All About The Chinese Space Programme

Go Taikonauts!

龙腾太空

Issue 33

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On 23 July China launched its 1st independent Mars mission Tianwen 1. The name goes back to the poet and philosopher Qu Yuan who could not find answers to his many questions about life and the cosmos. He directed his quest to the heavens above him by writing the poem "Tian Wen" - Questions to the Universe. CNSA decided to name all future missions for planetary exploration the Tianwen series. Credit: GoTaikonauts!/CNSA/NASA

Content

Chinese Space Quarterly Report

July - September 2020

by Jacqueline Myrrhe

SPACE TRANSPORTATION

CZ-4B

During the launch on 21 September, the CZ-4B rocket was equipped with small waffle-like grid fins, recovered from a CZ-4B launched in 2019 and overhauled for reuse. The grid-fin system started working after 1st stage separation. They supported the 1st stage's landing and transmitted flight data to ground stations, which will be helpful for subsequent system optimisation, application expansion and landing site prediction. According to the China Aerospace Science and Technology Corporation (CASC), the grid fins narrowed the range of the landing areas by more than 85 %. The grid fin re-use is an important step towards developing fully reusable launch vehicles. Grid fin control technology on a Chinese launcher was tested for the 1st time on a CZ-2C rocket on 26 July 2019.

CZ-5

For the CZ-5 Y4, launching the Tianwen 1 Mars mission, Chinese 3D printing system supplier Farsoon Technologies used a laser sintering platform and high-performance polymer powder FS3300PA to produce 50 parts (each: 370 x 100 x 125 mm) for the rocket's static firing skirt - the interstage ring. The skirt provides a temporary structural medium between the stage and the aft support ring to protect the unlocking device.
Hunan-based Farsoon Technologies is supplier of industrial plastic laser sintering and metal laser sintering systems. The company manages China's 1st national 3D printing lab and has with Farsoon Americas a North America establishment.

3D printed static firing skirt parts for the CZ-5 rocket. Credit: Farsoon Technologies

SEA LAUNCH

CASC is developing the spaceport in Haiyang City, Shandong Province. On 26 August, Wang Xiaojun, Head of China Academy of Launch Vehicle Technology (CALT) went to Haiyang to inspect the Sea Launch Port under construction. He was accompanied by leaders from the Shandong Provincial Department of Industry and Information Technology and representatives of Yantai City and Haiyang City. The delegation was satisfied with the progress made. The space port is the core of a wider cluster of aerospace and high-end manufacturing industries.

SAST's new commercial launcher

At the 22nd China International Industry Fair (CIIF) in Shanghai, the Shanghai Academy of Spaceflight Technology (SAST) exhibited a new medium-sized carrier rocket. The liquid-fuelled rocket is 59 m long, has a take-off thrust of about 500 t and a take-off weight of approx. 430 t. It will use the more environmentally friendly kerosene-LOX propellants. The fairing has an adaptable diameter of 3.35 m to 5 m. By varying the number of boosters, the rocket can reach different orbits and accommodate flexible payloads requirements. It can be launched from inland and coastal launch sites.

SAST's new launcher exhibited at the 22nd China International Industry Fair (CIIF) in Shanghai. Credit: SAST

The launcher inherits mature technology and adopts modular and serialised design. Also, a smart flight condition diagnosis and online trajectory planning system is incorporated. Design optimisation led to structural weight reduction and improved efficiency for simple testing and launching. The 1st flight is planned for the time period 2021-2025. It will compete in the commercial launch market for domestic and foreign commercial payloads.

YUANWANG 3

In early July, the 2nd generation space tracking vessel Yuanwang 3 (YW-3) set sail from its Shanghai-based shipyard after completing maintenance on the shafts and propellers which has improved the reliability of the ship's power system.

YUANWANG 5

On 9 August, Yuanwang 5 (YW-5) returned after 58 days in the Pacific Ocean to its home port in Jiangsu Province. It had supported the launch of Tianwen 1 and APStar-6D. After arrival at the port, crew members took a rest, examined facilities, and replenished supplies for the next sailing, which would include tracking the launch of the Chang'e 5 lunar mission.
On 24 September, YW-5 departed again from Jiangsu for a mission in the Pacific Ocean. It was the 3rd voyage of the ship in 2020. It will spend more than 100 days at sea and is scheduled to return in early 2021.

YUANWANG 6

The Yuanwang 6 (YW-6) docked at its home port of the China Satellite Maritime Observation and Control Department in Jiangsu Province on 3 July after completing the 55th Beidou navigation satellite maritime measurement and control mission. During the short 9-day stay in port, the crew took a rest and reorganised and maintained their equipment. The crew replenished the supplies, conducted drills, devised action plans, inspected facilities and got familiar with the new tasks ahead of the new voyage. Nearly 70 % of the crew worked on the ship for over 160 consecutive days to ensure the operations during the Corona pandemic.
On 13 July, YW-6 departed again from its home port in Jiangsu Province. The ship sailed to designated waters in the Pacific, Indian and Atlantic Oceans, went along new routes, and anchored in new locations. This was the 1st time for a Yuanwang ship to perform missions in the 3 oceans during a single voyage. During the 100 days of maritime operations, YW-6 supported multiple space launches.

YUANWANG 5, 6, 7 – Tianwen 1 launch

3 Yuanwang ships provided maritime monitoring support for the launch of the Tianwen 1 Mars mission on 23 July. They were all positioned in the Pacific Ocean when the CZ-5 rocket took off from Wenchang cosmodrome at 04:41 UTC (12:41 BJT)

About 6 min after lift-off, YW-6 detected and locked in on its target. The other two vessels, YW-5 and YW-7, took turns in the next 30 min of tracking operations, until Mars transfer trajectory insertion was accomplished 36 min after launch.

As scheduled, YW-5 and YW-7 returned to port, while YW-6 sailed to its next satellite tracking position. After the early phase, ground stations of China's deep-space monitoring network took over tracking TW-1. Operated by the Xi'an Satellite Control Centre, the network consists of 3 monitoring stations, the Kashgar antenna in Xinjiang Uygur Autonomous Region, the Jiamusi receiver in Heilongjiang Province as well as the station in Argentina. The Argentina station, operational since 2017 only, was the 1st of them to track the probe on 23 July at 13:21 BJT. Jiamusi and Kashgar received the signal at 21:37 BJT on 23 July and 1:00 BJT on 24 July, respectively.

YUANWANG 5 and 7

On 11 July the crews on the YW-5 and YW-7 space tracking ships celebrated China Sailor's Day. They organised a "nautical show" and "skill competition". On board of YW-5, which had just completed the APStar-6D tracking mission, a flag-raising ceremony was held. On YW-7, sailing, navigation and marine knowledge was tested. The crew had a refresher course in the use of the traditional nautical instruments compass and sextant. Also, demonstrations in rope knotting, sign flag raising, and smoke signals were given.

YUANWANG 21 and 22

Mid-September, YW-21 and YW-22 were loading CZ-5 components at Tianjin port and left for Qinglan Port, Hainan Island. At Qinglan, the rocket parts were transferred to special trucks and driven by road to Wenchang launch site.


left: Sailor Day knot competition. middle: Sailor Day lecture competition. right: Sailor Day anchor display. Credit: PLA Daily News/An Puzhong

For a detailed reporting on the movements of the Yuangwang vessels, please, read our report on pages 27-33.

Wenchang Space Launch Centre

The launch site on the Hainan Island in China's south offers favourable conditions for space launches. Its low latitude of 19°36′ N allows for an increase of payload capacity compared with more northern locations. Also, the island situation allows for sea transport of big rocket parts and supports a wide shooting range into GEO and polar orbit, not affected by trajectories over inhabited areas. Wenchang has facilities for the launch of the CZ-5 and CZ-7.

In general, after the rocket parts arrive at Qinglan Port in Wenchang, they get transported with special trucks by road to the launch site. There, the parts get mounted in the final assembly facility. The completed rocket is rolled-out to the launch pad via rails in a 2-hour long procedure. The launch tower also serves as the workshop for all final testing and preparation until 6 hours before launch when the tower segments are opened and retracted.

For the actual launch, the rocket engines, powered by liquid fuel, are pyrotechnically ignited what triggers the start of turbo pump operation. The ignition powder used in the CZ-5 and CZ-7 rocket engines is triethyl borate which produces a green flash upon combustion. That flash is followed by enormous white smoke produced by evaporating water from the cooling and noise reduction system. This high-performance system starts spraying water out of two 600 t water tanks on either side of the rocket once the launcher is 5 m above ground. 20 sec after lift-off the rocket starts turning and rotating (rolling), by swinging the engine nozzles for adjusting its flight direction to reach the predetermined orbit.

Since the inauguration of the Wenchang launch site in 2016 up to August 2020, 7 launches were conducted: 4 for the CZ-5 series and 3 for the CZ-7 series.

Hainan Island, with its unique subtropical environment offers generous possibilities for tourism. In principle, anybody can come to view the launch from the public beaches or the roof top of hotels or houses.

Wenchang's 2 launch towers: left for CZ-5 and right for the CZ-7. Credit: Chen Xiao

Green ignition flash of the CZ-5. Credit: Shi Yue

LUNAR and DEEP-SPACE Exploration

CHANG'E 3 (CE-3)

As of 1 September, the Chang'e 3 (CE-3) lunar mission has been on the Moon for 2,453 Earth days. One of the few still operational scientific payloads is the Lunar UV-Telescope, managed by the National Astronomical Observatories in Beijing. The automatic instrument is monitoring variable stars and even returned an image of the Pinwheel Galaxy (M101) from the Moon.

Radio amateurs periodically pick up signals from the CE-3 lander and have confirmed CE-3's activity.

The solar-powered lander operates during the lunar day and communicates via X- and S-band with ground stations in Kashi and Jiamusi. The lander is warmed during the lunar nights by a radioisotope heater unit.

After in-depth analysis of the Channel 1 data from the lunar penetrating radar (LPR) on the Yutu 1 rover, researchers from China University of Geosciences, Yangtze University, and Ningbo University of Finance and Economics found multi-layered young lava flows at CE-3's landing site in the northeast of Mare Imbrium (Sea of Rains). They determined 3 layers of thin, young mare basalts underlying the lunar soil.

In previous studies, the region was thought to be covered by one thick layer of dark basalt lava flows from volcanic eruptions which filled the basin after bombardments of asteroids 3.9 billion years ago. The eruptions produced successive layers of vertically deposited basalt. The researchers calculated the spatial variation and distribution of thickness of each layer and built a 3D stratigraphic model. According to the researchers, the young lava flows in the northern Mare Imbrium probably erupted from the same source as that in the southwest.

The findings have been published in the journal *Geophysical Research Letters*.

Yuan, Yuefeng; Wang, Fenghua; Zhu, Peimin; Xiao, Long; Zhao, Na, (2020), New Constraints on the Young Lava Flow Profile in the Northern Mare Imbrium, *Geophysical Research Letters*, 47, DOI: 10.1029/2020GL088938.

CHANG'E 4 (CE-4)

20th lunar day

The CE-4 mission has resumed work on the far side of the Moon. The lander woke up on 15 July at 05:48 BJT and the Yutu 2 (YT-2) rover on 14 July at 12:53 BJT.

Both were in normal conditions and all science instruments were working well. On the 20th lunar day, the neutron radiation detector and low-frequency radio spectrometer on the lander were switched on. The near-infrared spectrometer, panoramic camera, neutral atom detector and lunar radar on the rover continued to carry out planned scientific exploration.

Based on the lunar surface image data obtained earlier, the project scientists planned a route for YT-2, leading to the northwest of the lander toward the basalt area of an impact crater with high-reflective surface material. The rover travelled 27.64 m during the 20th lunar day accumulating a total of 490.9 m.

20th lunar night

For the 20th lunar night, the lander switched to stand-by on 27 July at 10:20 BJT. YT-2 entered the dormant state already earlier during the night, at 00:34 BJT.

4th batch of data

On 9 July 2020, CLEP's (China Lunar Exploration Programme) Data Release and Information Service System released the 4th batch of scientific data from CE-4 lander and rover. The data were operational data, including the scientific data acquired by the 4 scientific payloads on the lander and YT-2 during the 7th lunar day. In total 632 data files, with a total data amount of 2.95 GB were published.

Specific data include:

lander payload

Low frequency radio spectrum analyser: 2C level scientific data

rover payloads

Panoramic camera: 2B scientific data

Lunar radar: 2B level scientific data

Infrared imaging spectrometer: 2B scientific data

21st lunar day

The lander and rover have resumed work for the 21st lunar day. The lander woke up on 13 August at 14:54 BJT while the rover awoke on 12 August at 20:34 BJT. Both were in normal condition. The rover continued to move northwest. The panoramic camera, the near-infrared spectrometer, the neutral atom detector and lunar radar of the rover continued to collect scientific data.

5th batch of data

On 10 August, the 5th batch of science data was released. Data from the lander's low frequency spectrometer, the rover's panoramic camera, the rover's lunar penetrating radar as well as its visible and near-infrared imaging spectrometer were released on the website of CLEP's Data Release and Information Service System.

21st lunar night

On 25 August, CE-4 and YT-2 completed data collection for the 21st lunar day and switched to dormant mode. Until then, YT-2 had travelled 519.29 m.

As of 26 August, CE-4 has survived 600 Earth days on the far side of the Moon. The relay satellite Queqiao was also in good conditions, operating nominally.

Science Results

Scientists carried out extensive research based on the data transferred by the scientific payloads.

Through data from the visible/near-infrared imaging spectrometer, panoramic camera and lunar radar on the YT-2 rover, they analysed the spectrum, rock distribution, and shallow structure of the landing zone, and drew scientific conclusions on the morphology, material mineral composition, source and characteristics of the landing area.

For the 1st time, the composition of deep lunar material was obtained directly through in-situ exploration with the Lunar Penetrating Radar (LPR), revealing the complex geological evolution of the far side of the Moon, especially of the South Pole-Aitken Basin. It provides key evidence of the formation and evolution model of lunar soil, and also important reference for site selecting for future lunar missions' landing, inspection and exploration.

The Advanced Small Analyzer for Neutrals (ASAN) on the rover measured the energetic neutral atoms on the lunar surface, providing a reference for the estimation of the lunar surface radiation hazards and the design of radiation protection for future lunar astronauts.

The Low-frequency Radio Spectrometer on the CE-4 lander has acquired information about electromagnetic information below 40 MHz at the landing site which is of significance to the research of solar radio bursts at low frequency and the radio-quiet environment of the lunar far side.

6th batch of data

On 3 September, the National Space Science Data Centre released the 6th batch of CE-4 science exploration data acquired by the lunar lander and rover payloads during the 9th lunar day. In total 169 data files with a data volume of 2.64 GB were published. The data is provided by the Lunar and Deep-Space Exploration Research Department of the National Astronomical Observatory of the Chinese Academy of Sciences. It can be used for research

Data Standards

The Lunar and Deep-Space Exploration Research Department of the National Astronomical Observatory standardises the acquired data according to the data characteristics of each payload, and generates data products according to the respective class and PDS standard. 2A level data means they are calibrated. Level 2B data are 2A data with geometric information added. Level 2C data is level 2B data which was processed according to the specific requirements of the respective payload.

on the morphology, composition, geological structure and low-frequency radio environment of the far side of the Moon.

Lunar lander payload data

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

Rover payload data

1. Panoramic camera: 2B level scientific data
2. Lunar radar: 2B level scientific data
3. infrared imaging spectrometer: 2B level scientific data

With this release the first 6 batches of CE-4 science data have been publicly published. Users can access relevant data resources through the Space Science Virtual Observatory of the National Space Science Data Centre: *vsso.nssdc.ac.cn*

22nd lunar day

The CE-4 lunar lander and YT-2 rover have resumed work for the 22nd lunar day. The lander woke up on 12 September at 5:15 BJT and the rover on 11 September at 11:54 BJT.

YT-2 moved northwest toward the basalt area of an impact crater with high reflectivity about 1.3 km northwest of the landing site. Scientific instruments such as a panoramic camera, infrared imaging spectrometer, neutral atom detector, as well as lunar radar on the rover will carry out scientific detection. Until the end of the 22nd lunar day, YT-2 has travelled 547.17 m.

Radiation Measurement Results

The German Lunar Lander Neutron and Dosimetry (LND) instrument for measuring space radiation on board the CE-4 lunar lander has for the 1st time recorded temporally resolved cosmic radiation. Earlier devices could only measure the entire, cumulative mission dose.

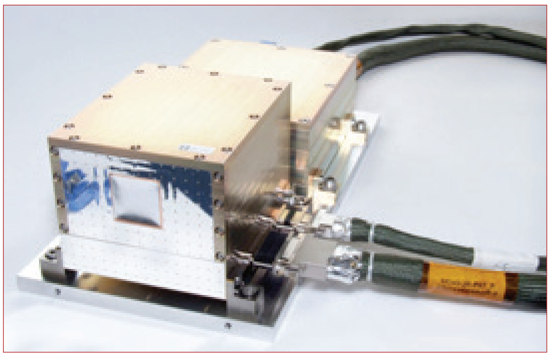
The data show that there are several sources of radiation exposure: galactic cosmic rays, sporadic solar particle events (for example from solar flares), and neutrons and gamma rays from interactions between space radiation and the lunar soil.

With the LND instrument it is possible to measure the various characteristics of the radiation field over time intervals of 1, 10 or 60 min. This enables researchers to calculate the equivalent dose, which is important for estimating biological effects.

Radiation is measured using the unit Sievert, which expresses the amount of radiation absorbed by human tissue.

The team found that the radiation exposure on the Moon is 1,369 μSieverts per day - about 2.6 times higher than the daily dose of an ISS crew member.

Considering the same time period, lunar explorer would get 200 to 1,000 times more radiation on the Moon than what we experience on Earth, or: 5 to 10 times more than passengers on a trans-Atlantic airline flight, according to the LND team lead Robert Wimmer-Schweingruber of Christian-Albrechts University in Kiel, Germany.



The LND in the laboratory in Kiel before the launch. Credit: Stefan Kolbe, Uni Kiel

That means humans should not stay longer than 2 months on the surface of the Moon without special protection measures, like habitats with an 80 cm thick shielding layer made from lunar soil. The study provided a reference for the estimation of the lunar surface radiation hazards and the design of radiation protection for future lunar astronauts.

The LND was developed and built by the Christian-Albrecht University of Kiel on behalf of the DLR Space Administration with funding from the German Federal Ministry of Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie; BMWi). The research conducted by the DLR Institute of Aerospace Medicine is supported by the Moon and Mars Exploration Studies (MoSES) project, which is part of DLR's Space Exploration Programme.

Shenyi Zhang, Robert F. Wimmer-Schweingruber, Jia Yu, Chi Wang, Qiang Fu, Yongliao Zou, Yueqiang Sun, Chunqin Wang, Donghui Hou, Stephan I. Böttcher, Sönke Burmeister, Lars Seimetz, Björn Schuster, Violetta Knierim, Guohong Shen, Bin Yuan, Henning Lohf, Jingnan Guo, Zigong Xu, Johan L. Freiherr von Forstner, Shrinivasrao R. Kulkarni, Haitao Xu, Changbin Xue, Jun Li, Zhe Zhang, He Zhang, Thomas Berger, Daniel Matthiä, Christine E. Hellweg, Xufeng Hou, Jinbin Cao, Zhen Chang, Binquan Zhang, Yuesong Chen, Hao Geng, Zida Quan, (2020), First measurements of the radiation dose on the lunar surface, *Science Advances*, eaaz1334

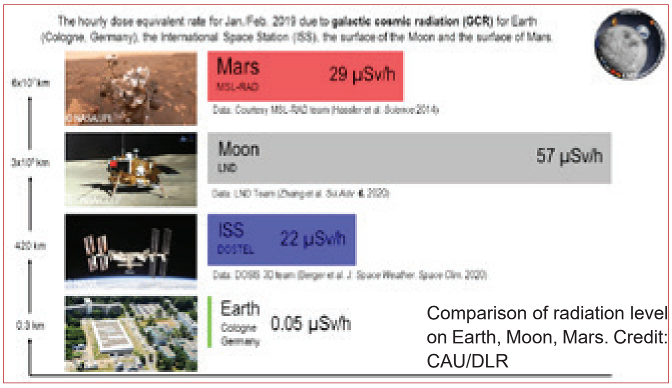
22nd lunar night

The CE-4 lunar lander and the YT-2 rover have been switched to dormant mode for the 22nd lunar night after working smoothly during the 22nd lunar day. The lander went into dormant mode as scheduled on 23 September at 7:30 BJT, and the YT-2 rover on 22 September at 23:18 BJT.

Another study which confirmed earlier findings about the thickness of the regolith, the subsurface structures and evolutionary history of the probe's landing site was published in September in *Nature Astronomy*.

The study revealed that the landing area of the probe had experienced multiple impact events and basalt magma eruptions. It could be shown that the materials detected by YT-2 come from the nearby Finsen impact crater rather than the basalt erupted from the lunar mantle, which filled the bottom of the Von Kármán Crater. The modification of lunar surface materials by asteroid impacts has a direct influence on the results obtained from orbital observations and landing site reconnaissance, and affects how scientists will implement the lunar sample return missions in the future.

Jinhai Zhang, Bin Zhou, Yangting Lin, Meng-Hua Zhu, Hanjie Song, Zehua Dong, Yunze Gao, Kaichang Di, Wei Yang, Hongyu Lin, Jianfeng Yang, Enhai Liu, Lei Wang, Yi Lin, Chao Li, Zongyu Yue, Zhenxing Yao, Ziyuan Ouyang, (2021), Lunar regolith and substructure at Chang'E-4 landing site in South Pole-Aitken basin, *Nature Astronomy*, Vol. 5, pp. 25-30



Comparison of radiation level on Earth, Moon, Mars. Credit: CAU/DLR

CHANG'E-5 (CE-5)

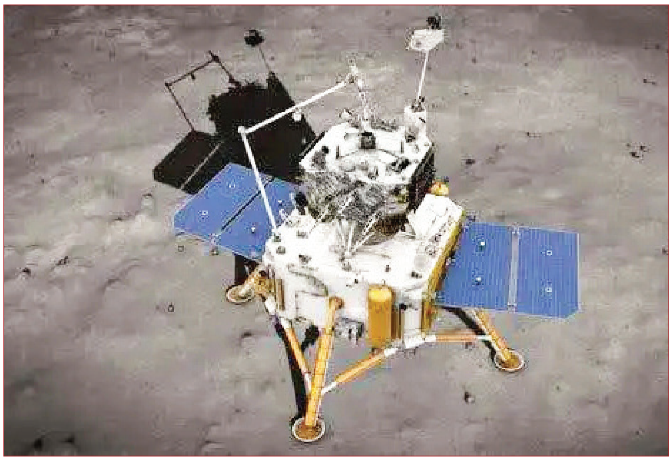
Mapping the landing site

A research team from the Aerospace Information Research Institute (AIR) of the Chinese Academy of Sciences has made a precise lunar crater map of the planned CE-5 landing area near Mons Rümker in Oceanus Procellarum, as well as a surface age analysis of the craters. The study was published in *Earth and Planetary Science Letters*.

The scientists used 765 photos of NASA's Lunar Reconnaissance

Orbiter's Narrow Angle Camera to generate a digital orthophoto map (DOM) of the CE-5 landing area with 1.5 m resolution. All 32,277 craters larger than 200 m in diameter were catalogued.

Mengna Jia, Zongyu Yue, Kaichang Di, Bin Liu, Jianzhong Liu, Gregory Michael, (2020), A catalogue of impact craters larger than 200 m and surface age analysis in the Chang'e-5 landing area, *Earth and Planetary Science Letters*, Volume 541, 116272, https://doi.org/10.1016/j.epsl.2020.116272.



