is received. Theoretically, they should be sent every 24 hr, but there can be some lengthy periods without them, leaving us having to 'join the dots' to infer their likely journeys in between.

At the start of the new year, Yuanwang 3 was in the mid-Pacific east of Roreti (2°S, 178°E) and returned to port on 18 January 2020. Yuanwang 5 was at anchor at its home base of Jiangyin, Shanghai. Yuanwang 7 was also at sea, returning from the Pacific via Guam and the southern Japanese islands, likewise back on 18 January, at which stage all three ships were in their home port. During their stays in their home port, the ships often reported movements, but these were generally a change of moorings in the extensive Yangtze anchorages around Jiangyin, Shanghai and not significant: and the terms Jiangyin and Shanghai will be used interchangeably. The only relevant launch during early January was the TJSW military communications satellite (7 January) and it seems reasonable to presume that Yuanwang 3 tracked this launch in mid-Pacific and once successful, returned to port. It is not known if Yuanwang 7 did so as well, for it issued a 'returning to port' notice on 1 January, suggesting not. The three ships stayed in port, presumably for the Chinese New Year. This is a normal pattern and China tends to avoid launches during the new year holiday. Yuanwang 3 remained there for the rest of the period, possibly for maintenance and repair, leaving the burden of tracking to 5, 6 and 7.

The next significant movement in the fleet was at the end of February. Yuanwang 5 left first (24 February), followed by Yuanwang 7 (28 February). Yuanwang 7 began a long journey to South America. There was no record of Yuanwang sailing there before and the Chinese themselves described it as a 'new, remote' route ***(1)***.

It at once identified its first destination as Durban, South Africa. Yuanwang 7 was through the Taiwan strait the next day, past Singapore on 4 March and the Maldives on 10 March, arriving in Durban on 19 March for four days, presumably for supplies. It attracted some press interest, where *The Mercury* described these ships as 'impressive' but their visits 'rare', with photographs appearing in *Africa Ports and Ships* maritime news ***(2)***. Leaving Durban on 23 March and listing 'Uruguay' as its destination, Yuanwang 7 arrived off Montevideo, Uruguay on 5 April. Its subsequent movements puzzled some commentators who wondered had the upcoming CZ-5 launch been delayed, but it would have been off Uruguay for the Palapa N launch on 9 April, which might explain the timing ***(3)***. CCTV made a

On 22 July, the day before the Tianwen 1 launch, a beacon was picked up from Yuanwang 7 in the Gulf of Guinea. There is certainty that Yuanwang 7 was in the Pacific that day. So was this beacon sent by Yuanwang 6? Credit: Marine Traffic

promotional video of Yuanwang 7 being on the first tracking ship mission ‘in the Atlantic’.

Yuanwang 7 made several short visits down the coast to Recalada, Bahia Blanca, Argentina (8, 18 April, 4, 7 May). Yuanwang 7’s movements at the time of the CZ-5 launch, 5 May were strange, departing Montevideo at 2.22 am local time that morning, and then sprinting down the coast to arrive at Recalada, at 4.26 am local time, returning to Montevideo by 3 pm. Its presence at neither location seems to have provoked local excitement or even notice. Its task must have concluded by 12 May, for that day Yuanwang 7 got under way, headed home at full speed, not even stopping at Durban on the way and was back in Shanghai on 6 June. The multiple, short visits to Recalada are difficult to explain. To speculate, China sent three ships to Argentina with medical equipment to combat the Covid 19 virus, so this could have been an early, first consignment. Another speculative explanation is that it was unloading equipment or supplies for transport to the Chinese tracking station in Patagonia.

Yuanwang 7 stayed in port in Shanghai for three weeks until 28 June when it set out for the south Pacific, likely for the Apstar 6D launch on 9 July. It was still there on 15 July (22°S, 146°E). Two days later, it was drifting Dead In Water (DIW) east of the island of Raivavae at 22°S, 142°E, likely awaiting the Tianwen mission on 23 July. A week later, its mission presumably complete, it put into the port of Suva, Fiji on 1 August for two days, before sailing through the Carolines on 9, the Philippines on 12 and returned to Shanghai on 15 August.

After its end-of-February departure, Yuanwang 5 was quickly in the Philippine Sea and in early March took up position in the area of Roreti, Tonga, Jarvis island and western Samoa for a month. This is a familiar tracking ship location, with the ship in the general range of between 162°E and 178°E longitude and between 4°S and 16°S latitude, not far south of the Equator. This seems to be perfectly located for tracking Beidou 54 on 9 March and the CZ-7 on 16 March.