Chang'e 5 artist's impression. Credit: CNSA

Launch

Yu Dengyun, Deputy Chief Designer of China's Lunar Exploration Programme, reconfirmed on 20 September during the 2020 China Space Conference in Fuzhou, Fujian Province that Chang'e 5 will be launched by a CZ-5 heavy-lift carrier rocket from the Wenchang Space Launch Centre in Hainan province by the end of 2020. The mission has to be completed within one lunar day (around 14 Earth days) since the spacecraft has no heating elements for surviving the lunar night. Sunrise in the targeted landing region of Mons Rümker is by the end of November.

CHANG’E 7 (CE-7)

China National Space Administration (CNSA) in cooperation with the Ministry of Education, the Ministry of Science and Technology, the Chinese Academy of Sciences and 3 other organisations is soliciting ideas for educational payloads aboard its CE-7 mission and an asteroid and comet exploration mission. CNSA is asking primary, middle school and university students in China to provide ideas for payloads that could fly aboard the CE-7 probe to the Moon's South Pole, and on another spacecraft to the asteroid 2016HO3 and the comet 133P.

Winners will be awarded with prize money and invited to witness on-site spacecraft launches. The deadline for applications is 31 October.

LUNAR SCIENCE BASE

China plans to establish a scientific station on the Moon and has started preparatory research, said Wu Weiren, Chief Designer of China's lunar exploration programme and an academician of the Chinese Academy of Engineering. He is now working on the planning and feasibility research on the proposed station and the lunar programme's 4th step. The scientist made the remarks at a ceremony on 08 September at CNSA in Beijing when the naming of an asteroid after him was announced.

Asteroid 281880 named after Wu Weiren

The Asteroid 281880 was discovered in August 2007 by researchers at the Xuyi Station in Jiangsu province's Xuyi county, which belongs to the Chinese Academy of Sciences' Purple Mountain Observatory in Nanjing. In June the International Astronomical Union approved to name the asteroid after Wu Weiren to honour his significant contributions to China's lunar and deep-space exploration programmes.

MARS

TIANWEN 1 (TW-1)

- Deep-Space Network

In preparation of the TW-1 Mars mission, China's 2 deep-space antenna were upgraded. The Kashgar station in Xinjiang Uygur Autonomous Region was complemented with a deep-space antenna array system, consisting of four 35-m diameter receivers. It is China's 1st deep-space array and will go into operation by the end 2020. The Jiamusi station in Heilongjiang Province hosts a 66-m diameter antenna which was recently upgraded. The Xi'an Satellite Control Centre - in charge of the antennas – conducted successful tests of the ground stations. Since October 2017, the Neuquén receiver in Argentina's Patagonia region is complementing China's deep-space network.

On 17 July, the CZ-5 Y4 rocket arrived at its launch pad at Wenchang Space Launch Centre in preparation for the launch of the Tianwen 1 Mars probe. Credit: Shi Yue/Chinadaily.com.cn

- Rocket roll-out

The TW-1 probe arrived on Hainan Island already in April by airplane. It was undergoing pre-launch preparations at the Wenchang cosmodrome. The CZ-5 Y4 rocket arrived at Wenchang in late May. Until July assembly and pre-launch tests were completed.

In a 2-hour process, the CZ-5 launcher was moved from the assembly and testing hall to the launch pad at the Wenchang Space Launch Centre at 08:00 BJT in the morning of 17 July. Over the next 6 days until launch, engineers conducted functional checks and final inspections and started fuelling the rocket ahead of launch. The exact launch date and time was depending on technical readiness and local weather conditions on Hainan Island. Rain has to be avoided as well as wind speed on ground above 8 m/s and at a height of 3-18 km above 70 m/s. The horizontal visibility needs to be better than 20 km. From 8 h before launch until 1 h after launch, there should be no thunder or lightning activity within 30 to 40 km from the launch site.

- Data Relay

Around 20 July, the modification of the data relay system consisting of the two GEO relay satellites Tianlian 1-02 and Tianlian 2-01 to prepare them for new tasks for the TW-1 mission was completed. They mainly provide global tracking and data-relay support for the country's in-orbit spacecraft.

- Launch

The TW-1 Mars mission launched on 23 July 2020 on board a CZ-5 rocket from the Wenchang Satellite Launch Centre on Hainan Island at 12:41 BJT (04:41 UTC). The launch put the CZ-5 back into operational status.

TW-1 is China’s 1st step in its planetary exploration of the solar system. TW-1 has an overall mass of 5 t. 36 min after launch, the probe entered Earth-Mars transfer trajectory. For more details on the launch, see: LAUNCHES section.

- Maritime Space Tracking

3 space tracking ships of China's Yuanwang (YW) fleet were positioned in the Pacific Ocean and provided maritime

monitoring and tracking support for the launch and early operation phase on 23 July. For more details see under section TRANSPORTATION.

- Mars Terrain Features in Mandarin

The Chinese Astronomical Society (CAS) invited experts to translate the Mars terrain terms issued by the International Astronomical Union (IAU) into Mandarin. The translations were reviewed and approved by a special committee for astronomical terms affiliated to CAS and the China National Committee for Terms in Sciences and Technologies.

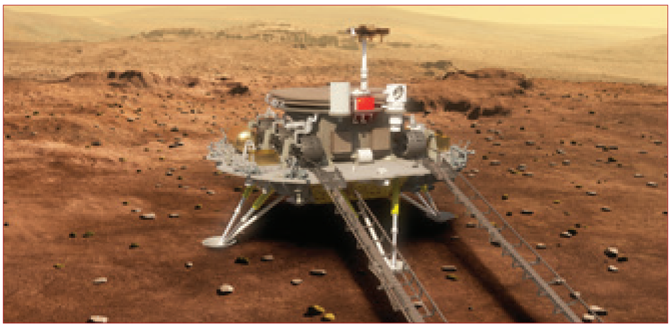
Following the successful launch of TW-1, CAS released the recommended Chinese names of 811 Mars terrain features and 1,136 Mars craters on its website. Users can find there a Glossary of Astronomical Terms operated by the National Astronomical Data Centre.

The landing area of Tianwen 1 - Utopia Planitia - would read in Mandarin: 乌托邦平原

link to CAS website with Glossary of Astronomical Terms

- Naming Competition

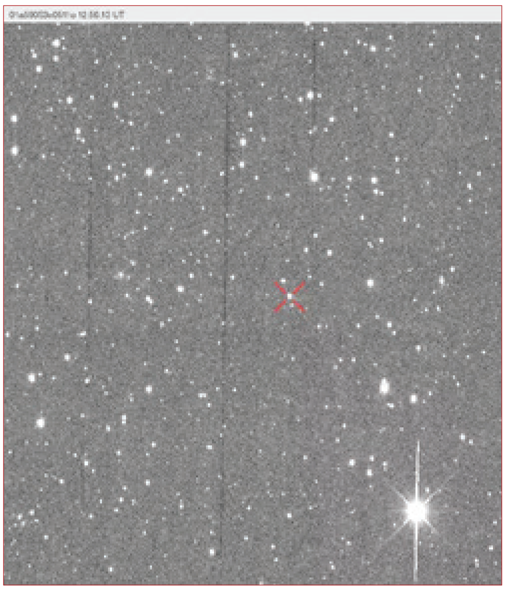
Chinese space authorities invited on 24 July the general public to take part in a global naming campaign for China's 1st Mars rover. The opening event of the campaign was hosted by CNSA's Lunar Exploration and Space Programme Centre in cooperation with the TW-1 project contractors including the China Academy of Space Technology (CAST) and CALT. China's search engine Baidu implemented the naming activity on its Baidu App. The rover naming event was open until 12 August.



China's 1st Mars rover is unveiled on 22 July in Wenchang, Hainan province, shown in footage from China Central Television. Credit: China Daily

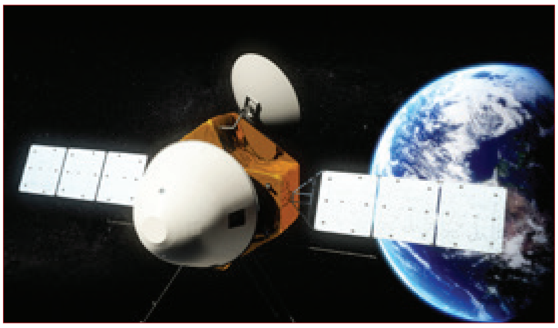
- NASA Camera Spots TW-1 Speeding Away

NASA Asteroid Watch tweeted on 24 July: "During routine survey operations for hazardous asteroids for NASA's Planetary Defense Coordination Office, the fallingstarIfA ATLAS-MLO telescope spotted China's Tianwen-1 on its way to Mars. Bon Voyage Tianwen-1!" The observation was done at the Asteroid Terrestrial-impact Last Alert System (ATLAS) facility at Mauna Loa on Hawaii Island.

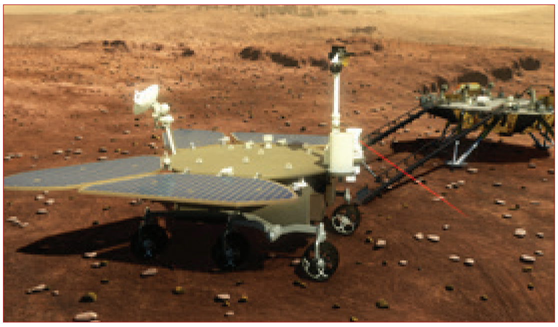


The image is showing China's Tianwen-1 Mars spacecraft as seen by the Hawaii-based ATLAS asteroid survey. Credit: NASA

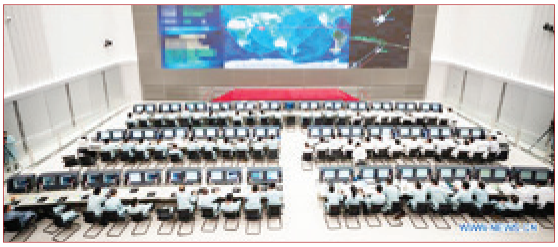
Tianwen 1 is launched on a Long March-5 rocket from the Wenchang Space Launch Centre in south China's Hainan Province, on 23 July 2020. Credit: Xinhua



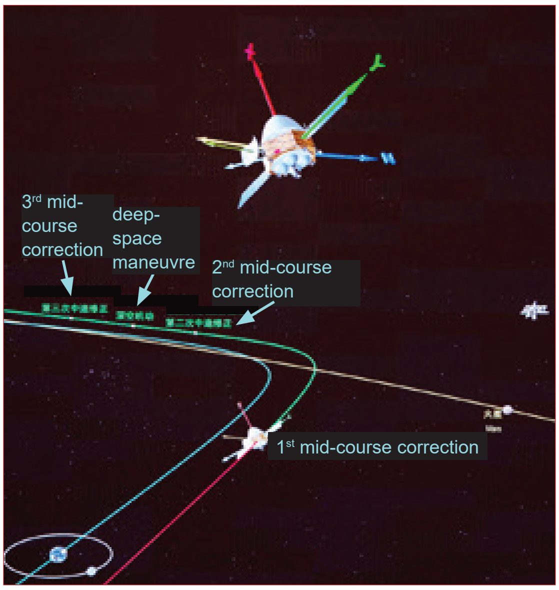
Concept of the TW-1 Mars probe. Credit: CLEP/ Xinhua



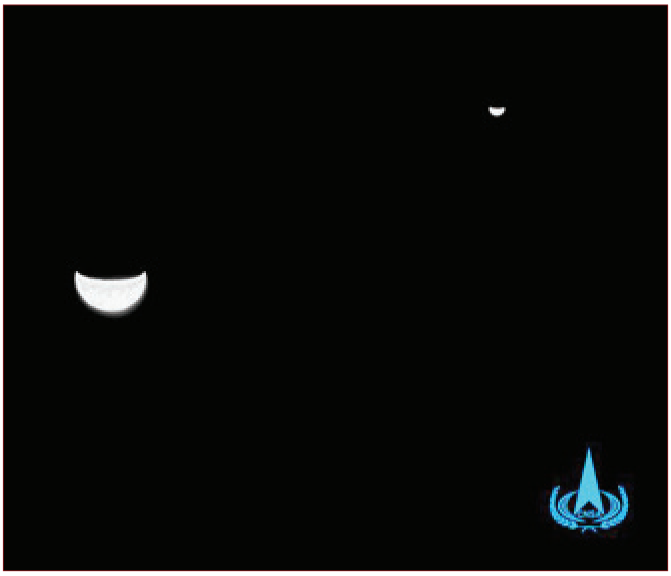
The artist's impression illustrates the rover's spectrometer with LIBS laser for remotely detecting the rock composition. Credit: CLEP/ Xinhua



View into the BACC during TW-1's mid-course manoeuvre on 2 August. Credit: Xinhua/ Cai Yang



The annotated graphic was shown on the screen at the Beijing BACC on 2 August 2020. It indicates TW-1's main manoeuvres. Credit: Xinhua/Cai Yang



The image captured by TW-1 on 27 July 2020 shows the Earth and the Moon. It was taken at a distance of 1.2 million km from Earth. Credit: CNSA/Handout via Xinhua)

- 26 September - Commemoration Stamps

On 26 September, a ceremony was held at the Wenchang Space Science Centre, on Hainan Island to commemorate the successful launch of TW-1 with issuing a set of stamps. In total, 7.8 million sets went into sale, each with a face value of 1.2 RMB (0.18 USD). The main image of the stamp shows the symbolised journey of TW-1 against the backdrop of Earth, Mars and the galaxy, suggesting that this Mars journey is just the 1st step in China's planetary exploration.

A philatelist is holding the TW-1 commemorative stamp at the release ceremony on 26.09.2020, in Wenchang. Photo: VCP

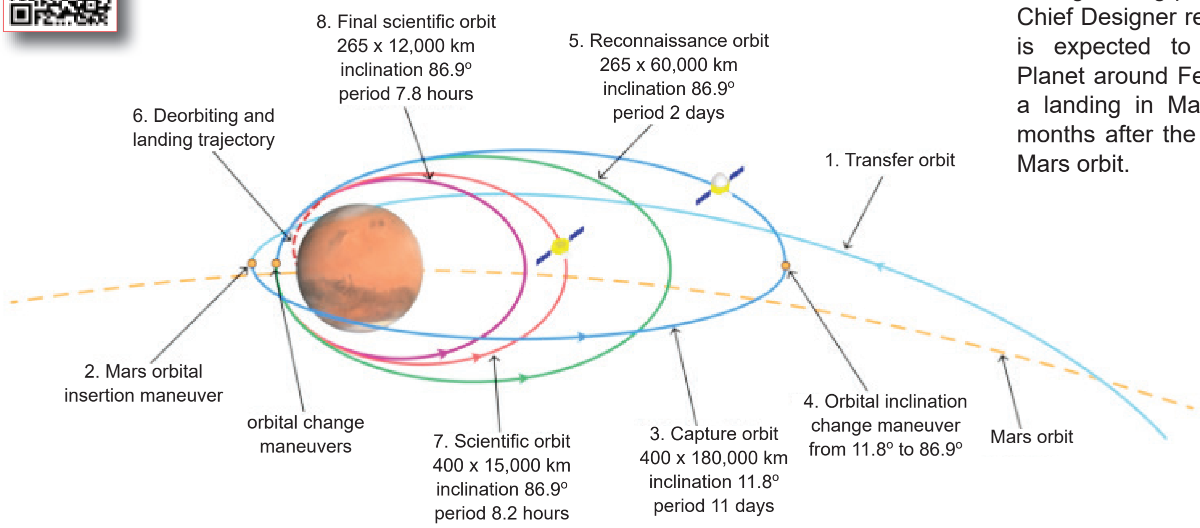
The stamps were printed using fluorescent ink, which gives the orbit a luminous effect under UV-light.

An exhibition and sales area were also set-up, including the 1st space philatelic exhibition in Hainan.

Manoeuvre/ activity	Date/time	Distance to Earth/ flown distance	activity
1st of the 13 scientific instruments starts operation	24 July 2020		The Mars Energetic Particle Analyzer on the orbiter was activated. It measures the spatial radiation environment of Mars and along the Earth-Mars transfer trajectory.
1st photo	27 July 2020	1.2 million km	Tianwen 1 sent a black-and-white photo, taken by its optical navigation sensor showing the Earth and the Moon.
1st orbital correction	2 August 2020, 7:00 BJT (1 August, 23:00 GMT)	3 million km	3,000 N main engine fires for 20 sec. The operation served also as a test of the performance of the engine.
Status test for all instruments	19 August 2020, 23:20 BJT	8.23 million km	Starting from 22:20 BJT multiple payloads, including Mars Magnetometer, Mars Mineralogy Spectrometer and High-resolution Camera, have conducted self-check. All instruments and systems work nominally.
	28 August 2020, 10:08 BJT	10.75 million km/ 100 million km	36 days of flight
2nd orbital correction	20 September 2020, 23:00 BJT (15:00 GMT)	19 million km / 160 million km	BACC commands 4 of the 120-N engines to work for 20 sec. (delay in communication by that time: 20 sec.) TW-1 is traveling away from Earth at a speed of about 300,000 km per day.
			To ensure the energy supply for the probe, the solar panels are constantly adjusted.

What do you know about Mars? Check out this infographic!

On 18 September, during the 2020 China Space Conference, Zhang Rongqiao, Tianwen 1's Chief Designer reported that TW-1 is expected to reach the Red Planet around February 2021 with a landing in May 2021, about 3 months after the probe's arrival in Mars orbit.



The planned orbital trajectory at Mars for Tianwen 1. Credit: Kaynouky/ Wikimedia Commons

SCIENCE

FAST Five-hundred-meter Aperture Spherical Telescope

An international team led by the South America Centre for Astronomy under the Chinese Academy of Sciences (CAS) has detected for the 1st time the neutral hydrogen line emission from 3 extragalactic galaxies by analysing data obtained by FAST's 19-beam receiver with only 5 min of exposure. The study of extragalactic neutral hydrogen detection is one of FAST's scientific objectives. The findings were published in the journal *Astronomy and Astrophysics Letters*.

By beginning of August, 132 pulsars discovered by FAST have been confirmed.

Mars Meteorites

Chinese scientists at CAS's Institute of Geology and Geophysics (IGG) were studying Martian meteorites and discovered for the 1st time coesite, a form of silicon dioxide.

GECAM - Gravitational-wave high-energy Electromagnetic Counterpart All-sky Monitor

Scientists working on the GECAM mission are facing an approx. 1-month delay caused by the temporary closure of electronics factories during the Corona pandemic. GECAM consists of 2 smallsats, each 150 kg, orbiting the Earth on opposite sides to monitor the full sky for gamma-ray bursts associated with gravitational-wave events. GECAM was scheduled for launch by the end of 2020. GECAM data will be compared with the results from ground-based detectors in the U.S., Europe, and Japan.

SVOM - Space Variable Objects Monitor

The gamma-ray telescope SVOM project is also facing a delay. The French-Chinese project team completed the integration and environmental testing of the prototype satellite in January 2020 in Shanghai. The review of the test results was done online and not as planned during a meeting in Chengdu. The initially planned launch for end of 2021, is now projected for mid-2022. Additionally, the French experts face delays from suppliers and the restricted access to their laboratories. In a changed work process, the Chinese team started assembling the first components of the flight test model and the French team gave support remotely from France.

HXMT - Hard X-ray Modulation Telescope

Using HXMT, an international team of scientists has discovered the strongest magnetic field ever observed on the surface of a neutron star. During an outburst of object GRO J1008-57 in August 2017, the team found from HXMT data a cyclotron resonant scattering feature (CRSF), which was measured at an energy of 90 keV. They calculated that the magnetic field that corresponded to this CRSF would be as high as 1 billion Tesla, which is tens of millions of times stronger than what can be generated in any laboratory on Earth.

The work was conducted by scientists from the Institute of High Energy Physics under the Chinese Academy of Sciences and the Eberhard Karls University of Tübingen in Germany. Results were published in *The Astrophysical Journal Letters* in August.

M. Y. Ge et. al., (2020), Insight-HXMT Firm Detection of the Highest-energy Fundamental Cyclotron Resonance Scattering Feature in the Spectrum of GRO J1008-57, *The Astrophysical Journal Letters*, Vol. 899, No. 1, DOI: 10.3847/2041-8213/abac05

Key Scientific and Technological Questions

The China Association for Science and Technology announced at the closing ceremony of the 22th Annual Meeting on 14 August in Qingdao, 20 key scientific and technological questions: 10 in frontier science and 10 in engineering. The move aims at raising awareness and support for the international scientific community to jointly tackle these challenges. The following frontier scientific questions including space were included:

- gravitational waves,
- special energy fields,
- digitised transportation infrastructure and self-driving vehicles,
- virtual model of physical world.

The 10 engineering challenges include the following topics from the space sector:

- horizontal take-off and landing technology,
- protection of key infrastructures from electromagnetic disturbances,
- navigation for unmanned vehicles without satellite technologies.

SATELLITES

Fengyun Online Training

On 22 June, the China Meteorological Administration (CMA) started its international training course on the basic principles of satellite remote-sensing which was for the 1st time held online. Over 620 trainees from 87 countries and territories signed up for the course. The main topic was satellite telemetry basics with the special use case of Fengyun (FY) satellite. The course content was tailored for technical personnel in satellite meteorology. It aimed at the promotion of international cooperation of FY users and elevating the international acceptance of China's FY meteorological satellites.

This year marks the 50th anniversary of the Fengyun satellite series and the 15th anniversary of the CMA Training Centre to hold international training courses on satellite meteorology.

On 14 September, 2nd International Online Course on the Application of Fengyun Satellite Data Products in Weather Prediction and Meteorological Disaster Monitoring was kicked off. It was an extension of the 1st satellite remote sensing basic training course. The training enhanced the capacities of the trainees to apply FY meteorological satellite products. 89 trainees from 36 countries attended the course.

New Fengyun Satellites

China plans to launch Fengyun-3E (FY-3E) and Fengyun-4B (FY-4B) in 2021. FY-3E will be the 5th member of the Fengyun 3 series of satellites in polar orbit and the world's 1st meteorological satellite in dawn-dusk orbit. It will improve the accuracy and efficiency of global numerical weather prediction.

FY-4B will be the 2nd geostationary meteorological satellite of the FY-4 series and is an upgrade of the experimental satellite FY-4A, launched in December 2016.

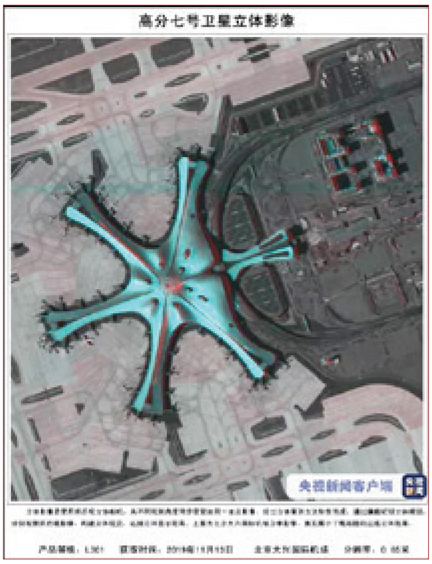
Gaofen 7

On 20 August, CNSA announced that Gaofen 7 (GF-7) has finished its in-orbit tests and started formal operation to serve its major users: the Ministry of Natural Resources, the Ministry of Housing and Urban-Rural Development and the National Bureau of Statistics. A handover ceremony was held. During the 8-month testing phase, the satellite has sent back more than 106,000 images. Equipped with 2-line scan cameras and a laser altimeter, GF-7 can provide imagery at the 1:10,000 scale and sub-metre resolution 3D mapping for users in China and countries participating in the Belt-and-Road Initiative. Its expected lifetime is 8 years. The Gaofen Programme started in May 2010 and is listed as one of the 16 national important projects in science and technology. GF satellites form a space-based, high-resolution Earth observation network. So far, 20 GF satellites have been launched, and all are in active service.

Gaofen-Duomo (GF-DM)

The Chinese Academy of Sciences (CAS) confirmed on 7 July that the 1st data was successfully received from the newly launched Gaofen high-resolution multi-mode imaging satellite (GF-DM). The ground station in Beijing's Miyun District tracked and received the downlink data on 3 July. The ground stations in Kashgar in Xinjiang Uygur Autonomous Region and Sanya in Hainan Province, as well as the China Remote Sensing Satellite

A 3D image of Mount Qomolangma taken by GF-7. Credit: CNSA/Gaofen



A stereoscopic image of Beijing Daxing International Airport produced by GF-7. Credit: CNSA/Gaofen

A multispectral image of Huludao city in Liaoning province in full colour produced by GF-7. Credit: CNSA/Gaofen

North Pole Ground Station, have also confirmed data reception. Until 6 July 1,012 GB were transmitted which are being processed.

During a ceremony, held on 29 September by CNSA in Beijing, the 1st batch of 20 images taken by the High-Resolution Multi-Mode Imaging Gaofen-DM satellite in sub-m resolution was published.

GF-DM is China's best optical Earth-observation satellite for civil use. On the images details such as high-voltage power lines between transmission towers and Chinese characters on top of buildings are distinguishable. Developed and built by CAST, the satellite carries high-resolution cameras, an atmospheric synchronisation corrector as well as an experimental device to verify the inter-satellite laser communication terminal mounted on the spacecraft.

GF-DM data is mainly used for surveys of natural resources, emergency management, agricultural and rural area administration, environmental protection, and forestry and grassland monitoring.

The batch was produced by the Chinese Centre for Resources Satellite Application under CNSA and with the support of user departments at the Ministry of Natural Resources. GF-DM is the 1st civil aerospace scientific research project, realised as a public-private partnership (PPP). The government is responsible for the development, data reception and processing of satellite images. It authorised the National Space Administration for Earth Observation and Data Centre as the implementation agency of the PPP project.

A consortium formed by China Siwei Surveying and Mapping Technology Co., Ltd., and China Great Wall Industry Group Co., Ltd., was selected as the partner for private capital. The consortium covers parts of the R&D cost and has the right to operate the satellite for 8 years. During the operation period, it provides free public service data to some users as stated in the PPP contract, and standard or advanced data products to commercial customers. The utilisation rights will go back to the government after the contract expires.

At the press conference, the National Space Administration Earth Observation and Data Centre, China 4D Surveying and Mapping Technology Co., Ltd., and China Great Wall Industry Group Co., Ltd., signed a high-resolution multi-mode satellite PPP cooperation agreement.

An image of Beijing's Bird Nest taken by the High-Resolution Multi-Mode Imaging Satellite on 16 September 2020. Credit: China Daily

Haiyang 1D (HY-1D)

On 2 September, the National Satellite Ocean Application Service of the Ministry of Natural Resources confirmed that a marine observation test of the HY-1D ocean-monitoring satellite has been completed. The test provided synchronous observation data from ground and space to check the satellite's payload performance and data quality. HY-1D was launched on 11 June. Together with the HY-1C satellite, launched in 2018, the HY-1D will form China's 1st civil-use satellite constellation to increase its global observation coverage and improve its monitoring of ocean colour, water temperature, coastal resources and the environment. Once completed, the constellation will also offer support for industries such as meteorology, agriculture and water conservation.

Haiyang 2B (HY-2B) and CFOSat

A 35-day field calibration test for the 2 ocean observation satellites HY-2B and China-France Oceanography Satellite (CFOSat) was completed in north China's Inner Mongolia Autonomous Region. The test included the calibrations of microwave scatterometers - radar instrument for measuring ocean surface winds and waves simultaneously - which are key payloads on both satellites. The test was led by the ministry's National Satellite Ocean Application Service and assisted by staff members from the China Academy of Space Technology.

Ziyuan 3-03

2 days after launch, several ground stations have received data from the mapping satellite Ziyuan 3-03 (ZY-3-03). The Miyun Ground Station in Beijing first tracked and received the downlink data on 26 July. Later the same day, the Kashgar Ground Station in the Xinjiang Uygur Autonomous Region also linked up with the satellite. As of 26 July, 120 gigabytes of data were received.

ZY-3-03 will join its predecessors ZY-3-01 and ZY-3-02 to form a constellation of mapping satellites to capture high-definition, 3D images and multispectral data. The Ministry of Natural Resources is the main user of the ZY-3 satellites. Since the launch of ZY-3-01 in January 2012, 897 terabytes of data were received. The Aerospace Information Research Institute of the Chinese Academy of Sciences is in charge of the ground stations.

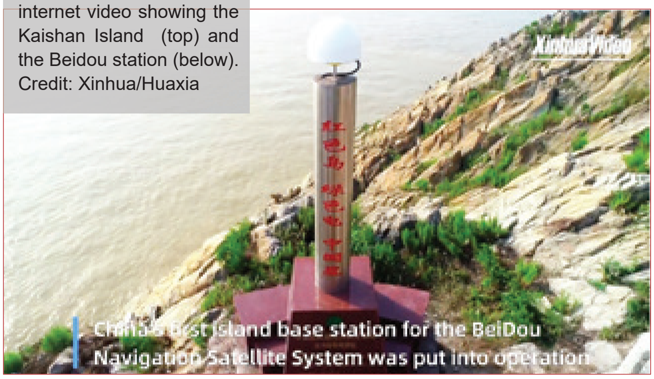
NAVIGATION

Beidou-3 G3

By one week after launch, the 55th and last satellite of the Beidou Navigation Satellite System (BDS), Beidou-3 G3, had entered its GEO position at 110.5° East. The Xi'an Satellite Control Centre, in joint operation with other national ground stations, is responsible for mission operations. All payloads were switched on, checked and were operating nominally. In a next step, the centre was testing the satellite's platform and its inter-satellite links. After a week-long examination of the results of the in-orbit tests, the satellite was connected with the BDS-3 system and started operation.

Kaishan Island base station

China's 1st island base station for the Beidou Navigation Satellite System was put into operation on the Kaishan Island in Jiangsu Province. The base station provides high-precision positioning service and transmits standard time for the island and the surrounding waters, and greatly improves the operation capacity of the island's micro-grids. Through a newly built antenna, the base station will be connected with Beidou satellites in real time. More island stations are expected to become operational.



Screen grab from Xinhua internet video showing the Kaishan Island (top) and the Beidou station (below). Credit: Xinhua/Huaxia

Urumqi base station

The 1st base station with a ground-based augmentation system was completed in Urumqi, in Xinjiang Uygur Autonomous Region. The station, built by the State Grid Xinjiang Electric Power Co Ltd., will offer high-precision positioning timing and emergency communication for the electricity industry. The construction of the base station in Xinjiang is part of a project launched by the State Grid to build 1,200 Beidou base stations for high-precision positioning, timing, and emergency communication services for the electricity industry.

The 1st base station with the Beidou Navigation Satellite System is located in Urumqi, capital of Northwest China's Xinjiang Uygur autonomous region. Credit: Song Deyi/Chinadaily.com.cn

Beidou 3 commissioned

On 31 July, Chinese President Xi Jinping, also chairman of the Central Military Commission, attended a ceremony at the Great Hall of the People in Beijing and declared the official commissioning of the Beidou Navigation Satellite System (BDS) and consequently, the formal operation readiness of the BDS-3 system for global users. The system started providing full-scale global services the same day. After the ceremony, Xi visited the exhibition of the construction and development of the BDS, and listened to explanations of project construction, operation services, application and promotion, international cooperation, and prospects for future development.

Xi encouraged the space experts to further develop BDS applications and ensure the quality of follow-up work, such as the stable operation of the system, to make new and greater contributions to China's economic and social development. Until 2035, it is planned to install a more comprehensive and integrated BDS and expand the application of the system.

President Xi Jinping announces the commissioning of the Beidou Navigation Satellite System on 31 July. Credit: Xinhua

Beidou Press Conference

On 3 August, The State Council Information Office held a press conference on the completion and commissioning of the Beidou Navigation Satellite System (BDS-3). Ran Chengqi, Director General of the China Satellite Navigation Office and the spokesperson of the Beidou Navigation Satellite System, gave

explanations and answered media questions. Ran Chengqi stressed that China's development of core technologies and its attainment of self-reliance were the top achievements in the decades-long process in building the BDS. More than 500 key components for BDS are "100 % made in China". More than 400 agencies and 300,000 research personnel and technicians have been involved in the development of more than 160 key core technologies, from inter-satellite links to high-precision atomic clocks. Within China, the system has been integrated into essential national infrastructure, including electricity, finance and communications.
Ran announced that 28 nm Beidou-enabled chips for mobile devices are in mass production and the mass manufacturing of high-precision 22 nm high-precision positioning chips is targeted for the first half of 2021. The new generation positioning chip is the core part of satellite navigation products and supports GPS, Glonass and Galileo. It is only a quarter of the size of the last generation and consumes 1/5th of the power. The chip can achieve cm-accuracy for real-time positioning in areas like surveying and mapping, unmanned aerial vehicles, autonomous driving and deformation monitoring, which will accelerate the integration of time and space information technology with 5G communication, AI and IoT. Already now, depending on constellation, ground stations and augmentation system, the BDS system can provide high-precision services with cm-level accuracy in real-time processing and mm-level accuracy in post-processing.

The software on the Beidou satellites can be upgraded in-orbit for improving capabilities and technology, as well as extend the satellite's life span. Some of the new satellites are already equipped with 70% new technologies.

The significance of the Beidou system is based on its continuous improvement and the creating of an Beidou ecosystem focussed on a wide range of applications, including supply chains of manufacturers and service providers. China continues to encourage Chinese enterprises to produce computer chips and other components for the Beidou system through the use of tax policies, provisions of loans and the protection of intellectual property rights.

International Utilisation

As the 1st BDS overseas centres, the China-Arab States BDS/GNSS Centre has contributed to the training of experts and supported the construction of regional cooperation mechanisms such as the China-Arab States Cooperation Forum.
BDS has been recognised by the International Civil Aviation Organisation (ICAO) as one of the 4 GNSS core constellations. The 1st international standard for mobile communication supporting the BDS-3's upgraded signals has been issued. The 1st BDS shipping terminal test standard has been released by the International Electrotechnical Commission (IEC).
BDS is part of the International Satellite System for Search and Rescue. Work is now underway on a standard document and accession test of BDS-3 regarding maritime search-and-rescue.
In 2013, the use of more than 500 high-precision Beidou terminals in Myanmar indicated the 1st large-scale application of Beidou high-precision products in agricultural data collection and land precision management in Southeast Asia.
In 2015, the BDS-based high-precision receiver was used in the construction of the 300 m high building of the National Bank of Kuwait headquarters, ensuring the vertical measurement error was kept within the mm-range. This was the 1st time that Beidou had been used for monitoring high-rise building construction overseas.
In 2018, the BDS system contributed to the offshore pile-driving project in Heritance Aarah, Maldives, by providing all-weather and high-precision services, intelligent monitoring, visual operations and high-precision construction.
The BDS system has also been applied in Singapore, Cambodia, Laos, Russia and many parts of Europe to facilitate high-precision operations, supporting government services, cadastral survey and land management, ensure the safety of transmission and distribution lines and the stability of power systems, and track trains in real time to facilitate logistics development.
In addition, Indonesia, Malaysia and Thailand are among others actively utilising the BDS system to explore the development of smart cities. So far, the basic Beidou products have been exported to more than 120 countries and regions and have been successfully applied in ASEAN, South Asia, Eastern Europe, West Asia, and Africa.

BDS Innovation Base

On 27 August, the city of Beijing launched an innovation base for the Beidou satellite navigation sector, aimed at accelerating the development of high-tech industries, and improving the Beidou industrial ecology in the capital, among them Beijing's Beidou navigation and location service industry and the formation of a Beidou satellite navigation industrial park. The innovation base is a hub for companies and institutions linked to the Beidou industrial chain to provide integrated services, such as product development, industry incubation, international cooperation, industry exchange, and application experience. Beijing has the most complete Beidou industrial chain of the country, with about 116 major enterprises, and an industrial scale of over 50 billion RMB (about 7.2 billion USD) in 2019.

Beidou Application – Wild animal tracking

e-commerce provider Alibaba and satellite manufacturer Commsat joined forces to track wild Asian elephants living in Yunnan Province. Commsat designed a collar for wild elephants with Beidou-enabled services such as high-accuracy navigation and positioning, short message transmission and narrowband-IoT. The device will locate and report the exact position once the animal moves out of its habitat, providing early warning to authorities. The frequency of reporting will intensify once the elephant enters areas with human population. The data will also facilitate research about wild elephants' living habits. A joint team sent by Commsat and Alibaba will go to Yunnan in October to start a trial run of the technology. Human-elephant conflicts are common in Yunnan caused by shrinking habitats caused by deforestation.

Beidou User Stories
Beidou provides users with a wide range of application services. Read the numerous and different successful stories, told by Beidou users.

Beidou for Meteorology

China Meteorological Observation Centre of CMA pointed out that BDS has been utilised for meteorology from an early stage. The dynamic accuracy of Beidou's sounding system over China's territory has reached 0.4°C for temperature, 5% for humidity and 0.3 m/s for wind measurement, which is close to cutting-edge sounding systems. The further optimised version of the BDS-3 can further improve the measurements.
In Beidou-enabled water vapour sounding, CMA has completed the construction of 35 framework network baseline stations and meteorological sector data processing centre and obtained high accuracy and high spatial and temporal resolution of the troposphere and ionosphere in quasi real-time. All software and hardware of the system were indigenously developed in China.

Beidou Applications for fishery

Qinhuangdao Port, a leading coal port in north China, has successfully switched all its public navigation aids to BDS on 31 July. Also, Beidou position indicators are installed on every boat of China's fishery fleet, allowing authorities to locate the exact position of the boats in real-time and give prompt notification for severe weather situations. The Beidou position indicator is non-detachable, and the built-in battery lasts 5 years and realises the real-time location of the boats even when they are in the open waters.

TELECOM

ChinaSat 16 in-flight connectivity

Qingdao Airlines introduced on 7 July high-speed internet services on board of its modified Airbus A320. During the almost 3 hours long flight of QW9771 from Qingdao to Chengdu, passengers, mainly government officials, contractors and representatives from enterprises involved in the programme, were able to watch high-definition videos and make video calls. A live broadcast was also conducted, the 1st of its kind in China's civil aviation history. The aircraft provides internet access based on the XstreamSAT system with a bandwidth of up to 150 MB/s by using China's high-throughput communications satellite Zhongxing 16 (ChinaSat 16, Shijian 13). The satellite resource was provided by China Satellite Communications Co., Ltd., a CASC subsidiary. Qingdao Airlines said that modifications on the aircraft began in November 2019 and the 1st test flight was made in January 2020. The plane's certifications and tests were conducted from December to June.

China's 1st passenger jetliner offering onboard high-speed internet service, a Qingdao Airlines' aircraft, was put into commercial operation on 7 July 2020. Credit: Civil Aviation Administration of China (CAAC)

SATELLITE APPLICATIONS

Gaofen / Fengyun

Upon request of the Ministry of Emergency Management, the Chinese Centre for Resources Satellite Application used twice a day the GF-series of satellites for concerted Earth observation in flood-stricken areas in southern China. The returned data were processed and sent to relevant departments and local governments in the affected areas through a special data transmission line. The GF-data were combined with the FY meteorological satellites observations which focussed on all major river basins and lakes in China 4 times a day. The FY-4A, the most advanced meteorological satellite, monitors the weather every 10 min. The centre also uses the European Sentinels and other multi-source satellites for comprehensive monitoring.

Haiyang (HY)

The National Satellite Ocean Application Service is cooperating with a coral reef research centre at the Guangxi University to monitor coral reefs in the South China Sea, using sea surface temperature data from the HY marine satellite combined with high-resolution EO satellites. The aim is to locate coral reef bleaching and analyse surrounding sea temperature, and find measures for coral reef protection and restoration in the South China Sea. The South China Sea has seen coral reef degradation in the past 50 years, and the monitoring of the coral reef ecosystem is critical for the management and sustainable development of coral reef resources.

Sea Surface Temperature

A joint team of researchers from the State Key Laboratory of Satellite Ocean Environment Dynamics, the CAS Key Laboratory of Ocean Circulation and Waves, the Centre for Ocean Mega-Science, and the College of Marine Sciences of the Shanghai Ocean University, developed the satellite data-driven deep-learning model for forecasting the evolution of sea surface temperature associated with the tropical instability wave. Their study was inspired by available satellite remote sensing data and advancements in deep-learning technology. They have explored key marine data and established a deep-learning model to conduct oceanic forecasts. During the 9-year testing period (2010-2019), the model accurately and efficiently predicted the sea surface temperature field. The study demonstrated the strong potential of the satellite data-driven deep-learning model as an alternative to traditional numerical models for forecasting oceanic phenomena. The research result was published in the journal *Science Advances*.

Zheng, G., Li, X., Zhang, R-H., Liu, B., Purely satellite data-driven deep learning forecast of complicated tropical instability waves, *Science Advances*, 2020, 6, 29, eaba1482, DOI: 10.1126/sciadv.aba1482

Space Archaeology - Digital Belt and Road (DBAR)

The DBAR is an international scientific programme for Earth observation and big Earth data aimed at the sustainable development of the Belt-and-Road Initiative by sharing data, technologies and knowledge and experience. It will take a targeted approach to conduct in-depth research and scientific cooperation in the development of the big Earth data platform, in observing environmental changes, disaster risk reduction, water resources management, urban development, agriculture and food security, coastal zones and natural and cultural heritage.

The DBAR-Heritage Working Group is committed to using spatial information technology to grasp the authenticity and integrity of the World Heritage sites along the Belt-and-Road countries and identify challenges in their conservation, so as to formulate well-targeted protection strategies. Space archaeology is a new branch of archaeology, which is highly interdisciplinary and links natural sciences, sociology and humanities.

In 2018, Prof. Wang Xinyuan, Deputy Director of the International Centre on Space Technologies for Natural and Cultural Heritage (HIST) under the auspices of UNESCO led a space archaeology research team, including scientists from Tunisia, Italy and Pakistan, to discover 10 ancient Roman archaeological sites in Tunisia. They were unearthed at the western end of the maritime Silk Road after 2 years of remote sensing image processing and field investigation. The precise locations of the site were identified by using the satellite remote sensing along with navigation and positioning systems. It was the 1st time that a Chinese scientist had led such a project, involving major countries in Asia, Europe and Africa, to discover foreign archaeological remains and conduct systematic research by using space information technology in the field survey.

Antarctica's snow and ice coverage

A research team led by the National Marine Environmental Forecasting Centre has developed a forecast system for land-fast ice in east Antarctica's Prydz Bay, offering help for expeditions in the area. The new system combines satellite remote sensing data and numerical simulation to obtain dynamic changes in the growth, fragmentation, and range of land-fast ice. It can provide 10 day forecasts for the thickness of ice and snow, ice surface melt as well as the area of internal ice melt.

Arctic Navigation

Chinese researchers used remote sensing and model forecast data to help Chinese trade ships Tian'en and Tianyou safely

navigate the Northeast Passage of the Arctic in summer 2020. The researchers from the Aerospace Information Research Institute of the Chinese Academy of Sciences figured out the automatic method of satellite remote sensing data processing, as well as algorithms for deriving sea ice and ocean dynamics parameters. The researchers provided digital services for wind field, sea ice cover and sea ice concentration for the ships.
The Arctic navigation security service is a successful application of remote sensing data and enhanced space information observation ability in ensuring shipping safety.

Geological Hazard Monitoring

Heavy rainfall brought by typhoons can lead to secondary disasters such as land- and mudslides. At the construction site of a substation in Xiamen, a steep slope about 100 m long and 9 m high has been posing a safety threat. The issue was solved by 2 sets of Beidou geological disaster monitoring devices put into use in June, which provided cm-level displacement monitoring accuracy. The devices monitored the geological situation in real-time and reported the exact position of any minor change. Such devices have also been installed in some substations near the mountains in Xiamen, Longyan and other cities to guarantee stable power supply during the typhoon season.

BNU-1

China's 1st polar-observing satellite, BNU-1 (Ice Pathfinder), has obtained 2,501 images covering the Arctic and Antarctic regions during a full year of operations. The satellite was designed by the Beijing Normal University (BNU) and jointly developed by the China Great Wall Industry Corporation and the Shenzhen Aerospace Dongfanghong Satellite Co., Ltd., BNU held a press conference on 12 September in Beijing, where a series of 850 images of the Antarctic ice sheet and 1,025 images showing the Arctic region were released. The satellite also provided remote sensing data of Greenland in 70 m resolution. Users can download all the data and images for free.

Xingyun 2-01 and 2-02

Xingyun 2-01 and 2-02 developed by the Xingyun Satellite Co. under the China Space Sanjiang Group Co. Ltd., and launched on 12 May, are the 1st satellites of China's space-based IoT project. By mid-August they have established 2-way communication with a complete inter-satellite laser communication process and stable telemetry. The laser communication payload of each satellite weighs 6.5 kg and consumes 80 Watt.

ADVANCED TECHNOLOGY

Xiaoxiang 1-03

The Xiaoxiang 1-03 satellite completed a 1st experiment with a de-orbiting sail. The test aimed at meeting the 2018 CNSA regulation "Measures for Space Debris Mitigation and Protection Management" which asked for de-orbit capabilities of low-orbit satellites within 25 years after end of operation.
On 21 January 2019, SpaceTY launched Xiaoxiang 1-03. On 18 April 2019, at 13:12:50 BJT, the satellite completed the main scientific test and deployed the de-orbit sail. Imagery from the surveillance camera showed that the sail was deployed normally. The orbital attenuation has been measured and evaluated, and the results show that the de-orbit time of the satellite will be shortened from 16 years to 6 years. SpaceTY published in the Chinese language journal *Space Debris Research* the paper: Design and Practice of Active De-orbit Technology for Small Satellites.

Liquid Helium production

A new liquid Helium factory in Yanchi County (Ningxia) started operation on 21 July. The produced Helium is extracted from the waste product of natural gas. The current output of the factory is expected to reach 20 t per year what is not much compared to the 4,300 t China uses every year. However, since the cost for the production are comparatively low, more factories could be built to meet demand. Nearly all Helium used in China, including for the CZ-5 rocket, is mostly imported from the United States or U.S.-owned facilities in other countries.

COMMERCIAL

ROCKET COMPANIES

Prospects for Commercial Companies

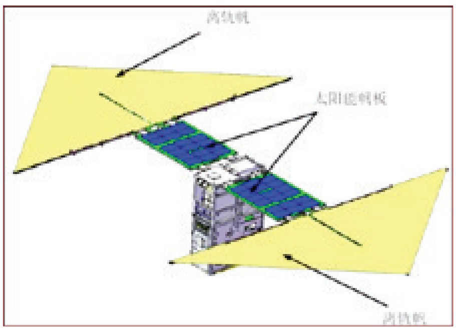
Prof. Yang Yuguang from CASIC and Vice Chair of IAF Space Transportation Committee told CGTN that China will have private companies better than SpaceX sooner or later. "You see they are already very innovative and very active in developing new technologies." He also believes there will be no essential conflict between private companies and state-owned enterprises because of the enormous size of the market potential. "In the up-stream and down-stream, there are more such examples. You can choose the components, parts, devices or subsystems from either the state-owned companies or from the private companies. For the downstream, such as applications, you can see more companies in China already engaged in providing services related to Earth observation, communication and others." Yang also said space technology-based applications will grow faster, especially the combination between space technology and information technology will be a very important field in the future, and both state-owned companies and private ones can do more. According to him, China is already transitioning from the era of exploration to the era of exploitation.