Yuanwang 5 put into Suva, Fiji, on 23 March, for over a week. This year, there was none of the diplomatic fuss over such visits. It then set sail for the central Pacific. These movements coincided perfectly with the Palapa launch on 9 April, although the launch failed and the ship had departed by the 15. Yuanwang 5 was back in China for 20-25 April, quickly heading back to east of the Philippines, a well-known location for following the CZ-5 ascent to orbit (8°N, 130°E). It was on its way back from there by 8 May and back in port in Jiangyin on the 10. After just over a month at home, Yuanwang 5 was back at sea on 14 June and by 19 June had reached a mid-Pacific location of 8°N, 138°E. Beidou 55 followed a week later on 23 June, so it is reasonable to presume that this was its purpose. Yuanwang 5 was still at sea to track Apstar 6D on 9 July from 1°S, 179°E. The ship announced Suva as its destination the next day, arriving there on the 12.

Yuanwang 5 departed for the open sea on 16 July, but there are no position reports until the 31 when it was stopped at 2°S, 152°E, but it is reasonable to presume that it tracked Tianwen in the meantime. The fact that it was there a week after the launch suggests that it may have been still following Tianwen as it sped away from Earth. This must have been sufficient, for by 3 August it was north of the Equator near Palau and back in Shanghai on 8 August. On its return, China confirmed that it had indeed tracked Apstar and Tianwen during its 58-day mission ***(4)***. Thus by mid-August, Yuanwang 3, 5 and 7 were all in port.

Meantime, where was the real but non-signalling Yuanwang 6? China reported that Yuanwang 6 had sailed for the Pacific on its first mission since Chang’e 4 (December 2018) on 20 May 2020 after almost 18 months of maintenance and calibration tests ***(5)***. A month later, it was reported that it had carried out its first assignment, tracking Beidou 55, locking on to it 20 min after lift-off and holding the satellite for 600 sec. It was announced that the ship would also be on station for Tianwen and it is reasonable to presume that it stayed at sea to track it. But from where?

Yuanwang 6 must have returned home straight after Beidou 55, because it departed again from Shanghai on 13 July for, it was reported, a 100-day mission in the Pacific, Indian and Atlantic oceans ***(6)***. One intriguing beacon was picked up from Yuanwang 7 in the Gulf of Guinea on 22 July, the day before the Tianwen launch. The problem is that it could not have been Yuanwang 7, because we are certain that it was in the Pacific that day. So was this Yuanwang 6? This is an old Soviet tracking ship location, but it is not inconceivable that it might be used by China as well. By contrast, Yuanwang 6 would have had the time to get there, although there are no reports that it did so or stopped en route. China reported that the three Yuanwang, 5, 6 and 7 had all tracked Tianwen, but whilst 5 and 7 would now return home, 6 would sail to its next but undisclosed mission area ***(7)***.

Conclusions

One is left with the impression that the operational complement of the tracking fleet is three ships, with the assumption that one will be in port at any given time. For almost all this period, Yuanwang 3 was in port for maintenance and repair, leaving the other three the burden of the tracking work. As before, it is possible to follow Yuanwang 5 and 7 to locations that coincided with tracking-critical launches: the CZ-5, CZ-7 and those to geosynchronous orbit (TJSW-5; Beidou 54 and 55, Palapa, Apstar 9D). Ships generally depart from their locations quite quickly once launches have been carried out; except for Tianwen, when they lingered, presumably to follow the spacecraft on its path to Mars; and the CZ-5, for the important test of the new prototype piloted spacecraft. There is a general pattern of at least one or two tracking ships assigned to each mission, but the critical nature of the Tianwen launch is more than evident, with all three ships assigned to tracking.

By way of locations, the most commonly used is the one described here as mid-Pacific ('mid' as in equatorial), with one more southern Pacific destination. One location not at all used this time was western Australia, but the reason is not known. Perhaps the big surprise here was the journey of Yuanwang 7 to Montevideo, a new destination and its brief dash down the coast unexplained. We are left with many question marks about the real Yuanwang 6 and can speculate that a new location has been identified in the Gulf of Guinea.

Acknowledgements

My thanks to Marine Traffic for beacon data; and Jacqueline Myrrhe for information concerning the Yuanwang 7 visit to Recalada.

Yuanwang 7 seen in Durban. Credit: The Mercury

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Yuanwang 2

Yuanwang 4

Yuanwang 3

Yuanwang 7

Yuanwang 5 and 6 are depicted on page 26.


Thinking
in
visions!
E = m x rc²