CASC - CASIC Cooperation

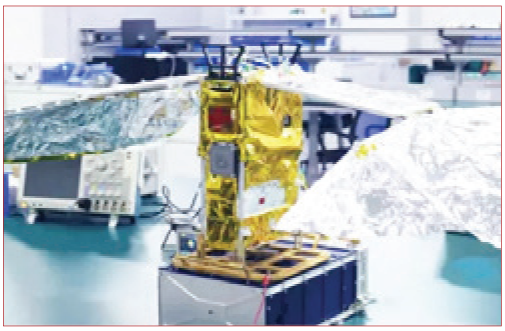
On 28 August, CASC and CASIC signed a strategic cooperation agreement which aims at building a world-class aerospace conglomerate and a world-class aerospace defence company. The companies also commit to improve China's aerospace international competitiveness and international influence. Other objectives are the joint support for the military's modernisation and to serve national strategic needs.

Galactic Energy

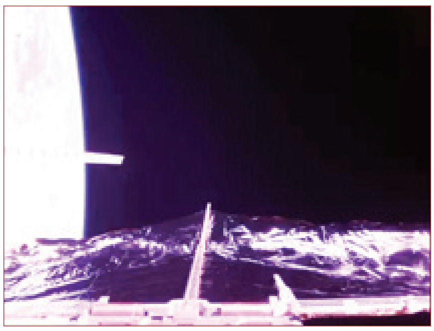
Galactic Energy (Beijing Xinghe Dongli Space Technology Co. Ltd.) signed on 3 September an agreement with the town of Jianyang (Chengdu) for the construction of a new-generation



Schematic of the unfolding mechanism of Xiaoxiang 1-03 de-orbit sails. Credit: SpaceTY



Ground test of the deployment of the de-orbit sail on Xiaoxiang 1-03. Credit: SpaceTY



The external camera on Xiaoxiang 1-03 took this image after the in-orbit deployment of the de-orbit sail.

commercial launch vehicle innovation and production base. The facility will be for research, development and production of liquid-propelled rocket engines for Galactic Energy's Pallas series of launchers. The base has a planned total investment of about 225 million USD.

iSpace

iSpace announced on 25 August a Series B round of financing of 1.2 billion RMB (174 million USD) - one of the highest amounts for the Chinese commercial space sector. The investment was led by Beijing Financial Street Capital Operation Centre, followed by CICC Alpha, Taizhonghe Capital, Sequoia Capital China and some smaller investors.

The money will be mainly used for the development of the Hyperbola (SQX) rockets, the development of its JD-series of reusable liquid oxygen methane engines, and for professional training of personnel.

Landspace

Landspace announced on 9 September it has completed a series C+ funding of 1.2 billion RMB (about 175 million USD). The financing was led by Sequoia Capital China, Country Garden Venture Capital, Matrix Partners China and Cornerstone Capital, with contributions from the National SME Development Fund and others. It was one of the largest fundraisings in China's private space industry. It will support the development of the Zhuque 2 (ZQ-2) liquid-propellant launcher, as well as the research and production of medium and large liquid oxygen-methane carrier rockets. In total, Landspace raised 1.8 billion RMB over the past year. The company will focus on the demand for commercial satellite launches and enhance the payload capacity of the ZQ series liquid-propellant rockets.

By the end of August, Landspace had completed hot firing tests for its 80 t Tianque 12 and 10 t Tianque 11 rocket engines.

Shaanxi Zhongtian Rocket

On 25 September, Shaanxi Zhongtian Rocket, a CASC subsidiary, completed a successful IPO on the SME Board of the Shenzhen Stock Exchange, resulting in approx. 25% of the company's shares now being publicly traded. Zhongtian debuted at a price of 12.94 RMB per share, which went up quickly, valuing the company at nearly 3 billion RMB (450 million USD). Zhongtian will use the funding to continue its solid rocket engine development, increase production capacity, and add production lines. The company also has significant business in missile manufacturing.

Zhongke Aerospace – CAS Space

29 September was the official start of the construction of Zhongke Aerospace's (Beijing Zhongke Aerospace Exploration Technology Co., Ltd., - also: CAS Space) rocket production facility in Nansha District in Guangzhou. The establishment will be part of the Nansha Science City for which CAS and the regional Guangzhou government signed an agreement in 2019. It will integrate R&D, production, final assembly and testing, and eventually be capable of producing 30 rockets per year. It is expected that the rocket manufacturing project will promote innovation across the Greater Bay Area of Guangdong, Hong Kong, and Macao.

SATELLITE SECTOR

Commsat

On 01 September, private satellite manufacturer Commsat, headquartered in Beijing, started the construction of its intelligent satellite manufacturing facility in Tangshan, a coastal city in Hebei province. The factory is located in the Lunan District and will become operational around the beginning of 2021. Its initial production capacity will be about 100 satellites in the range of 50 to 500 kg, making Commsat China's 1st private manufacturer to develop and operate satellites over 100 kg. The Tangshan facility will be equipped with pulse-line manufacturing, automated transport vehicles and intelligence technologies for a fast, cost-effective production. The plant will not only manufacture satellites but also conduct research on space-based communication technologies and ground applications. Commsat is also planning to build a satellite payload factory in the city of Yibin in Sichuan Province.

GalaxySpace

GalaxySpace announced during the 2020 China Space Conference that its new broadband communication satellite has entered the assembly stage after the company completed the development of the satellite's payloads.

Origin Space - Space Resource Utilisation

Origin Space wants to launch a space mining robot in November. The 30 kg NEO-1 mission will test and verify in-orbit technologies, such as orbital manoeuvring, simulation of small celestial body capture, intelligent spacecraft identification, and control. 1-2 years later, the NEO-2 spacecraft will be launched for hard landing on the Moon. An optical space-based telescope, named Yuanwang 1, will go into space in 2021 to identify space mining targets.

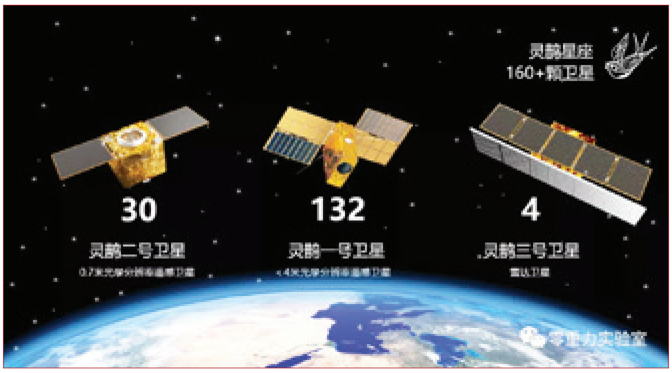
Zero Gravity Lab - Magpie Constellation 2.0

On 19 September, Zero Gravity Laboratory announced the Magpie Constellation 2.0 (Linque) plan at the Commercial Industry Forum of the 3rd China Space Conference, held in Fuzhou. The Magpie Constellation will consist of components with different capabilities, including remote sensing satellites with an optical resolution of around 1 m or better. The multi-sensor data can be used for diverse purposes.

Lingque 1 will be formed by 132 6U cubesats, with an optical resolution of around 4 m, and operates in SSO and LEO at an altitude of 500 km. After the constellation is fully deployed, it will form a high-resolution Earth observation network, with a global coverage every 12 hours, and a 30 min revisiting time of key areas.

Lingque 2: The Lingque 2A satellite will be launched in the second half of 2021. The Lingque 2 constellation will become an intelligent remote sensing system consisting of 30 satellites, ground stations, data control stations, cloud service centres, and user mobile terminals. It will be suitable for upstream and downstream applications of the entire satellite industry chain, from satellite production to space Big Data ground systems, Cloud centre to terminal production, content production, etc.

Lingque 3: The Lingque 3 Constellation will be complemented with 4 radar satellites (InSAR).



The magpie constellation plan consists of a mixed network constellation composed of Magpie 1, Magpie 2, and Magpie 3. Credit: Zero Gravity Lab

OTHER COMMERCIAL ACTIVITIES

Mynaric

German laser communication company Mynaric which develops and manufactures laser products for satellites, announced on 30 July that it will not launch its Condor laser communication terminal for inter-satellite connectivity on board a Chinese spacecraft. It said in a statement on its website "... to cease its business activities in China. Mynaric, having not delivered any laser communication hardware to China to date, will start at once to extricate itself from ongoing, but as yet uncompleted, transactions with customers in China. Having realised the strategic importance of laser communication, Mynaric was already well into a monetised divestment plan from the Chinese market through a buy-out which has now stopped."

Mynaric had proactively requested official clearance by the German government of a planned export of laser communication products to a Chinese customer, which the German government did not give. Mynaric stated that the intervention protects foreign relations and it proves the geo-political importance of laser communication and the strategic importance of Mynaric's products. Mynaric is also very active on the U.S. market where it expects governmental business opportunities.

Beijing Tech Hub with Mega Aerospace Cluster

Beijing's northern Haidian District plans to build a 100 billion RMB (14.8 billion USD) aerospace industry cluster in the northern region of the town's Zhongguancun Science City. The project was announced on 19 September at a press conference during the 2020 Zhongguancun Forum held in Beijing. With a total construction area of nearly 1 million m^2, the project will include the areas of satellite internet innovation, Beidou satellite navigation, and space information services, as well as industrial applications. The Haidian administration will provide policy support for enterprises settling in the cluster, including investment funds, rental assistance, R&D subsidies, support to housing rental. As one of the cradles of China's aerospace industry, the Zhongguancun Science City gathers more than half of the country's academics and experts, leading enterprises, and scientific research institutions in the field. The region has formed a whole industrial chain, covering satellite development and manufacturing, ground stations and terminal equipment, satellite telemetry, tracking and control, as well as satellite operations.

Nanjing Industrial Park

With an investment of 18 billion RMB (about 2.7 billion USD), the space-themed industrial park will be constructed in Nanjing's Luhe District and is scheduled to open to the public in 2022.

As the first of its kind in Jiangsu, the park will feature a science and technology innovation centre for the aerospace industry, a national science education base and an international innovation zone. It will integrate advanced elements of lunar exploration and aviation technologies into amusement projects.

RESEARCH AND DEVELOPMENT

Blue Book on Climate Change in China 2020

On 24 August, the China Meteorological Administration (CMA) published the Blue Book on Climate Change in China 2020 which provided the latest information on the climate change status derived from remote and ground-based monitoring data of China and the world. The focus of the book is on changes in the atmosphere, hydrosphere, cryosphere, terrestrial biosphere and driving factors of climate change. The Blue Book indicates that many key indicators of the climate system are undergoing accelerating changes. China is confronted with more extreme climate conditions, pronounced regional differences of precipitation changes, and more days of rainstorm.

From 1951 to 2019, annual average temperature in China had risen by 0.24°C per decade, what is higher than the global average. From 1961 to 2019, annual average precipitation in China is on a mild increase, with more extreme heavy rain events and more days of rainstorm.

From 1870 to 2019, average global sea surface temperature has risen notably. The sea level change in coastal regions of China is higher than the global average level in the same period. The year 2019 is the most intense year of global glacier melt since 1960. In recent years, vegetation coverage in China has also steadily increased.

Space-based mutation breeding

The use of 5 types of forage grasses, resulting from space-based breeding programmes has been approved by the government for nationwide or provincial-level cultivation. That was reported during a workshop on space breeding for forage grass held by the China High-Tech Industrialisation Association in Lanzhou, Gansu Province. Compared with natural or conventionally bred types of forage grasses, these space-developed versions feature higher protein content, greater annual yields, shorter growth periods and better resistance against diseases and insect pests. Forage grass seeds flew for the 1st time in 1992 on board of FSW-13. Since then, more than 100 kinds of seeds and seedlings of forage grasses were launched on board of approx. 30 Chinese spaceships, including the SZ-10, SZ-11, Tiangong 1 or the re-entry module of the prototype of the new-generation manned spacecraft, where 20 types of grass seeds launched on 5 May and returned 3 days later.

Other space breeding projects involving grains, vegetables, and fruits have led to more than 200 new types of mutated plants that have been approved for large-scale cultivation in China. Space breeding can generate mutants faster and more conveniently than ground-based experiments and can bring about some desirable traits that are hard to introduce otherwise. Many kinds of crops such as wheat and tomatoes that were bred in space have been in domestic markets for a long time.

INTERNATIONAL COOPERATION

APSCO - Asia-Pacific Space Cooperation Organisation

- 3rd APSCO Extraordinary Council Meeting

The 3rd APSCO Extraordinary Council Meeting was held on 11 August in Beijing at APSCO Headquarters for the selection of the new Secretary-General. Candidates from China, Thailand, and Iran were nominated. Following the APSCO procedure, Ms. Yu Qi from China, was selected as the new Secretary-General for a 5-year term, starting on 1 November ending on 31 October 2025. She succeeds the current APSCO Secretary-General Dr. Li Xinjun.

- Online Training

APSCO and the Aerospace Information Research Institute of the Chinese Academy of Sciences (AIR-CAS) jointly organised the online training on "Quantitative Remote Sensing Information Technology and its Applications" from 3-7 August in Beijing. The course was followed by 90 participants from Bangladesh, Indonesia, Iran, Mexico, Mongolia, Pakistan, Peru, Thailand, and Turkey. This training was focused on quantitative remote sensing information technology and its application cases on precision agriculture crop, pest and disease monitoring and forecasting, measurement and monitoring of carbon dioxide (CO_2) in the atmosphere, marine ecological and environments, vector-borne disease.

- Earthquake Research Project

The Critical Design Review (CDR) Meeting for the 'APSCO Earthquake Research Project Phase II: Integrating Satellite and Ground Observations for Earthquake Signatures and Precursors' was held via teleconference from 20-23 July. The Project Management Board and delegates from all APSCO Member States participated in the meeting. After the CDR, a 2-day technical training course was given by the project experts, explaining the payloads for the satellite, data processing, demonstration of ionosphere data access on the SOAP Platform and hands-on practice.

- CubeSat Competition Project

The 1st Expert Group Meeting on the Feasibility Study of the CubeSat Competition Project was organised online by the APSCO Secretariat on 14 and 15 July. Delegates from all APSCO Member States participated in the meeting.

- Beihang Training Course

From 24 August to 5 September, APSCO and the Beihang

University Beijing jointly organised the online training on "GNSS/BDS Frontier Technologies and Applications".
The course was given in 2 different time schemes to accommodate 90 participants in 19 countries in different time zones. (Algeria, Bangladesh, Bolivia, China, Ethiopia, Indonesia, Iran, Jordan, Mexico, Mongolia, Myanmar, Nigeria, Pakistan, Peru, Russia, Turkey, Togo, Uzbekistan, and Vietnam).
The lectures focused on GNSS Principles and BDS Status, GNSS Navigation Receiver, GNSS High Precision Application and Augmentation, GNSS Ionospheric Monitoring and Space Weather, GNSS Reflections and its Remote Sensing Applications, and GNSS and Self-driving Technology.

- China Space Day

An APSCO Delegation attended the China Space Conference 2020, held from 18-21 September in Fuzhou. During the conference, the APSCO delegation closely interacted with CNSA, China Space Foundation and Fujian government officials on possible future cooperation in space related fields or organising joint training and forums.

ARGENTINA

With effect from 24 July, China and Argentina have extended earlier framework agreements, signed in 2012 and 2015 for cooperation in space exploration. Both countries are looking for possibilities in the development of spacecraft and other space exploration instruments, as well as ground infrastructure to launch and control space missions and satellites.
Other points of common interest are exchange of data, research findings, academic experts and the creation of a sub-committee led by officials from both sides. The Argentinian interests are represented by the government's space agency CONAE for Argentina and CNSA for China.
As part of the agreement, in 2012 Argentina has already allocated an area of 2 km^2 to China for building a ground station in the Neuquén Province in Patagonia. The land is leased to China for 50 years.

Link to the Publication of the Official Bulletin Law Framework Agreement for Cooperation in the field of Space Activities between the Government of Argentine Republic and the Government of the People's Republic of China

EGYPT

EgyptSat-2 / MisrSat-2

The initial design review of the EgyptSat-2 (MisrSat-2) satellite project was done in a 3 week-long online conference between the Egyptian Space Agency and CASC. The Director of the International Economic Cooperation Affairs Department of the Ministry of Commerce of China and the Egyptian Space Agency signed a document for the start of the implementation phase. The overall progress on the project was affected by the Corona pandemic. EgyptSat-2 is now scheduled for completion in August 2022 and for launch in December the same year.

For the satellite integration, an assembly and testing centre is currently under construction with inauguration planned in September 2022 in the International Space City. The African Union decided to establish an African Space Agency which headquarters will be located in Egypt's International Space City. Kenya, Uganda, Ghana, Sudan, and Nigeria aim for the launch of a joint African Development Satellite.

IRAN

On the occasion of the launch of China's Beidou 3 satellite, Iranian Ambassador to China, Mohammad Keshavarz-Zadeh, said that there is a lot of potential for aerospace cooperation with China. He also referred to Iranian aerospace students in China who can be a bridge between the two countries in this field. Currently, 2,000 Iranian students are studying in China.

RUSSIA

On the occasion of the 5th anniversary of the creation of the state-owned corporation Roscosmos on 13 July, newspaper *Komsomolskaya Pravda* spoke with Dmitry Rogozin, Head of Roscosmos, about the future of Russian space activities. Regarding options for international or bilateral cooperation for lunar exploration, Rogozin told the media that he had a teleconference with the Head of CNSA, Zhang Kejian, in the morning of the very same day of the interview. Rogozin and Zhang agreed to begin the 1st steps in the definition of a future lunar base, which will hopefully become an international project. Rogozin stressed that China has achieved a lot over the last years what has earned his respect. China is a "worthy partner". Russia is about to restart its once so successful lunar exploration missions. The planned series of 'Luna' missions and the next generation heavy-lift rocket could support an international lunar research base at the Moon's South Pole region. China and Russia shared information about their respective lunar plans and are trying to find synergies in their efforts. "Therefore, China, yes, is certainly our partner.", Rogozin stressed.

SWEDEN

On 21 September, Sweden's state-owned space company Sweden Space Corporation (SSC) said it would not renew contracts with China or accept new Chinese business for providing telemetry, tracking and command services via its space tracking station in Yatharagga, Western Australia, 350 km north of Perth, due to changes in geopolitics. The contract started in 2009 via which SSC gave China access to its antennas in Sweden, Chile and Australia. The Australian antenna is located next to an SSC satellite station used mainly by the U.S. and its agencies, including NASA. China last used the Yatharagga Satellite Station in 2013 to support the SZ-10 mission. State-media Global Times said China's homegrown Beidou navigation system has now inter-satellite links to reduce reliance on ground stations and ensure the continuity of high-precision global services. Beidou scientists and architects have taken limited access to overseas ground stations into consideration since the very beginning.
There is at least a decade left on the contract with SSC. However, Yatharagga has not been used or visited by Chinese space experts for many years, Global Times reported, referring to Chinese space insiders. "We can still visit and utilise the facility in Western Australia for many years to come, and even losing access to it would hardly affect China's upcoming space exploration and key manned space programmes," sources very close to the Chinese space tracking system stated. China intends to renew its cooperation with SSC after the current contract expires, the sources added, without saying if that covered the Australian facility.

UAE

The UAE Ambassador to China, Ali Obaid Al Dhaheri, visited CAST in Beijing. He stressed that there are "a number of opportunities and possibilities for the UAE space agency to work with the CAST team in the future.", possibly in space exploration.
At an event on 6 August, dedicated to Mars exploration, ambassadors and diplomats from countries including China, the UAE, Namibia, Mali, Nepal, Uruguay and Azerbaijan signed an initiative on Peaceful Space Exploration.

USA

The Hong Kong Satellite Remote Sensing Ground Receiving Station, run by the Institute of Space and Earth Information Science of the Chinese University of Hong Kong (CUHK), receives real-time data from civil remote sensing satellites which are used to monitor natural disasters. The station monitors an area stretching from southern Japan to India and Indonesia.
The cooperation protocol between the U.S. Geological Survey

(USGS) and the Hong Kong institute, once signed in 2009 included data sharing and training. The agreement ran out by the end of 2019 and was not renewed. The founder of the institute told SCMP that there is nothing secret about its work and added that China now has another station in Hainan province, which is able to provide similar data.

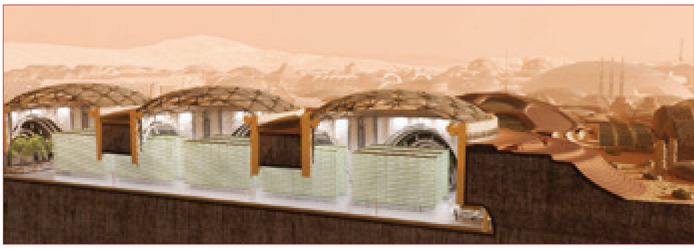
2nd Sino-U.S. Space Commercialisation Workshop

On 19 September, the Secure World Foundation and the Chinese Society of Astronautics co-hosted a "Perspectives Dialogue: Key Views for Areas of Interest and Understanding". During the session commercial space related stakeholders from the U.S. and China shared their viewpoints on trends, challenges, and opportunities in the commercialisation of space. The workshop, run on the margin of the 2020 China Space Conference helped to understand the commercial space efforts in the two countries and to discuss transparency measures. The U.S. presenters participated through pre-recorded talks while the Chinese participants were present on-site.

EDUCATION

Over 3,000 project proposals were submitted to the international Future Mars Competition, organised by the China Intercontinental Culture Centre (CICC) and SPACEnter Space Science and Technology Institute under the Astronaut Centre of China. The goal of the competition is to promote aerospace science around the world and to search for creative ideas on future life in the fields ranging from clothing, food, living, transportation to technology applications, entertainment, travel patterns, and education.

The winner of this year's Gold award in the architecture category was the Innspace team of students from the Wrocław University of Technology for their innovative IdeaCity concept of a Martian base and their residential dome project, utilising shape memory materials. Innspace's Ideacity is a Mars colony, laid out on a hexagonal shape with the sides measuring 400 m. The majority of its structures is underground to guard the inhabitants against the harsh Mars conditions and radiation.



IdeaCity concept of a Martian base and residential domes. Credit: Wrocław University

Qian Xuesen University

Hunan Province in Central China unveiled a plan to construct in Liuyang city a new university of science and technology named after Qian Xuesen. The authorities wish to support the development of higher education in the region. The overall planning for the university has not yet been finalised.

MISCELLANEOUS

U.S. Ex-Im

SpaceNews reported that the Export-Import Bank (Ex-Im) of the United States is supporting U.S. commercial space companies which have to compete with Chinese service providers through its "Program on China and Transformational Exports". The bank was mandated by Congress to provide to U.S. space industry loan rates and terms that must be competitive with those in China. It is believed that Chinese companies are offering Earth imaging data and analytics services to customers, often governments all around the world, for a highly competitive pricing. Also, the in-orbit delivery model which includes all-round financial package by China Great Wall Industry Corporation CGWIC is a strong competition for Western launch service providers. Stephanie Bednarek, Director of Commercial Sales at SpaceX, told SpaceNews that the company competes frequently with Chinese-backed launch companies. "It's fair to say that SpaceX may view Ex-Im as an extension of our sales force and an asset that's really critical to help us win international business," she said. As of 2015, Ex-Im was lacking congressional authorisation for loans above 10 million USD which was per 20 December corrected with a 7-year re-authorisation.

China photographed from the ISS

On 12 September 2019, the crew members of the Expedition 60 on board the International Space Station took a night-time photo of the bright urban lights of the two Chinese port cities Xiamen and Quanzhou. On 9 August 2020, NASA decided to publish the photograph as "Image of the Day", writing on its website: "Xiamen and Quanzhou stand out amidst a complex network of roads and railways and the night-darkened waters of the South China Sea. The mountainous inland areas are less illuminated but smaller towns and roads zig-zag through the valleys. Closer to the coast, several islands and small harbours make up one of China's busiest port regions. Offshore, two bright clusters of pixels are likely ships traveling to or from one of the harbours. The ancient city of Quanzhou was once one of the most important ports along the Maritime Silk Road. Beyond its role as a major centre of commerce and trade, Quanzhou remains a major manufacturing centre in China."

Xiamen and Quanzhou. Credit: NASA - ISS060-E-60237

Journal *Space: Science & Technology*

The American Association for the Advancement of Science (AAAS) together with the Beijing Institute of Technology (BIT) launched the new English-language Science Partner Journal *Space: Science & Technology*. BIT cooperates with CAST in managing the journal. It is an online-only Open Access journal. The goal of the new journal is to publish high-quality, high-influence research articles, reviews, editorials and perspectives from the world's top universities and research institutions on the intersections, frontiers and hot topics in the space field. The journal's scope includes space science, space technology, and space infrastructure and services as the 3 major domains. Dr. Peijian Ye, Academician of the Chinese Academy of Sciences and Professor at the China Academy of Space Technology serves as the Editor-in-Chief, while Yulin Deng, Professor at the Beijing Institute of Technology, Academician of International Academy of Astronautics (IAA), and the President of IAA Life Science Department is the Executive Editor-in-Chief.

Space: Science & Technology
Link to the journal website - see QR code left or go to:
https://spj.sciencemag.org/journals/space/about/

Business as Usual in the Middle Kingdom
Blaine Curcio writes in SpaceWatchGlobal on the impact of the Corona pandemic on the Chinese space sector. He found that the space industry has continued to grow over the course of the year 2020. This has been met by increased government initiatives related to space, something that has occurred on national and regional level. As a consequence, some of the Chinese space companies have moved away from Beijing. He predicts that in the longer-term, the increased involvement of local and provincial governments in concert with commercial companies will likely lead to innovation, albeit in a comparatively inefficient way due to overlapping responsibilities and duplication of work.

2020 China Space Conference
The 2020 China Space Conference showcases China's achievements: from an actual spacecraft re-entry module to vegetables grown from space seeds, explore what China has achieved in space exploration.

The Rise of China in Space
Cindy Pom produced a mini documentary on the current status of China's space ambitions. The 7 min video can be seen on her YouTube channel "Newsthink".


Space Art Exibition: A space science art exhibition was opened in Xi'an on 28 August and will last until 30 November. Credit: Xinhua/Liang Aiping

Space Art Museum

The "Space Art Museum" online opening ceremony and "Snowland-Love-Tiangong" 1st popular science public art exhibition was held on 29 September 2020 at the Tsinghua University Art Museum in Beijing. The event was organised in cooperation with China Manned Space Exploration Office (CMSEO), the Art Museum of Tsinghua University, Beijing Shenzhou Aerospace Culture and Creative Media Co., Ltd., and Beijing Wanhu Chuangshi Culture Media Co.
The opening of the museum adds a cultural aspect to China's manned space project and builds a bridge between technology and life, engineering and society. The museum plans for popular science education, art creation, cultural communication, social welfare and other activities. In the exhibition the visitors can experience with virtual reality technology the appearance and internal structure of the Chinese Space Station, giving the audience an insight into the work and life of taikonauts in space. Remote sensing images and space science and technology application results educate about the outcome of the space programme.

Book Review: China in Space
Brian Harvey is a renowned author of books about China's space ambitions. After 7 years, the 2nd edition of his milestone book on China's space programme was published. It provides a comprehensive overview of all aspects of Chinese space activities, as well as the historical context and an outlook to the future.

2020 China Space Conference in Fuzhou, Fujian Province

The 2020 China Space Conference took place from 18-21 September in Fuzhou, capital of Fujian Province. The conference was based on the theme "Promoting the aerospace spirit and embracing the Starry Sea". The conference was organised by the China National Space Administration, China Association for Science and Technology and the Fujian government. It was supported by the China Aerospace Science and Technology Corporation CASC, China Aerospace Science and Industry Corporation CASIC, International Astronautical Federation IAA, International Society of Space Law and APSCO and sponsored by Chinese Society of Astronautics and China Space Foundation.

The conference consisted of 16 events, including a main forum, a non-public meeting, 2 international forums, 7 academic (technical) forums, a cultural forum, an education forum, 2 popular science activities and an exhibition.
At the opening ceremony, the "Major Space Project Award" and the "Qian Xuesen Outstanding Contribution Award" were presented by China Space Foundation. Also, Chinese researchers announced the 10 most challenging subjects in space science and technology such as nuclear-powered spacecraft, heat-resistant materials for reusable aerospace vehicles, horizontal take-off and landing vehicle including hybrid propulsion and space debris removal. State-owned space enterprises signed agreements with the Fujian Province Government on cooperation in aviation and space industries.
During the conference, academicians from the Chinese Academy of Sciences and the Chinese Academy of Engineering, distinguished researchers and industry representatives discussed various topics such as China's development strategy for its space sector after the Covid-19 pandemic, breakthroughs in key technology fields, the development of space information industry along the maritime Silk Road, the space-based information industry's future as well as global space cooperation.

Opening Ceremony of the 2020 China Space Conference in Fuzhou. Credit: Xinhua/Lin Shanchuan

Lunar Manned Mission

Zhou Yanfei, Deputy Chief Designer of China's Manned Space Programme, said during his keynote speech at the 2020 China Space Conference that planners, designers and engineers have concluded feasibility studies of a human lunar landing concept and discussed all aspects of a Chinese human lunar programme. There are some technical and engineering difficulties which need to be solved: a more powerful carrier rocket, a suitable crew spacecraft, a ground support system able to support lunar surface missions, and taikonauts with experience of lunar flights and lunar surface operations.

Zhou Yanfei, Deputy Chief Designer of China's manned space programme talking during the 2020 China Space Conference. Credit: Global Times/Deng Xiaoci

With respect to the launcher, the researchers outlined 2 approaches: either a new heavy-lift rocket with more than 35 t of payload capacity for lunar transfer orbit, or adjusting the next-generation human-rated rocket, currently under development. The engineers would give preference to the redesign of an existing rocket in order to have earlier results. The rocket would transport taikonauts and components to a lunar transfer orbit to assemble a landing capsule, which will then take astronauts to the lunar surface. The most likely launch site would be Wenchang Space Launch Centre with return options on land or at the sea. The launcher's payload capacity would be 25 t into translunar orbit, mass at take-off would be 2,200 t, almost 3 x of the CZ-5. The 1st stage is composed of 3 boosters, each 5 m in diameter. The China Academy of Launch Vehicle Technology is supposed to build the 87 m tall rocket, double as high as the CZ-5. A conceptual model of this rocket was exhibited during the Zhuhai Airshow in 2018.

A manned space lab deployed to the Moon that is able to support multiple astronauts in their days-long lunar exploration activities is also part of the tentative roadmap. Zhou also added: China wishes to use the manned lunar missions to carry out scientific surveys and technology demonstrations, explore ways to develop lunar resources and strengthen the nation's space capabilities. Unlike other nations, China must depend on its own science and technology to realise its goals.

Space Transportation

Bao Weimin, Academician of the Chinese Academy of Sciences and the Director of the Committee of Science and Technology under the China Aerospace Science and Technology Corporation, told the conference audience at the 2020 China Space Conference that he envisions China will be able to operate regular and diverse suborbital, orbital and space-to-ground traffic by 2045. The regular flights will include 1-hour journeys between global destinations, transportation between ground and orbit, and routes between orbits. He estimated that by 2045, China can operate over 1,000 spacecraft flights per year, transporting a total of 10,000 tonnes of freight and 10,000 passengers.

Welcome to the Dongfang Hour Podcast

On 11 September 2020, the only English-language podcast discussing Chinese aerospace and technology went on air with a YouTube channel. Dongfang Hour (literally "Eastern Hour"), is hosted by consultant and entrepreneur Blaine Curcio and aerospace engineer Jean Deville, both based in China. In a stand-alone format or with expert guests, the Dongfang Hour hopes to bring entertaining yet resourceful, and balanced yet pointed insights from within the Chinese ecosystem.

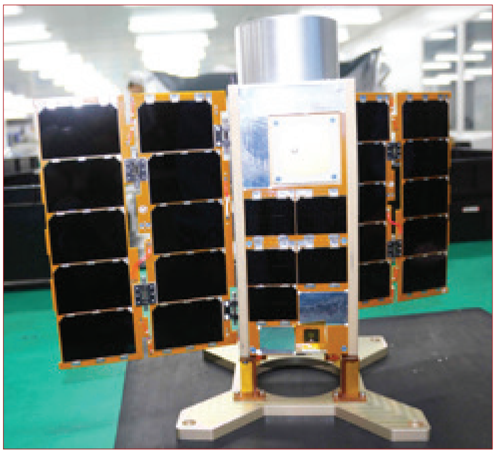
LAUNCHES

2020-042A
2020-042B
03 July 2020 - 03:10 UTC (11:10 BJT)

launch site: Taiyuan Satellite Launch Centre - TSLC, LC9
launcher: Chang Zheng 4B - CZ-4B
payloads: Gaofen-Duomo (GF-DM)
Xibaipo (BY70-2, Baiyu-02)

China successfully sent a **Gaofen** high-resolution multi-mode integrated imaging satellite into a Sun-synchronous, polar orbit. The 2.400 kg satellite is for civil remote-sensing. It is equipped with 2 solar arrays and a 1 m-long telescope-like camera payload which can take images of 50 cm resolution in the panchromatic band and of 2 m resolution in 8 multi-spectral bands.

GF-DM was developed and built by Dongfanghong Satellite Co., Ltd. The 6-sided, cylindrical construction is based on the company's agility platform. The satellite can be very precisely stabilised and oriented. During its expected 8 years of life time, the satellite will provide high-precision remote-sensing data for surveying and mapping, natural resources, emergency management, agriculture, ecological environment, residential construction and forestry.


The Xibaipo science popularisation satellite. Credit: CNSA

The seondary payload on this launch was the 2U amateur radio cubesat **Xibaipo** - a cooperation project between the China Centre for Aerospace Science and Technology International Communications and the No.1 Middle School of Luquan District, in Shijiazhuang, Hebei Province. The 3 kg satellite has a life time of 180 days. With its amateur radio payload (UHF/VHF) and a miniature Earth observation camera it serves outreach and educational purposes.

2020-043A
04 July 2020 - 23:44 UTC (05 July 2020 - 07:44 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC
launcher: Chang Zheng 2D - CZ-2D
payload: Shiyan 6-02 (SY 6-02)

SY 6-02 is part of the Shiyan 6 series of technology demonstration and research satellites and succeeds SY 6-01, launched in November 2018. SY 6-02, built by DFH Satellite Co. Ltd. for the Chinese Academy of Sciences, is a box-shaped satellite and equipped with 2 solar panels. 15 min after launch, it was placed in a 700 km orbit from where it will deliver space environment data and conduct related technology experiments.

2020-045A
9 July 2020 - 12:11 UTC (20:11 BJT)

launch site: Xichang Satellite Launch Centre - XSLC
launcher: Chang Zheng 3B/G2 - CZ-3B/G2
payload: APStar 6D

APStar 6D is a HTS telecommunication satellite of 5.500 kg mass. It is the 1st satellite based on DFH-4 Enhanced (DFH-4E) satellite platform with a hybrid propulsion system (chemical and electrical) and the 1st commercial Ku/Ka band high-throughput broadband communications satellite carrying the biggest payload designed and developed by CAST. It has 90 Ku-band user beams and 8 Ka-band gateway beams. The satellite incorporates key technologies such as Ku-band ultra-wideband multi-port power amplifier (MPA) and flexible switching of gateways. With a communication capacity of about 50 GB/s and single beam capacity of up to 1 GB/s, APStar 6D will serve its users with high-quality voice and data transmission. Because of the failure of ChinaSat-18 and Nusantara 2, both based on the DFH-4E satellite platform, APStar 6D is now the 1st DFH-4E satellite.
The dimensions of the box-shaped satellite are 2,36 x 2,1 x 3,6 m. Its dry-mass is 3,744 kg. It is equipped with 2 solar panels, delivering between 14.4 kW and 10.5 kW of power.
The satellite used a conventional liquid-fueled engine for raising its orbit over the weeks following launch until it reached GEO orbit on 17 July. After 18 days of drifting in GEO, APSstar 6D arrived at 134° East on 6 October. From then on, the electric plasma thrusters were used for North-South station-keeping. On 18 July, the responsibility for the satellite was handed over from the Xi'an Satellite Control Centre to the user ground station. APStar 6D's life time is 15 years. It provides high-quality, efficient, cost-effective high-throughput satellite broadband communication services and various applications for China and Asia-Pacific with coverage from the East Indian Ocean to the Western Pacific. It will serve maritime communications, aviation airborne communications, land vehicle communications and fixed satellite broadband internet access. It is the 1st component of a future global HTS system with 3 to 4 GEO satellites.
Usually, APStar satellites were owned by Asia Pacific Satellite of Hong Kong, but this one is owned by the affiliate APT Mobile Satcom Ltd., (APSATCOM) in Shenzhen. In recognition of the 40th anniversary of the Shenzhen Special Economic Zone, the satellite is also called ShenshenSat. APT Mobile SatCom ordered the satellite in 2016, the year the company was founded by CASC together with the Ministry of Transport and the Shenzhen municipal government. But the launch was delayed by 2 years. The project was managed by CGWIC. It was CGWIC's 12th in-orbit delivery of a communications satellite.

2020-006F Failure
10 July 2020 - 04:17 UTC (12:17 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC, mobile platform
launcher: Kuaizhou 11 - KZ-11
payloads: Jilin 1-Gaofen 02E (Jilin 1-02E, BilibiliSat)
CentiSpace 1-S2 (Xiangrikui 2 - Weili 1-02)

The failure of the 1st launch of Expace's Kuaizhou 11 carrier rocket was the 3rd launch failure for China in 2020 (16 March: CZ-7A; 9 April: CZ-3B/G2). A malfunction occurred during the late phase of the flight, pointing to an issue with the liquid-fueled manoeuvring stage of the 3-staged solid-fuel launcher. The specific cause of the failure needed further analysis and investigation.
Once the KZ-11 becomes operational, it will take over from the CZ-11 as the most powerful solid-propellant carrier rocket in China. Its payload capacity is 1,500 kg into LEO or 1,000 kg into 700 km SSO. KZ-11 is a 25 m long, 2.2 m diameter launcher with a lift-off mass of 78 t. The payload fairing can vary between 2.2, 2.6 and 3 m. Research and development for the KZ-11 began in 2015 at CASIC's subsidiary China Space Sanjiang Group in Hubei Province. Its 1st flight was planned for 2017 but the constructors needed 5 years to overcome challenges with the rocket's liquid-propellant attitude-control propulsion system. The aim was to replace the one offered by the original supplier and use components made by 3D printing. Also, more than 90 % of the rocket is made of composite materials.
The 230 kg **Jilin 1-Gaofen 02E** is a remote sensing satellite, providing data on forecasting and managing geological disasters for commercial customers and data for natural resource exploration. It is an oblong-shaped satellite with 2 solar panels and 2 camera systems. One sensor takes ultra-high-definition color videos at a resolution of around 0.76 m and a multi-spectral imager has a resolution of 3.1 m. The image swath is around 40 km, transmitted to the ground stations with a rate of 1.8 Gbps. It was built by Changguang Satellite Co. Ltd. but sponsored by online streaming platform Bilibili. A replacement satellite was finally launched on 15 September with a CZ-11 from the Sea Launch platform.
CentiSpace 1-S2 was built by the Innovation Academy for Microsatellites (Microsat CAS/IAMCAS). The 97 kg satellite, based on the WN100 satellite bus, was intended to provide GNSS augmentation techniques using a laser inter-satellite communication link and would have become part of a series of LEO navigation satellites, operated by company Future Navigation Technology Co. Ltd.

2020-049A
23 July 2020 - 04:41 UTC, 12:41 BJT

launch site: Wenchang Satellite Launch Centre - WSLC, LC101
launcher: Chang Zheng 5/YZ-2 - CZ-5/YZ-2
payload: Tianwen 1 (TW-1)

China's 1st Mars probe, and at the same time 1st planetary mission, took off on board a CZ-5 rocket. The launcher entered a 30° inclined parking orbit and then made a 2nd burn from 05:08 to 05:17 UTC to reach escape velocity at 12.05 km^2/s^2. The probe, still attached to the 2nd stage left Earth's gravitational sphere on 27 July and entered a 1.02 x 1.60 AU x 1.1° solar orbit.
The Tianwen 1 mission combines 3 units in one spacecraft: an orbiter, a landing unit and a surface rover. The overall mass is 5 t. Of it, the orbiter has an estimated dry mass of 1,645 kg with 1,530 kg of propellant. Attached to it is a 1,745 kg Mars entry and landing vehicle. The lander with its 7.5 kN throttlable engine has a mass of 1,285 kg - including the 240 kg rover.


Testing the APStar 6D satellite in the factory. Credit: CAST


The APStar 6D satellite is equipped with a new generation solar panel system. Credit: CAST


APStar 6D is the 1st of a 3-4 satellite GEO constellation for global broadband. Credit: CASC

The whole combination will enter Mars orbit. There, the entry segment detaches from the orbiter and performs its deorbit burn and landing sequence supported by aeroshell, parachutes and rocket engine.
TW-1 was built by CAST on request of CNSA. The orbiter is a box-shaped probe, 4.0 m high, with 2 solar arrays. The orbiter is conducting all manoeuvres on the flight to Mars. The entering of a 265 x 11.943 km Mars orbit, inclinded by 86.9°, is planned for 21 February 2021.
On 11 Sepember, on the way to Mars, the probe ejected the unpropelled mini camera cube FCC (Fenli Coliang Chuangan). Next to the cameras on each side of the cube, the hardware contained batteries and data transmission device to send the photographs to the orbiter. 2 of the images clearly show the TW-1 probe.

More details on the Tianwen 1 mission on pages 6 - 8.

2020-051A
2020-051
2020-051
25 July 2020 - 03:13 UTC (11:13 BJT)

launch site: Taiyuan Satellite Launch Centre - TSLC
launcher: Chang Zheng 4B - CZ-4B
payloads: Ziyuan 3-03
Tianqi 10
Longxia Yan 1 (NJU-HKU-1)

The 2,650 kg **Ziyuan 3-03** imaging satellite is based on CAST's Phoenix-Eye 2 satellite bus. It is a box-shaped satellite with the dimensions of 1,8 x 2,0 x 2,2 m. It has a paylaod section with 3 cameras and a laser altimeter and 2 solar panels.
The resolution of the 3-line array panchromatic stereo camera is 2.1 m, the resolution of the conventional panchromatic camera is 3.5 m and the one of the infra-red multi-spectral camera is 6 m. The collected data can be used for mapping, agriculture, infrastructure planning, natural resources management, transportation, emergency response and environmental protection. Ziyuan 3-03 will join 2 predecessors of the Ziyuan series and the Gaofen 7 satellites. Its projected lifetime is 8 years (some sources say: 5 years).
The launch also transported 2 secondary payloads into space.
The 50 kg **NJU-HKU-1** X-ray astronomy satellite (Lobster Eye 1, Lobster Eye X-ray Exploration Satellite) was jointly conceptualised by Nanjing University and Hong Kong University. It was built by the 508 Institute of CASC, the Shanghai ASES Spaceflight Technology Co.Ltd., and China Building Materials Academy (CBMA). The micro satellite's objective is to verify the technology of ultra-large field of view imaging in the search for dark matter signals in the X-ray spectrum. Its Lobster-Eye X-ray optics use microchannel plates as a X-ray equivalent of optical fibers to make a very wide field image of the X-ray sky. The lobster-eye optics concept was developed in the 1970s in the U.S. but turned into practice only now.
Tianqi 10 is a 50 kg cubesat for an narrow-band IoT constellation in LEO. It will be operated by Beijing-based satellite operator Guodian Gaoke. The small satellite is the 7th in the company's Tianqi network, which will offer space-based Internet of Things services. Tianqi 10 was - like NJU-HKU-1 - developed by the Shanghai ASES Spaceflight Technology Co. Ltd., a research institute under the Shanghai Academy of Spaceflight Technology (SAST).

2020-054A
2020-054B
06 August 2020 - 04:01 UTC (12:01 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC
launcher: Chang Zheng 2D - CZ-2D
payloads: Gaofen 9-04
Q-SAT (Zhongli Yu Daqi Kexue Weixing)

The 50th CZ-2D rocket launched the CASC-built Gaofen 9-04 Earth observation satellite. GF-9-04 is equipped with an optical sub-meter resolution paylaod and will be mainly used for land surveys, city planning, land right confirmation, road network design, crop yield estimation and disaster prevention and mitigation. GF-9-04 will join the existing network of Gaofen and other Earth-observing satellites.
The secondary payload was the Gravity and Atmosphere Scientific Satellite (Q-SAT). It is a technology test satellite, developed by Tsinghua University. The design of the satellite supported the training on the university's satellite system design approach. Its scientific purpose is to collect high-precision data of the Earth's gravity field, and measure the orbital atmospheric density.

2020-058A
2020-058B
2020-058C
23 August 2020 - 02:27 UTC (10:27 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC,
launcher: Chang Zheng 2D - CZ-2D
payloads: Gaofen 9-05
Tiantuo 5 (TT-5)
DGSW (Duo Gengheng Shiyan Weixing)

Gaofen 9-05, developed by Aerospace Dongfanghong Satellite Co., Ltd., is another in the series of modern optical remote-sensing satellites with a high resolution of under 1 m. It will join the Gaofen network already in orbit. Different Gaofens have different sensors which can be optical, infrared and radar imaging sensors. The constellation is used for land surveys, city planning, land right confirmation, road network design, crop yield estimation and disaster prevention and mitigation. Its data will also contribute to the Belt-and-Road Project.
The 78.5 kg **Tiantuo 5**, developed by the National University of Defense Technology (NUDT) in Changsha, will test and verify new data collection technologies for maritime and air traffic, ocean buoys and IoT-communication. The satellite is equipped with an attached solar array and a new electric propulsion system for small satellites.
DGSW is a multipurpose experimental satellite of the Academy of Military Sciences in Beijing. It will test and verify technologies such as communication, navigation and remote sensing in orbit.

2020-063A
2020-063G
04 September 2020 - 07:30 UTC (plus or minus one minute, based on analysis of TLEs) (15:30 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC
launcher: Chang Zheng 2F/T - CZ-2F/T
payload: Chongfu Shiyong Shiyan Hangtian Qi (CSSHQ)

Not much information became public about this launch of a re-usable test spacecraft. It was lifted into a a 332 x 348 km x 50.2o orbit. Xinhua reported on 6 September that after a period of in-orbit operation, the spacecraft had returned and successfully landed at the scheduled landing site in China. Jonathan McDowell pointed out that landing must have accured around 02:00 UTC with a candidate landing site being the runway 05 at an air base at 89.27° E 40.78° N near Lop Nor. He also reported that "on 5 September around 22:30 UTC, a few orbits before the landing, a new object separated from the spacecraft and was cataloged as 2020-063G. It may be a service module or solar array jettisoned prior to the deorbit burn."
SCMP also reported some details: "A copy of an official memo circulating on social media warned staff and visitors to the launch site not to film the lift-off or discuss it online. The

document also said "all units should strengthen personnel security education and personnel management during missions to ensure that there is no leakage of secrets." A military source confirmed the authenticity of the document, saying: "There are many firsts in this launch. The spacecraft is new, the launch method is also different. That's why we need to make sure there is extra security." The source declined to comment on the details of the mission but suggested "maybe you can take a look at the US X-37B".

2020-064A
07 September 2020 - 05:57 UTC (13:57 BJT)

launch site: Taiyuan Satellite Launch Centre - TSLC
launcher: Chang Zheng 4B - CZ-4B
payload: Gaofen 11-02 (GF-11-02)

GF-11-02 is a optical remote-sensing satellite and has a resolution in the sub-meter range. It will be mainly used for land surveys, city planning, land registration work, road network design, crop yield estimation and disaster prevention and mitigation. The new satellite will also offer information support for the Belt-and-Road construction. Gaofen 11-02 will be operated together with the Gaofen 11-01 satellite, launched in 2018. There was no other information available.

2020-008F failure
12 September 2020 - 05:02 UTC (13:02 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC
launcher: Kuaizhou 1A - KZ-1A
payload: Jilin 1-Gaofen 02C

The optical remote-sensing satellite Jilin 1-Gaofen 02C failed to enter the preset orbit because of abnormal performance during the rocket's flight. The cause of the failure was under investigation. Out of 10 Kuaizhou-1A missions it was the 1st failure and the 4th Chinese failure of 2020, out of 26 launches so far.
Jilin 1 Earth observation satellites are developed and operated by Changguang Satellite Technology Co. Ltd. (CGST), a commercial spin-off of Changchun Institute of Optics, Fine Mechanics and Physics of the Chinese Academy of Sciences. There were reports that the satellite was also assigned the name Neimonggol 1 (Inner Mongolia Satellite 1) what might be related to a cooperation with that region.

2020-065A 2020-065B 2020-065C
2020-065D 2020-065E 2020-065F
2020-065G 2020-065H 2020-065J
15 September 2020 - 01:23 UTC (9:23 BJT)

launch site: Debo 3, Yellow Sea
launcher: Chang Zheng 11 - CZ-11
payloads: Jilin 1-Gaofen 03B-01, Jilin 1-Gaofen 03B-02, Jilin 1-Gaofen 03B-03, Jilin 1-Gaofen 03B-04, Jilin 1-Gaofen 03B-05, Jilin 1-Gaofen 03B-06, Jilin 1-Gaofen 03C-01, Jilin 1-Gaofen 03C-02, Jilin 1-Gaofen 03C-03

The 2nd sea-launched CZ-11 flight took off the coast of Haiyang from the electrically self-propelled barge Debo 3. The Taiyuan Satellite Launch Centre was responsible for launch operations. Debo 3 has a length of 159.6 m, a width of 38.8 m, a depth of 10.9 m. When reaching its maximum loading capacity of 20,500 t, its displacement is 12,000 t and maximum speed is 12 knots. Debo 3 was originally build for emergency rescue, sea salvage and transporting very big hardware for offshore industries, like oil rigs.
All mission preparations and countdown operations were conducted from the command and control ship Beihai Jiu 101, positioned in the launch zone. 13 min after launch, the CZ-11 placed 9 Gaofen imaging satellites into a 535 km orbit. The satellites, built by Chuangguang Satellite Technology, are based on the Jilin 1-Gaofen 03A. They are box-shaped with one solar panel and an optical payload. Each of the satellite has a mass of around 42 kg. They have improved characteristics such as a lightweight structural design, an integrated electronic system, low-cost, quantitative cameras, low power consumption, low weight, and high-resolution imaging capacity. The 6 B-satellites are equipped with a pushbroom imager of 1 m resolution. The other 3 are video satellites of which one is for video sharing platform Bilibili and another for CCTV. Bilibili lost its 1st video satellite in the failed debut of the Kuaizhou 11 rocket in July. The company intends to offer high-quality color videos views of space and the Earth to the public. In the future, the satellite will also provide customised service for Bilibili users.


CZ-11 sea launch. Credit: Shi Xiao/Chinadaily.com.cn

The satellites, including the video satellites for Bilibili and CCTV, joined the Jilin 1 constellation. Its data will be used for land resource survey, urban planning, disaster monitoring and other purposes. The full constellation is intended to consist of 138 Earth observation satellites, capable of global coverage 5-7 times a day.

2020-066A
21 September 2020 - 05:40 UTC (13:40 BJT)

launch site: Jiuquan Satellite Launch Centre - JSLC
launcher: Chang Zheng 4B - CZ-4B
payload: Haiyang 2-03 (Haiyang-2C, HY-2C)

HY-2C is China's 3rd ocean environment satellite. Placed in an 66° inclination orbit, it will form a network with the HY-2B launched in 2018 and HY-2D planned for 2021 to carry out 24/7 all-weather high precision monitoring of maritime data including sea surface height, wave height, wind and temperature as well as oceanic water colour. The constellation can provide every 6 hours wind data of 80 % of the world's sea surface. The satellite has a radiometer, a radar altimeter, a scatterometer and a microwave imager. Another instrument on board can provide information on the identification of vessels, and to receive, store and transmit buoy measurement data in China's offshore and other marine areas. HY satellites play a key role in China's ocean resource surveys, disaster relief and environment management. HY-2C was developed by DFH Satellites based on the CAST 968 satellite bus. The 1.5 t satellite is box-shaped with a payload section and a controllable solar panel. The Ministry of Natural Resources is responsible for the satellite operation.
The 1st stage of the CZ-4B was equipped with 4 grid fins. It was the 2nd test of grid fins for limiting the drop zone (1st time: 2019).

2020-067A
2020-067B
27 September 2020 - 03:23 UTC (11:23 BJT)

launch site: Taiyuan Satellite Launch Centre - TSLC, LC9
launcher: Chang Zheng 4B - CZ-4B
payloads: Huanjing 02A (HJ-2A), Huanjing 02B (HJ-2B)

The 2 environmental monitoring satellites were launched with little announcement. Both identical box-shaped satellites

were built by CAST and are based on the CAST-2000 satellite platform bus. They are complemented by a box-shaped payload section containing 2 hyperspectral imagers (IRMS und HSI) of 48 m resolution and 1 multispectral instrument (WVL) of 16 m resolution. The satellites also host an infrared imager and an instrument for atmospheric sonding. Power supply is provided by 2 solar panels. HJ-2A and HJ-2B are characterised by high mobility, precision control and stability, as well as high payload adaptability and long operational life.
The satellites will replace the HJ-1A and HJ-1B, the previous generation of environmental monitoring satellites, to provide services concerning environmental protection, natural resources, land utilisation, water conservancy, agriculture and forestry. They will operate together with the Gaofen 1 and 6 satellites.


The HJ-2 engineers with the 2 satellites in the clean room. Credit: CAST

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

http://news.xinhuanet.com
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https://www.nasaspaceflight.com
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http://www.planet4589.org/space/jsr/jsr.html
http://www.spaceflightfans.cn/
https://dongfanghour.com/

AIR	Aerospace Information Research Institute
AIS	Automatic Identification System
AIT	Assembly, Integration & Test
AO	Announcement of Opportunity
APSCO	Asia-Pacific Space Cooperation Organisation
ASAN	Advanced Small Analyzer for Neutrals
BACC	Beijing Aerospace Control Centre
BDS	BeiDou satellite navigation System
BIT	Beijing Institute of Technology
BJT	Beijing Time
BNU	Beijing Normal University
BRI	Belt-and-Road Initiative
CALT	China Academy of Launch Vehicle Technology, 1st Academy of China Aerospace Science and Technology Corporation CASC
CAS	Chinese Academy of Sciences
CAS	Chinese Astronomical Society
CASC	China Aerospace Science and Technology Corporation
CASIC	China Aerospace Science and Industry Corporation
CAST	China Academy of Space Technology
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
CONAE	Comisión Nacional de Actividades Espaciales - Argentina National Space Activities Commission
CSES	China Seismo-Electromagnetic Satellite

CSS	Chinese Space Station/China Space Station
CSU	Technology and Engineering Centre for Space Utilisation
CZ	Changzheng, Long March
DBAR	Digital Belt-and-Road Programme
DFH	Dong Fang Hong
EO	Earth Observation
FAST	Five-hundred Metre Aperture Spherical Radio Telescope
FY	Fengyun
FYESM	Fengyun Meteorological Satellites in Disaster Prevention and Mitigation
GECAM	Gravitational-wave high-energy Electromagnetic Counterpart All-sky Monitor
GEO	Geostationary Orbit
GF	Gaofen
GNSS	Global Navigation Satellite System
GRAS	Ground Research Application System
GTO	Geostationary Transfer Orbit
HY	Hongyun
HY	Haiyang
HXMT	Hard X-ray Modulation Telescope
IAU	International Astronomical Union
ICG	International Committee on Global Navigation Satellite Systems
IoT	Internet of Things
ICAO	International Civil Aviation Organisation
LEO	low Earth orbit
LEOP	launch and early orbit phase
LFRS	Low-frequency Radio Spectrometer
LND	Lunar Lander Neutron and Dosimetry
LOX	liquid oxygen
LPR	Lunar Penetrating Radar
LRO	Lunar Reconnaissance Orbiter
MEO	medium Earth orbit

NSSC	National Space Science Center
P/L	payload
PNT	Positioning Navigation and Timing
PPP	public-private partnership
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
SQX	Hyperbola
SSC	Sweden Space Corporation
SSEC	Space Science and Engineering Centre
SSO	Sun-Synchronous Orbit
SVOM	Space Variable Objects Monitor
SZ	Shenzhou
TW	Tianwen
TQ	Tianque
TT&C	Space Telemetry, Tracking and Command Station
UAV	unmanned aerial vehicle
UN	United Nations
UNOOSA	UN Office for Outer Space Affairs
UTC	Coordinated Universal Time
VLBI	Very Long Baseline Interferometry
VTVL	vertical takeoff, vertical landing
WMO	World Meteorological Organisation
YT	Yutu
YW	Yuanwang
ZQ	Zhuque
ZY	Ziyuan

Imprint

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Designing the China-Russia lunar base
Critical role of Chang'e 8 mission

by Brian Harvey

The agreement in March 2021 on a planned Chinese-Russian lunar base, formally confirmed at the GLobal EXploration (GLEX) conference in St Petersburg in June, sent ripples through the world press **(1)**. The International Lunar Research Station (ILRS) may well signal a realignment of the 'space world' between the United States, Europe, Japan and allies on one hand; and China and Russia on the other. As the designers get to work, it is useful to consider the technical contributions that each of these two parties can 'bring to the party', especially the person emerging as the lunar base chief designer on the Chinese side, Professor Guo Linli.

Before examining the Chinese contribution in detail, it is important to appreciate the heritage of its partner, the Russian side. The Soviet Union had always intended that its first lunar landing be a prelude to ever-longer semi-permanent and permanent occupations. Chief designer Vasili Mishin commissioned the original design study, *Principles of the construction of long-term functioning lunar settlements* (1969) compiled by the builder of cosmodromes, Vladimir Barmin and his construction company KBOM, called *Galaktika* and also informally 'Barmingrad'. In 1974, the next chief designer, Valentin Glushko, commissioned the study *Zvezda*, compiled by Vladimir Prudnikov, to suit the more straightened circumstances of the programme at the time. In further preparatory work on the ground, the Institute of Bio-Medical Problems (IBMP) ran simulations of long-duration spaceflights, one of a year (1967-8); while in Krasnoyarsk Iosef Gitelson developed closed cycle systems for food and water called Bios (1964-84), essential for a functioning lunar base. Although one could say that the most concrete outcome was a plastic model set sold in the children's store, *Detsky Mir*, the Soviet Union did build up a strong theoretical and practical foundation for constructing a lunar base.

Lunar bases: the Russian heritage. Credit Roskosmos

The Soviet lunar programme effectively ended with Luna 24 in 1976. Its resumption in recent years, as set down by the Lavochkin design bureau, was based on a series of landers, orbiters and rovers (Luna 25-8) preceding a new-style, two-stage lunar polar base, 'Luna Polygon'. Here, an automated lunar base, a common landing point for robots, would pave the way for later human occupation. For this purpose, Russia began in the 2010s developing a new piloted spacecraft (PTK-NP, then *Federatsiya*, then *Orel*, then *Orlyonok*) for human lunar flight and new heavy-lift launchers (Soyuz 5, Angara), their iterations changing shape numerous times. Reminiscent of the 1960s, simulation lunar missions were run and continue under the Sirius programme.

What could China bring to this party? Its principal early contribution was the Yuegong 'lunar palace' closed cycle laboratory, developed by Moscow-educated Liu Hong and her team. This ran a 105-day mission in 2014 and then a year (2017-2018), producing important results in the fields of food, liquids, air circulation, health and psychology. Design work began on a launcher capable of reaching the Moon, the CZ-9, while a spacecraft capable of piloted lunar flight was tested, the Shiyan Zhwang Zhi (2016) and Xinyidai Zairen Feichuan Shiyan Chuan (May 2020).

The other part of the jigsaw was lunar base design. First mention of the idea was by the veteran Moon campaigner, Ouyang Ziyuan, who in *Academicians envisaging the 21st century* issued to mark the new millennium, outlined the building of a lunar base from first landfall to a self-sufficient colony, drawing an analogy with China's polar base on Earth, the *Xuelong*. The key personality to emerge here was Guo Linli of the China Academy of Space Technology (CAST) and the Dong Fang Hong Satellite Company, who presented *A manned lunar base* in 2014, although her subsequent presentation to the GLobal EXploration (GLEX) conference in Beijing in summer 2017 attracted more attention **(2)**. At the Vienna COPUOS in 2018, China proposed an Unmanned Lunar Research Station for 2030 (similar to Luna Polygon), to be followed by an occupied one, called the International Space Research Station (ISRS) **(3)**; followed by *Living on the Moon - a Chinese conceptual lunar base* (2019). This was the background to the 2021 agreement publicized at the 2021 GLEX.

As this shows, Russian and Chinese thinking and planning seem to be converging, independently of one another, at the same point, even with similar language. One version even anticipated the 2021 agreement by including Luna 27 on the site. Guo Linli herself was familiar with international studies, being a member of the Moon Village Association, the Global Expert Group on Sustainable Lunar Activities and the editorial board of *Space: Science and Technology*.

What was different about Guo Linli's ideas, compared to the Russian studies, was that it took advantage of new technologies; the Yuegong experience; and In Situ Resource Utilization (ISRU) which had been unknown to the creators of *Galaktika* and *Zvezda*. Guo Linli proposed not only traditional rigid modules, but inflatable ones (one built by Bigelow was already attached to the American segment of the International Space Station, so the concept was proven) and modules constructed by 3D printing. Her proposals for biological regenerative systems, microbial waste treatment and growing food (e.g. plants, mealworms) referenced and drew on Yuegong. Power came from solar cells, nuclear sources and fuel cells which would electrolyze water and oxygen (ISRU). Physically, the design comprised three modules in a T-shape: living cabin; experiment cabin; and support cabin (energy, supplies and pressurized hatch). On the surface in the immediate vicinity were automated spacecraft, rovers, landers, vertical solar panels and transmission dishes, with an Earth low on the horizon casting a dim ghostly blue light on the base.

One of the most important expositions of Chinese thinking was evident in a presentation by Guo Linli (CAST) with Michel Blanc

(France), called *Relevant technologies and validations assumptions for ISRU* **(4)**. Here the importance of the Chang'e 8 mission becomes apparent. As is already known, Chang'e 6 is to match the Chang'e 5 sample return, but by returning rock from the lunar south pole. Chang'e 7, also at the south pole, will focus on on-site examination and analysis of the lunar soil while deploying a small rover and flyer. Chang'e 8, also at the south pole, will take this a stage further with active ISRU experiments. Its 300 kg laboratory is located on the flat top of the spacecraft, location of the return cabin on Chang'e 5.

After unfolding its solar panels, Chang'e 8's first task is to deploy its remote arm, which will collect up to 100 g of samples from the regolith and lift them in to the laboratory, where they will be placed in a small sealed electrolytic high-temperature furnace (there will be four). This furnace will then operate, heat up to 2,000˚C for 2 hr to separate the oxygen from other gases. Each furnace is in the shape of a drum using 500 W power for a platinum rhofium thermocouple electrode. It is hoped to turn 16% of the sample into oxygen which will then be fed into an oxygen tank. The composition of the other gases will be measured. Knowing that ISRU works will be a key point in determining the nature of the lunar base.

ILRS the plan. Credit CNSA. Roskosmos

The first formal iteration of the design of the Russia-China International Lunar Research Station was published in June 2021 to accompany the announcement in St Petersburg. It outlines the precursor missions (Luna 25-8, Chang'e 6-8); the rocket development required (CZ-9, Angara); five stages of developing the ILRS (1-5); prospective location (e.g. Amundsen crater); and the opportunities for international cooperation. The illustrations are broadly in line with what has already been published in the Lavochkin Luna Polygon studies and those of Guo Linli in CAST. There are some additions to the base now: an energy module, a telecommunications mast and module, 'hopping robots' and 'intelligent mini-rovers'.

At present, the ILRS prospectus has been circulated worldwide to invite the participation of interested countries and institutes. Over the next number of years, we may expect that precursor missions (notably Chang'e 8) and the development of new rockets and piloted spacecraft will proceed in parallel with the elaboration of Moon base design that draws on both the long-standing Russian heritage and the more recent work by Guo Linli in China.

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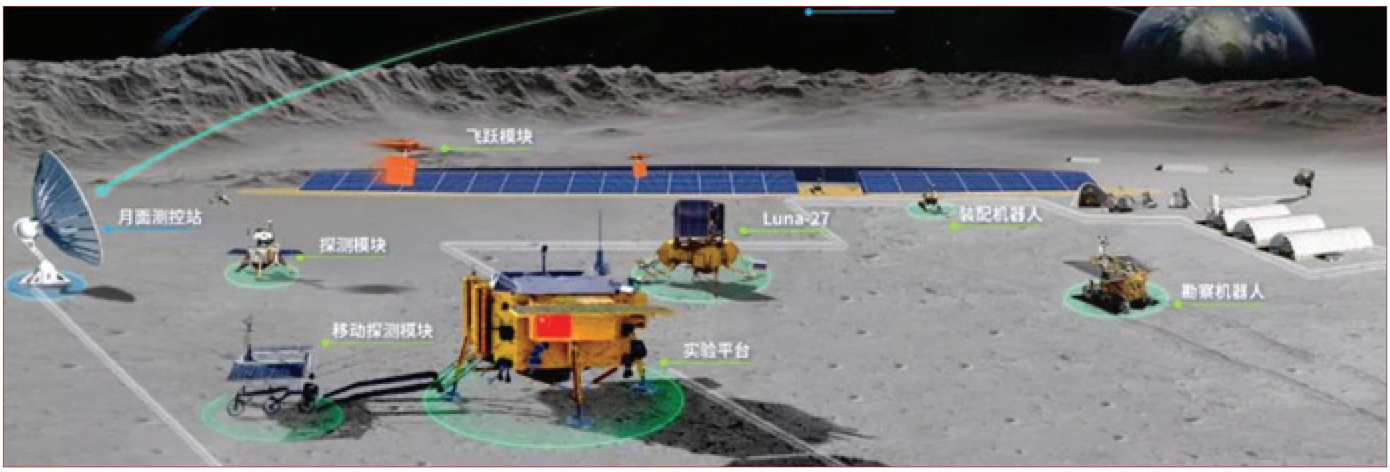
Russia China agreement March 2021



The base at an early stage. Note Luna 27

Following Yuanwangs during a high-profile year

by Brian Harvey

Context

This is the fourth, concluding article in the *Following Yuanwang* series (GT 26, 27, 31) examining the movements of the Chinese space tracking fleet over August 2020 to July 2021. This period saw the launch of Chang'e 5 to the Moon (November), the Tianhe space station (April) and the subsequent launches of the Tianzhou 2 cargo ship (May) and the Shenzhou 12 piloted spacecraft (June), all critical missions during a high-profile year for China. To repeat the finding of the earlier articles, the tracking ships are not used for all Chinese space missions but focus on human spaceflight; deep-space (Moon and Mars); new heavy launchers (CZ-5, 7); and missions to 24 hr or geosynchronous orbit, (e.g., communications, weather satellites). With the completion of the Beidou navigation satellite network, launches to 24 hr orbit are now fewer. The tracking ships are not routinely used for CZ-2, 4, 6 and 11 launches of smaller satellites into low Earth orbit. The purpose of these articles is to follow the fleet's activities; get a picture of their pattern of operations, especially their locations; and see what light they can shed on the space programme as a whole.

	Date	Spacecraft	Tracking ship
2020	11 October	Gaofen 13	YW-5 mid-Pacific
2020	24 November	Chang'e 5 launch	YW-5 south Pacific YW-3 and YW-6 in: Indonesian archipelago
2020	16 December	Chang'e 5 re-entry	YW-3 Arabian Sea YW-6 western Australia
2021	20 January	Tiantong 1-03	YW-5 mid-Pacific YW-7 Davao
2021	4 February	TJSW 6	YW-5 mid-Pacific
2021	12 March	Shiyan 9	YW-3, 5 Pacific YW-6 in Singapore Straits
2021	29 April	Tianhe	YW-5 Leyte YW-6 Sunda Islands
2021	29 May	Tianzhou 2	YW-5 Carolines YW-6 Leyte
2021	2 June	Fengyun 4B	YW-5 Carolines YW-5 Leyte
2021	17 June	Shenzhou 12	YW-5 Carolines YW-6 SE Japan
2021	6 July	Tianlian 1-05	YW-7 Carolines YW-3 Indian Ocean

Table 1: Missions tracked by Yuanwang tracking ships, August 2020-June 2021.

First, for those new to Yuanwangs, 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. They are a substantial investment of human and financial resources. Our knowledge of their movements is based on their continuous, 'live' location signals and daily or more periodic beacon position reports, in this case picked up by Marine Traffic in Greece. Such signalling should be seamless, but in practice there can be lengthy gaps between signals; differences between reported locations and 'live map locations', so inferences must be made in some instances. In the past year, one mystery has been solved, which was the repetitive movements of Yuanwang 6 up and down the south-east coast of China, which were strange for a tracking ship. As suspected, it was not Yuanwang 6 at all, but a busy bulk carrier with an erroneously attributed beacon. This does mean, though, that we have a long gap in data from the real Yuanwang 6 during this time.

Tracking is essential for obtaining downlink data from spacecraft in distant destinations out of Line Of Sight (LOS) of the Chinese landmass (e.g. Moon, Mars); for the later stages of launches as they head out over the Pacific and enter orbit; for end-of-first-orbit burns to 24 hr orbit or deep-space and their subsequent outward journey; for spacecraft returning from the Moon (e.g. Chang'e 5); and for critical moments of re-entry of piloted spacecraft. Put negatively, lack of data when something goes wrong means the lack of telemetry data to indicate the problem. When the CZ-5 failed over the Philippines in 2017, telemetered data was likely important in determining the nature and sequence of the problem.

China, like the USSR earlier but unlike the United States, lacked friendly overseas nations where it could base a network of ground tracking stations sufficient to provide global tracking of space missions. China does now have ground bases in Swapokmund, Namibia and Neuquen, Patagonia. It has also benefitted from the use of facilities in Malindi, Kenya; Karachi, Pakistan; and Dongara on Australia's west coast. Other stations have been accessed on an *ad hoc* basis (e.g., Addis Ababa, Ethiopia; Santiago, Chile).[i] The use of Dongara was withdrawn in September 2020, while China's continued use of ESA's facility in Malindi, Kenya has not been reported for some time. The fact that Tianlian 1-03 is now stationed over this former location suggests not. Chang'e 5 recovery maps indicated a tracking site in Pakistan (presumably Karachi), so presumably this is still available.

Tracking ships are important for filling gaps in land-based coverage. There have been a number of consistent locations for tracking ships: east of the Philippines, the entry-to-orbit point for rockets ascending from Wenchang launch site, Hainan; mid-Pacific for the long gap in the land mass between Asia and America, at varying equatorial points eastward; and south Pacific, about 20°S in the Cook Islands. Earlier articles identified other locations, such as west of Australia and the sea coast near Argentina and Uruguay.

Normally at least one tracking ship is in home port of Jiangyin, Shanghai at one time for cyclical maintenance, so up to three are available at any one time. The quietest period is normally the Chinese New Year holiday (mid-January to March) when launches are avoided. The distinctive tracking ships often attract curiosity when calling in to ports en route like Suva, Fiji, frequently used; and Durban, South Africa.

Generally, the tracking ships are either in home port; travelling to and from their destinations, generally at speed; in a foreign port (e.g. Suva); or circling at low speed or Dead In Water (DIW), when they are tracking or awaiting a tracking event. It is assumed that they do not track when travelling at high speed nor when in foreign port, for they would likely come under observation if they did.

Another important element of the tracking network is the space-based Tianlian system in 24 hr orbit, analogous to the American TDRS system. The fifth Tianlian, 1-05, was launched on 6th July 2021, at the end of the period under study. The graphic on page 32 shows the location of Tianlian 1-03 (east Africa), 1-01 (Indian Ocean) and 1-04 (mid-Pacific) (1-02 was not indicated and may not be in service, nor was Tianlian 2-01 shown). Finally, a note that Chinese press announcements on the role of the ships are intermittent and often non-specific, especially about locations, so the interpretations here are those of the writer based on the raw data of the beacons. The reader should bear in mind the 'join-the-dots' nature of this research, that some dots are far apart and that this narrative is based on interpretation of sometimes limited data.

Tracking ship movements, August 2020 - July 2021

At the start point, August, Yuanwang 3 was still in port for a continuing, prolonged period of maintenance and repair. Yuanwang 5 had returned to Shanghai on 10th August after 55 days, having been in the Pacific to cover the early stages of the Tianwen 1 mission to Mars and the launch of the Apstar 6D communications satellite. Similarly, Yuanwang 7 returned from the Pacific to home port on 15th August. The situation of Yuanwang 6 is unclear, for its beacon was turned off, but it may have been in the Atlantic.

Yuanwang 3

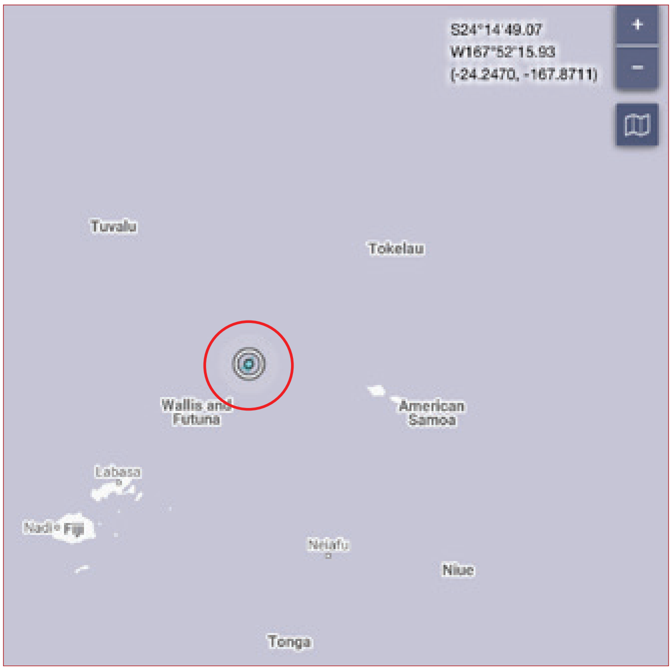
Yuanwang 3 's long period in port ended when it left Shanghai on 20th November 2020 for the Chang'e 5 mission (see text box: *"Tracking the Chang'e 5 Moon mission"*). In the new year, Yuanwang 3 stayed in port until 20th February 2021 for its first excursion of the year, with the reported destination of the Pacific. Yuanwang 3 sailed through the Philippine Sea (23rd February), past Palau (26th February), reaching the Carolines the following day and Micronesia on 1st March. The principal launch in mid-March (the 12th) was Shiyan 9 on the CZ-7A, so that was its likely purpose. Three days later, Yuanwang 3 was on the equator in the Marshall Islands at 166°E heading back west, through the Carolines on 19th March and was back in port (Nantong, near Shanghai) on 24th March, then Jiangyin the next day. This appears to be a classic, out-and-back for one mission tracking operation.

Yuanwang 3 was not at sea again until 16th May, looking as if it might be sailing to track Tianzhou 2. Surprisingly, it did not go very far, ending up in the Zhoushan anchorage down the coast on the 19th, staying there for some time and returned to Shanghai the following month. On 18th June, Yuanwang 3 set out with an announced destination of the Indian Ocean. The ship sailed past Vietnam on 21st June, was through the Indonesian islands 23rd June and reached the southern Indian Ocean at 16°S, 96°E by the 27th June. The only upcoming launch was the Tianlian 1-05, which took place on 5th July. By 16th July, Yuanwang 3 was in the Ruau archipelago, west of Borneo, heading home via Singapore. Thus, it seems that Yuanwang 3 was used for Chang'e 5 (see text box: "*Tracking the Chang'e 5 Moon mission*"); Shiyan 9; and Tianlian 1-05.

Yuanwang 5

Yuanwang 5 began the first journey of the period on 25th September, passing through the Philippine Sea on the 27th, past Palau on the 29th and was at a typical, previously-used position east of Roreti in the Gilbert Islands on 7th October, west of Baker Island and Howland Island, almost on the equator at the international date line. It was most likely there for the launch to 24 hr orbit of Gaofen 13 on 11th October on the CZ-3B from Xi Chang. The day before, Yuanwang 5 announced a new port destination in Fiji. Announcing a new port *before* the key point of a mission has been reached may be tempting fate but is not unusual and, in the event, Yuanwang 5 did not get to Suva, further south, until 28th October. It stayed there only two days before lying offshore in early November, presumably awaiting Chang'e 5 later in the month (see text box: *"Tracking the Chang'e 5 Moon mission"*).

By mid-January 2021, Yuanwang 5 was back in mid-Pacific, again east of Tuvalu and travelling at low speed. It is likely that it tracked Tiantong 1-03 on 20th January, but following the earlier precedent announced the previous day its intention to travel to Suva, where it arrived on the 24th January. After only three days,



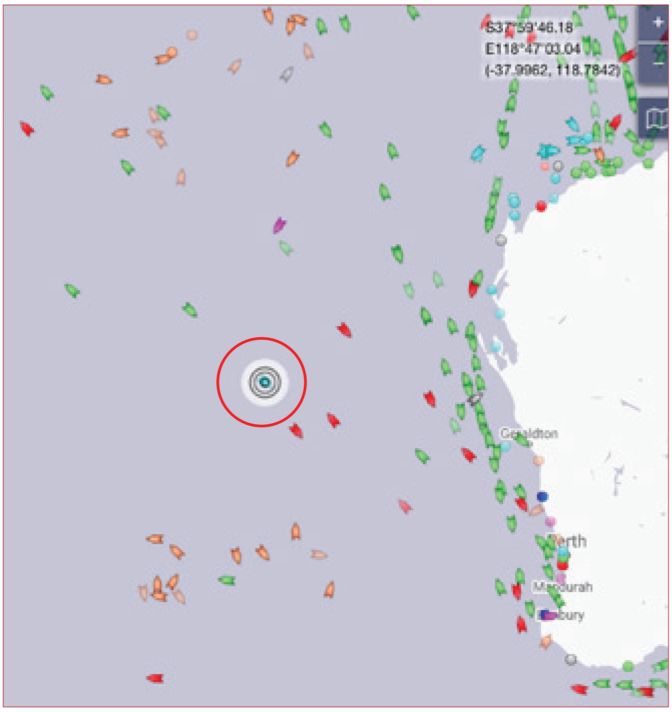
Yuanwang 5 in a typical location in the south Pacific on 2 February 2021. Credit: Marine Traffic/Google Maps

the ship left for Samoa and by the 31st was back east of Roreti, travelling at slow speed and then DIW till mid-February. It was in a good position to track TJSW-6 on 4th February, probably the only ship to do so, before putting into Suva again on 19th February. The ship left Suva a week later on 26th February, heading north east back to its previous locations and was most likely there for Shiyan 9 on 12th March. On 15th March it was in mid-Pacific on the equator at 179°E, the international date line and then returned home slowly through the Carolines (20th March), Taipei to the west and Naha to the east (25th March) and was back in home port on 27th March. Thus, both Yuanwang 3 and Yuanwang 5 were back in port by the end of March, joining Yuanwang 7, leaving only Yuanwang 6 at sea in the Singapore Straits. Yuanwang 5 was then part of the fleet following the space station (see text box: *"Space station: tracking Tianhe, Tianzhou 2 and Shenzhou 12"*)

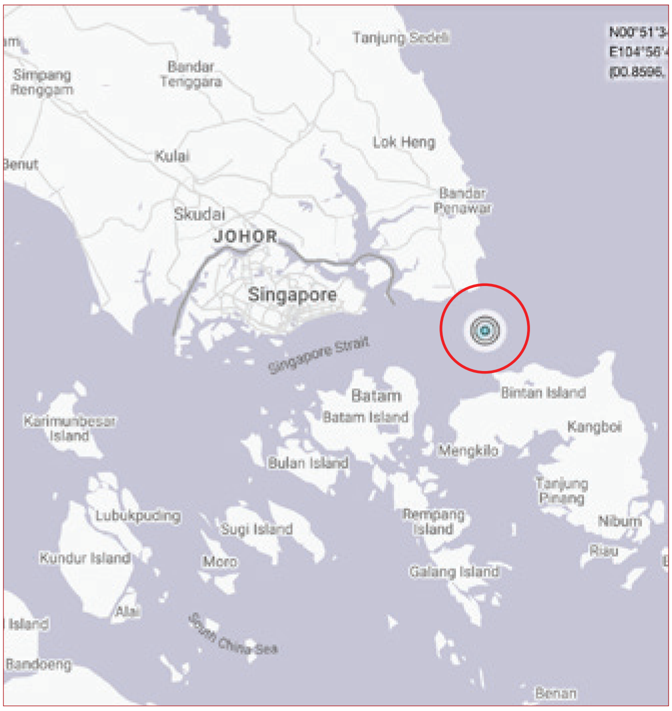
Yuanwang 6

There was a substantial press report on Yuanwang's departure from Shanghai on 13th July for an 18,520 km 100-day journey in the Pacific, Indian and Atlantic Oceans.[ii] China launched on 4 September an experimental, re-usable space craft where very little information became public. It might be that Yuanwangs were involved in that mission. Correct signals for Yuanwang 6 were not available until 22nd September when it left Durban, South Africa, apparently on its way home past Sumatra (4th October), Ho Chi Minh City (8th October), reaching Shanghai on the 13th October (about 100 days). Its signals thereafter were quite intermittent, with a single signal identifying it in the Singapore anchorage on 11th December. It is surprising that there were no press reports from Singapore about this or subsequent visits. Yuanwang 6 tracked Chang'e 5's Earthbound journey to re-entry on 16th December from the western Australia tracking location (see text box: *"Space station: tracking Tianhe, Tianzhou 2 and Shenzhou 12"*), but did not return immediately, staying on there for 12 days, which coincided with Yaogan 33 (*see: Discussion and conclusions*).

Yuanwang 6 was in port in January 2021, leaving in mid-February, passed Leyte in the Philippines on 15th February, heading south and reaching the Molucca Sea on 17th February, the Banda Sea the next day, heading west of Timor on the 19th into the Greater Sunda Islands. The use of the



Yuanwang 6 off West Australia on 18 December 2020.
Credit: Marine Traffic/Google Maps

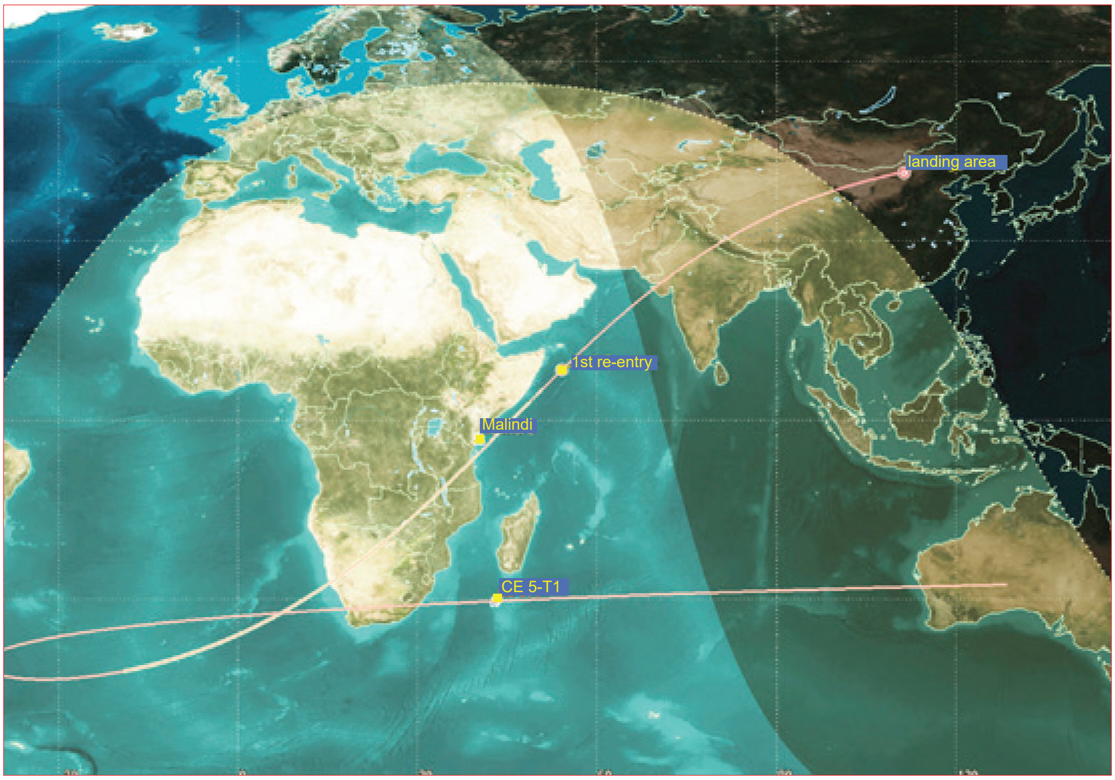


Yuanwang 6 in the Singapore Straits on 6 March 2021.
Credit: Marine Traffic/Google Maps

Indonesian archipelago as a tracking location has been a feature of this period. Yuanwang 6 spent some time in the Banda Sea, the Savu Sea and then the Sunda Islands to their south, the only launching during this period being Yaogan 31 group 3 on the 21st (*see: Discussion and conclusions*). Three days later, Yuanwang 6 announced a new destination of Singapore, for which it travelled south coast of Java, past Jakarta 26th February into the Java Sea and arriving in Singapore port on 1st March. After presumably taking on fresh supplies, the ship took up a low speed or DIW position in the Singapore Straits for March, a strange location granted the high traffic level in the area and the danger of collision. It would have been there for Shiyan 9 (12th March) and Yaogan 31 group 4 on the 13th, following which it travelled to the western Australia location, arriving on 24th March, where it waited DIW. The only upcoming launch was Shiyan 6-03 on 8th April. By 15th April, when signals resumed, Yuanwang 6 was in the Banda Sea north of Jakarta; south of Java the following day and DIW among the Sunda Islands on 18th April, well ahead of the CZ-5B launch on the 29th April and, for that matter, Yaogan 34 the following day. Yuanwang 6 must have returned to port soon thereafter, because it was heading out of Shanghai on 23rd May in time for the Tianzhou 2 launch (see text box: *"Space station: tracking Tianhe, Tianzhou 2 and Shenzhou 12"*).

Yuanwang 7

Apart from its participation in the Chang'e 5 mission, we have no reports on Yuanwang 7 for the second half of 2020. Yuanwang 7 left Shanghai on 15th January for the East China Sea. The principal mission at this time was Tiantong 1-03 on 20th January, when Yuanwang 7 was east of Davao, Mindanao in the Philippines, sailing on to the Banda Sea on 23rd January, but four days later announcing its return to Shanghai. This part of the mission coincided with Yaogan 31 group 2 on 29th January. The ship then steamed past Timor, through the Celebes Sea



The Chang'e 5-T1 inbound path over Australia projected on a map and also showing Malindi ground station. Credit: Luciano Anselmo

Tracking the Chang'e 5 Moon mission

The Chang'e 5 mission to recover Moon rock would inevitably place a heavy burden of responsibility on the tracking fleet. The mission involved a complex series of manoeuvres around the Moon, including rendezvous and docking, some stages of which would undoubtedly take place when the Moon was out of line of sight from China's ground stations; tracking the spacecraft during the return to Earth; and following the narrow re-entry corridor over the Indian Ocean. We know from the Soviet Luna recoveries that mission controllers faced difficult choices as to which parts of their missions should be controlled from land, or from tracking ships at sea. 24th November was the launch date for Chang'e 5, with the 16th December the date of sample return. Yuanwang 7 seems to have remained in port for the mission.

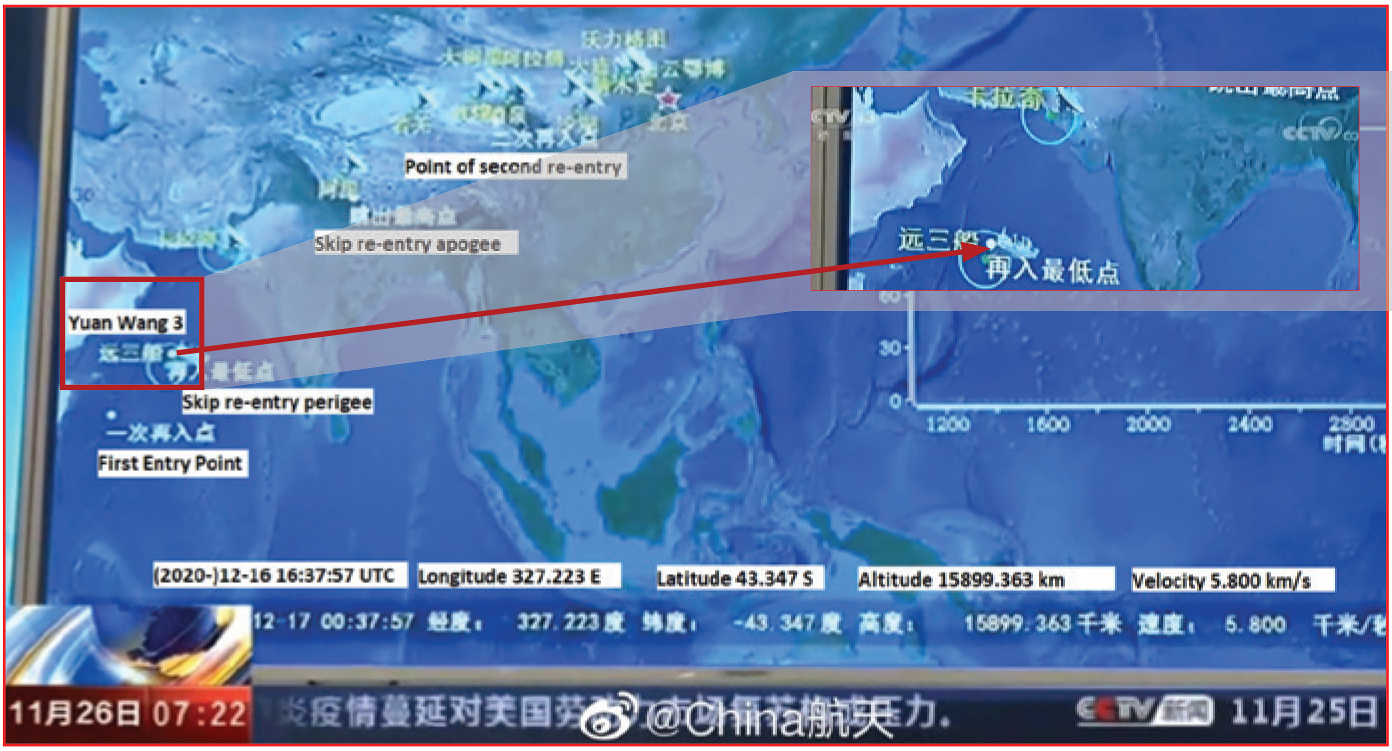
Some mapping data was unavailable during the mission but was reconstructed from position reports, but it appears that Yuanwang 5 and 6 were already at sea, confirmed by press announcements. They were joined by Yuanwang 3, which left Shanghai also on 20th November, reported in the press. At the time of the launch, Yuanwang 3 was in the Java Sea; Yuanwang 5 far away in the Pacific in the Cook Islands at 159°W; and Yuanwang 6 in the Celebes Sea. We know from the Chang'e 5-T1 mission that Trans Lunar Injection (TLI) began over the mid-Pacific (7.9°N, 158°E) and we have Yuanwang 5 underneath its path at 17°S, 159°W.[iv] Yuanwang 5 stayed in the Pacific during the Moonbound part of the mission.

As the mission proceeded, Yuanwang 3 stayed in the Indonesian archipelago off the Sunda Islands while Yuanwang 6 lay off Borneo, then the Java Sea. On 4th December, Yuanwang 3 was DIW off Sumatra and Yuanwang 6 was on its way to Singapore where it stopped. Yuanwang 3 now sped across the Indian Ocean, passing south of Sri Lanka on 8th December, reaching its tracking station for the re-entry at 60°E off Oman, where it circled. Yuanwang 5 must have left its Pacific Island location, for by 9th December it was returning home past the Philippines, joining Yuanwang 7 in port on 11th December.

Yuanwang 6 left Singapore on 9th December for a traditional tracking location west of Australia where it was circling at the time of re-entry. For this key moment, China had two ships at sea: Yuanwang 6 off western Australia and Yuanwang 3 off Oman. The fact that Yuanwang 3 was off Oman and Tianlian 1-03 over East Africa is strong evidence that the ground tracking station in Malindi was no longer available or in use. During the return to Earth of Chang'e 5-T1, China found it sufficient to rely on the Malindi station for this critical phase. Likewise, the location of Yuanwang 6 off western Australia is also significant. During its return journey to Earth, this location was directly in the line of sight of the returning Chang'e 5-T1, so it is likely to be the case here too.[v]

After recovery, Yuanwang 3 put in in Salalah, Oman, a hitherto unused supply port on 19th December, presumably for fresh supplies and appears to have been leaving on the 28th December. Yuanwang 6 did not yet return and continued to circle west of Australia: the only mission during this period was the single Yaogan 33 on the 27th December (*see: Discussion and conclusions*). The next day, it issued a 'return to Shanghai' notice. It is reasonable to presume that Yuanwang 3 and 6 were also back in port early in the western New Year.

In summary, the tracking locations for launch were far Pacific (Yuanwang 5) and Indonesia (Yuanwang 3 and 6); while for re-entry, they were west of Australia (Yuanwang 6) and the Indian Ocean off Oman (Yuanwang 3). Several ships were on the move during the mission, suggesting that tracking was less necessary then, automated, or that there was sufficient line of sight with the Chinese landmass.



top: The position of Yuanwang 3 during Chang'e 5's skip re-entry. Credit: CCTV/Waibo

insert - top right: Close-up of the screen in mission control showing the position of Yuanwang 3 during Chang'e 5's skip re-entry. Credit: CCTV/Waibo and reached Shanghai on 6th February. The TJSW-6 launch was on 4th February, but unless it slowed in the course of its fast return journey it is unlikely to have tracked it.

Yuanwang 7 stayed in port until 17th May, but the following day travelled to the Zhoushan anchorage down the coast from Shanghai, where it was joined by Yuanwang 3. This is a big archipelago not used before, at least in recent years and whose function remains obscure. It is possible that Jiangyin or other anchorages about were not available. Although Yuanwang 3 returned quickly to Shanghai, Yuanwang 7 stayed there into mid-June. In early July, it was reported that Yuanwang 7 had left anchorage to follow the launch of Tianlian 1-05 into geostationary orbit, the mission taking place on 6th July.[iii] At the end of June, Yuanwang 7 was in the Carolines where, presumably, it tracked Tianlian 1-05.

Concluding the story of the ship movements, by 8th July 2021, Yuanwang 5 and Yuanwang 6 were back in port in Shanghai; Yuanwang 7 was back in the Zhoushan anchorage; while Yuanwang 3 was returning to port from the Indian Ocean.

Discussion and conclusions

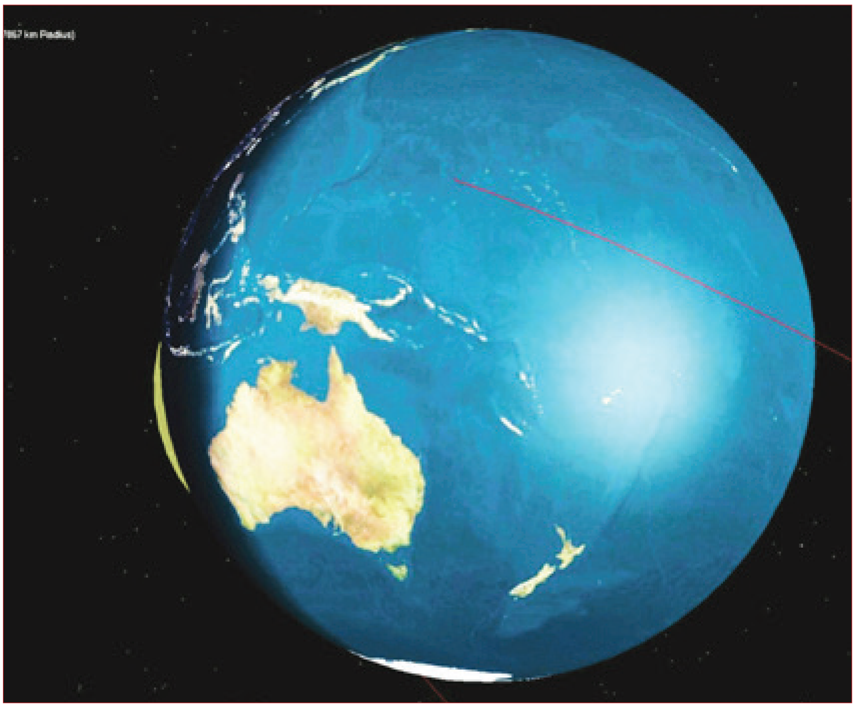
First, we may conclude that the tracking fleet was used to follow the missions as listed in Table 1. (see page 27). These seem to have been the main expeditions. The strongest evidence for these connections - apart from the published press - is the ship being either at low speed or DIW during the launch event; and leaving the position not long afterwards. There have been no reports that the tracking ships were involved in following the post-launch Tianwen 1 Mars mission, either entry to Mars orbit (10th February) nor the soft-landing on Mars (17th May), nor particular activity to suggest such a role. China presumably timed these events so as to be in line of sight with its ground stations.

Second, new locations have been in evidence, principal of which were the Arabian Sea (Yuanwang 3 for Chang'e 5 re-entry); Singapore Straits (Yuanwang 6); the Indonesian archipelago (Yuanwang 6 and 7); and the use of a new anchorage (Zhoushan, for Yuanwang 7), at one stage also for Yuanwang 3.

Third, the journeys appear to be a mixture of prolonged voyages in the course of which several spacecraft were tracked, combined with out-and-back journeys for individual missions.

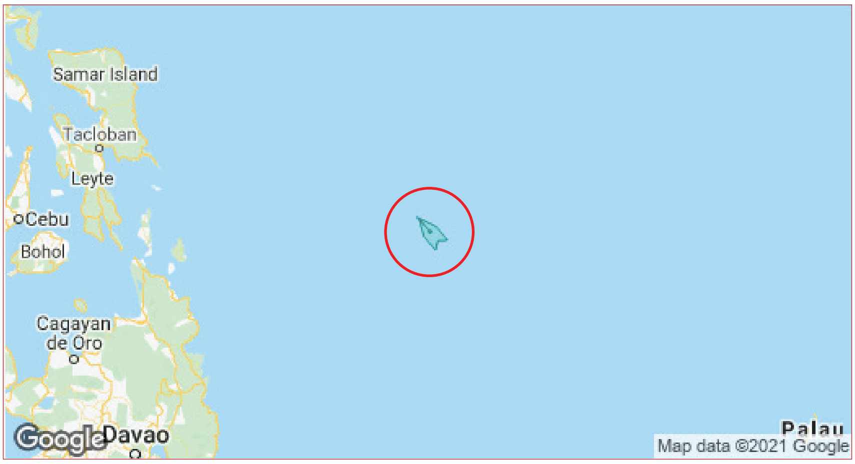
Fourth, some missions seem to have been more important than others. Two tracking ships appears to have been the norm, but two missions attracted three: Chang'e 5, which is no surprise; and the CZ-7A, the first mission of which had failed (March 2020), which must have prompted a high level of surveillance for the second mission (Shiyan 9, March 2021), which succeeded. What is surprising, though, is that only two ships were assigned to the Tianhe, Tianzhou 2 and Shenzhou 12 missions.

Fifth, an intriguing question arises as to whether the tracking ships were used to track the Yaogan missions. The first article (GT27) raised this possibility. Generally, the tracking ships are not used for low Earth orbit missions on the CZ-2 or CZ-4. However, one version of the Yaogan (Jianbing 8) uses a higher type of low Earth orbit, 1,100 km and it is possible that the ships could be used to test the arrival of the Yaogan in such an orbit and calibrate its signalling system. The following are the Yaogan missions from the period (Table 2 - page 33):



CE-5-T1 Trans Lunar Injection (TLI). Credit: Luciano Anselmo

Yuanwang 3's anchorage in Zhoushan on 25 May 2021. Credit: Marine Traffic/Google Maps



Yuanwang 5's position in the east Philippines during the Tianhe launch. Credit: Marine Traffic/Google Maps

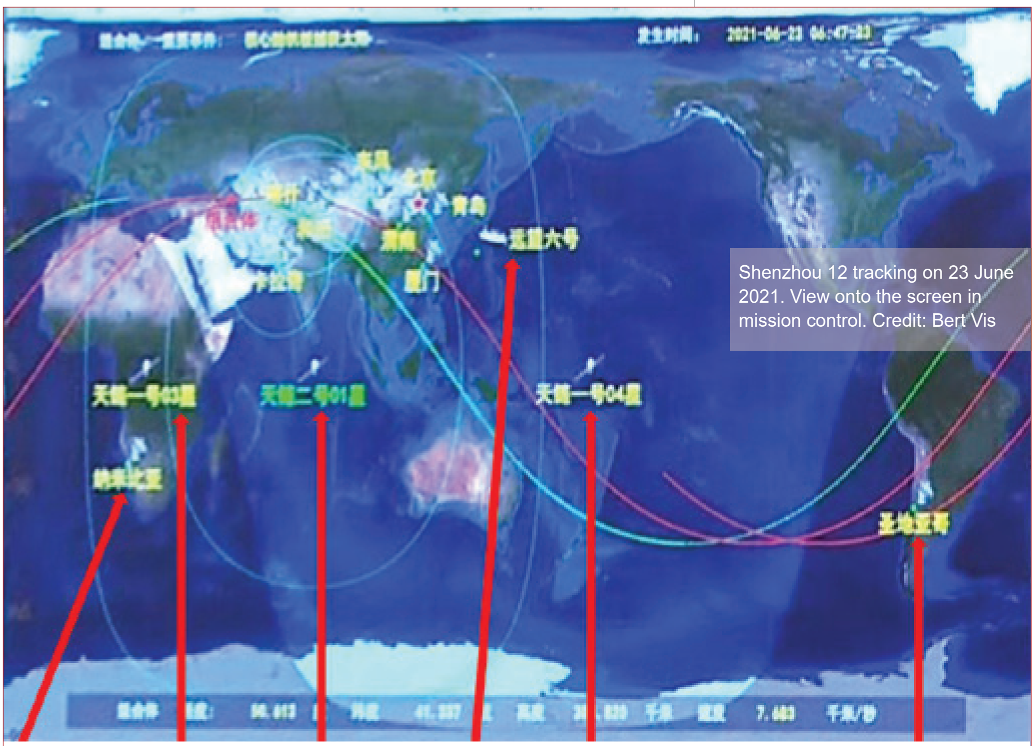
Space station: tracking Tianhe, Tianzhou 2 and Shenzhou 12

With the upcoming launch of the Tianhe space station (29th April), well flagged in advance, it was reasonable to expect that as many ships as possible would be sent out. In the event, only two did so, for Yuanwang 3 remained in port in Shanghai and Yuanwang 7 at the Zhoushan anchorage.

At the start of this set of missions, Yuanwang 6 remained in the Indonesian archipelago (Sunda Islands), while Yuanwang 5 left port on 20th April, reported in the press. Yuanwang 5 headed south between Fuzhou and Taipei on 23rd April, turned east south of Taiwan the next day, was off Luzon the following day and had reached Leyte on the 27th in time for the CZ-5B launch on the 29th April, so it must have tracked its ascent to orbit.

For Tianzhou 2, Yuanwang 5 seems to have stayed on location and was still off Leyte on 16th May, presumably awaiting the delayed launch of the CZ-7 Tianzhou 2, originally mid-May but in the event delayed until 29th May. Several days before the Tianzhou launch, it headed east into the Carolines, passed Nauru on the 26th, eastward of which in the Gilbert Islands we may presume it tracked Tianzhou 2 and possibly the Fengyun 4B on 2nd June. Yuanwang 6, having returned briefly to Shanghai in the meantime, sailed out again into the East China Sea on 23rd May, passed east of Taiwan on the 25th, was east of the Philippines the following day and reached the coast off Leyte on the 27th, two days before launch, taking the place of the now-departed Yuanwang 5. There it tracked Tianzhou 2 and possibly the Fengyun 4B on 2nd June.

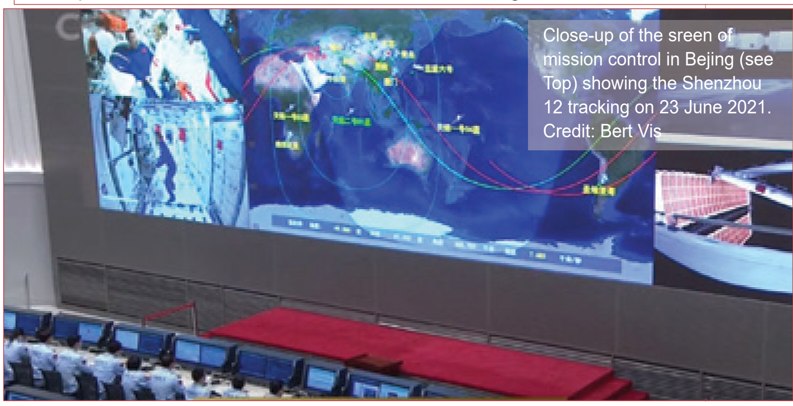
For the Shenzhou 12 launch on 17th June, Yuanwang 5 was still on location in the Carolines, at the time of launch north east of Palau near the island of Colonia. Two days after the launch, Yuanwang 5 appeared to be heading home to the northwest through the Philippine Sea, was off Shanghai by the 21st and back in home port the next day after 66 days. Yuanwang 6 was DIW at 26˚N, 135˚E, south east of Japan, perfect to place it under the path of a rocket ascending out of Jiuquan. The following day it was returning via the southern end of the Japanese archipelago, Kagoshima, the same parallel as Shanghai and was back in home port on the 21st and was still there on 16th July. Xinhua reported its return that day and that it had spent 29 days at sea covering Tianzhou 2 and Shenzhou 12, but did not give the locations nor mention Fengyun 4B. The press reported that Yuanwang 6 had direct voice communications with Shenzhou 12 during the key docking phase.[vi]


Shenzhou 12 tracking on 23 June 2021. View onto the screen in mission control. Credit: Bert Vis

Swakopmund Tianlian 1-03 Tianlian 1-01 Yuanwang 6 Tianlian 1-04 Neuquén

Neuquén ground station. Credit: CNSA


Neuquén ground station. Credit: CNSA



Close-up of the sreen of mission control in Bejing (see Top) showing the Shenzhou 12 tracking on 23 June 2021. Credit: Bert Vis

Swakopmund ground station. Credit: CNSA


	Date	Spacecraft	Specifics
2020	26 October	Yaogan 30 group 7	Low altitude
2020	27 December	Yaogan 33	New radar mission, 700 km
2021	29 January	Yaogan 31 group 2	High altitude
2021	24 February	Yaogan 31 group 3	High altitude
2021	13 March	Yaogan 31 group 4	High altitude
2021	30 April	Yaogan 34	High altitude
2021	7 May	Yaogan 30 group 8	Low altitude
2021	18 June	Yaogan 30 group 9	Low altitude

Table 2: Yaogan launches during the reporting period.

The high-altitude satellites, Yaogan 31, are generally three satellites flying together to triangulate the locations of the naval ships which they track and is also called the Jianbing 8 programme. The single Yaogan 34 flies at the same altitude and is co-planar with this group. By contrast, the Yaogan 30 group flies in a lower orbit, 600 km and is believed to be signals intelligence from land-based sources, so sea-based calibration is probably not necessary. Yaogan 33 is an outlier, believed to carry a new SAST radar but in a lower orbit, 600 km.

Can we establish connections between the tracking ships and these missions? This is not as easy as it seems. **First,** several Yaogan missions coincided with 'big' missions (Table 1) which required tracking anyway (e.g. juxtaposition of Yaogan 31 group 4 on 13th March with Shiyan 9 on 12th March). **Second**, there is evidence of occasions when possible opportunities to track Yaogans were missed. For example, Yuanwang 3 set out on 16th May, but by leaving a week earlier could have tracked Yaogan 30 group 8; similarly leaving port on 18th June, the day of Yaogan 30 group 9, but in insufficient time to track it. Yuanwang 5 was travelling to port on the day of the Yaogan 30 group 7 launch (26th October). On 21st February, it was in port in Suva, having arrived two days earlier, which suggests that it was not tracking Yaogan 31 group 3 on the 24th.

On the other hand, there are some candidates:

- On 27th December, Yuanwang 6 was at the western Australian location, having sailed there after the Chang'e 5 recovery. This coincided with the new radar satellite, Yaogan 33. It appears to have returned to port straight after;
- On 29th January, Yuanwang 7 was in the Banda Sea. Earlier, it left the Philippines after tracking Tiantong 1-03 (20th January) for the Indonesian archipelago. This coincided with Yaogan 31 group 2 and it announced its return the following day;
- On 24th February, Yuanwang 6 was in the Sunda Islands, coinciding with Yaogan 31 group 3 and it announced a new port of Singapore on the 24th;
- On 13th March, Yuanwang 6 was in the Singapore Straits for March, coinciding with Yaogan 31 group 4. It did not return home, but then sailed for the west Australia location.

Here, there is one to add. Yuanwang 6 made an expedition to western Australia on 24th March and rested DIW there. The only mission of note was Shiyan 6-03 on 7th April, whose mission was obscure but which shares a 1,000 km orbit with the Yaogan 31 series. Yuanwang 6 spent some time at the western Australia location in the period up to this mission and there is no other obvious explanation for its being there at this time.

This is quite strong evidence of the tracking ships being in particular tracking locations when no other missions were pending and of leaving as soon as these candidate missions were in orbit. It therefore appears that there are connections between Yuanwang 6 and 7 on the one hand and the high-altitude Yaogans, namely the Yaogan 31 group and the single Yaogan 34. There also appears to be a connection between the tracking ships and the new radar Yaogan (33) and Shiyan 6-03, which share characteristics with the high-altitude Yaogans. It seems therefore that:

- Yuanwangs do not track all Yaogans, but only the high-altitude Jianbing 8 and related missions;
- Conversely, connections between Yuanwangs and the lower-altitude Yaogan 30 series are weak;
- Not all Yuanwangs are involved, but only Yuanwangs 6 and 7. Is it possible that the more modern Yuanwangs 6 and 7 have the capacity to test Yaogan signals, but not the older ones?

There is evidence, therefore that Yuanwang 6 and 7 may have been used to test the functioning in orbit of the Yaogan 31 group; Yaogan 33; and Shiyan 6-03. This makes sense. If the role of the high-altitude group is to test signals from ships at sea, it would be logical to test them against Chinese ships first and to verify the new radar satellite.

Acknowledgements

My thanks to Marine Traffic for beacon data; Bert Vis for information and permission to use illustrations; Luciano Anselmo, Pisa, for information and permission to use illustrations.

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Yuanwang 3


Yuanwang 7

Chinese Space Flight in Chinese Science Fiction Literature

by Dominik Irtenkauf

When I asked the specialised German magazine KAPSEL (via https://kapsel-magazin.de/) if they knew any Chinese science fiction writers who maintain closer relationships to Chinese space engineers or contacted the Chinese Space Agency in order to have their material safely backed up, they told me they don't know of any. Which seeming like too short an answer, aroused my interest even more. They added that there haven't been posts on the topic on the platforms they regularly visit. Honestly speaking, I became a little suspicious.

Can't there really be any connections between the ambitious Chinese space programme and writers of fictional works?

There are examples from other countries where we know about authors who do have at least intellectual bonds to space flight. In the United States, Andy Weir for example wrote his novel *The Martian* and consulted several experts from the field. He follows a professional career in software development. In his spare time he is fascinated by astrophysics and the history of human space flight. Later, he interviewed astronauts from the Apollo Moon missions and his latest book is *The Astronaut*. So his contact with space is evident.

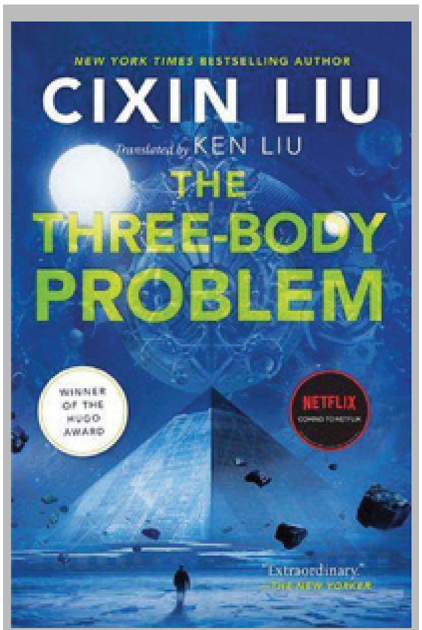
I started my own search into the jungle of Chinese speculative writing. Why I follow this path despite the obstacles, is because fictional writing can create speculative rooms in which certain things can be developed without fearing the risk of consequences.

Science fiction (SF) has been interesting in several socialist countries to develop different social models. SF writers have developed a precise language in and by which future technological and societal models can be run through, tested and then thought over. One prominent example are the Strugatzki brothers from the Soviet Union. They developed a metaphorical language in which they could ponder upon the highs and shortcomings of Socialism on its way to Communism. They extrapolated a scene into a vague future and by doing so, could portray sensitivity when they were still living under these current circumstances. In China there is much change nowadays and Western readers often know only little about them except for clichés and stereotypes.

What do Chinese writers face when they write science fiction nowadays?

A colleague from The Wired gives some hints in the following passage:

"Abroad, China's science fiction writers find themselves caught in a tug-of-war between competing geopolitical agendas. The Western world has always perceived China as a monolith, reading Chinese literature through the lens of Western dreams and



fears and viewing Chinese authors as either romantic dissidents clashing with the regime or soft-power tools parroting the Party's agenda. Recent developments - the US-China trade war, conflicts with Huawei and ZTE, closed borders, and China's aggressive posture as a technological superpower - have only exacerbated the situation. Hawkish academics pen reductive op-eds with subtitles such as 'To Know What the Chinese Are Really Up To, Read the Futuristic Novels of Liu Cixin,' as if one novel could demystify a nation of a billion people. Whereas five years ago President Obama touted *The Three Body Problem* as a must-read, last September, Republican senators condemned its Netflix adaptation, criticizing Liu for his politics."

Space flight delivers much material to work with as a narrator. Is it possible that no writer touches upon this essential part of space ambitions? I would guess: Rather not. Internationally, Cixin Liu is some sort of superstar of Chinese science fiction. His novels depict a wide cosmic scale: in one of his stories the Earth is being evacuated by large engines as the sun collapses. The Earth's surviving population seek for a new sun where it can feel at home. When the film *The Wandering Earth* was released, there has been a Space Day event where people from the Chinese space agency and astronauts could attend. After seeing the film, the taikonaut Chen Dong exclaimed: "The astronaut in the film played a vital role in saving mankind. His sacrifice touched my heart. If I happened to face a similar situation, I would definitely make the same decision." Cixin Liu said that "the sci-fi industry is a barometer of national strength, and sci-fi films need the backup of a strong economy that allows astronauts to turn fiction into reality." (quoted from: http://www.xinhuanet.com/english/2019-01/28/c_137781695.htm)

Science fiction literature and film seem to support some of China's ambitions to achieve a bigger role in space. However, the films rather relish in spectacular special effects and dramatic plots – so is Chinese science fiction movie culture trapped in Hollywood stereotypes? Maybe so. Maybe putting science fiction to film is mostly a bad idea because producers are fixed on megalomanic effects and highly dramatic plots?

Honestly speaking, I had problems when listening to a radio play which was based on the *The Three-Body Problem* trilogy. It has been so chaotic, and the aliens that were introduced into Liu's plot, just seemed annoying. Liu's work is diverse and includes not only space soap operas which are known by the movies based on his texts. He also writes different novels in which he tries to describe contemporary Chinese circumstances. This is where this kind of genre can evolve to its full potential.

In a SPIEGEL article, Liu was quoted that he thought science fiction is soon coming to an end and that there is more SF in a smartphone than in any piece written under the tag of science fiction. Liu seems to be influenced by his best-seller status and thus producing newsworthy headlines. Astonishingly, Liu doesn't take heed of social fiction which excelled in drafting future's societies or considering a female writer like Ursula K. Le Guin who constantly dived into anthropological musings in her books. Curiously enough, *The Three-Body Problem* rather focuses on improbable scenarios. Surely, this perception might be prevalent even with this newsletter's readers, as series like Perry Rhodan describe technologies and events which are highly fantastic. However, I reason for a different understanding. A nation confronted with challenges might find in science fiction literature a catalyst for sometimes painful societal and cognitive changes. What does that mean exactly?

China and Possible Futures

What if a convincing science fiction novel might propel the Chinese space programme? It could raise some interest for its long-time goals. Hard scientific facts might be better understood when being told in elegant literature. Qiufan Chen wrote a book (*The Waste Tide*) about the waste management in China and combined it with the depiction of slum life, precarious employments and traditional family clan systems where the family decides over your life. Such a plot rather seems to fall into the genre of social science fiction where civilisation's confrontation with new technologies and social role models are more important than space exploration. Chen regularly worked for Google and is involved in the computer tech business plus technology transfers. He might be fallible to writing literature promoting space exploration. However, his debut novel is far from entering into (outer) space. He seems to be more akin to a science fiction tradition which has become known under the label "New Wave" where the inner space is more important than exploring the outer space. The New Wave was influenced by modern literature and sociology plus popular culture. It introduced different literary techniques into the science fiction genre. It is linked to writers like Brian Aldiss, James Graham Ballard, Thomas Disch, Michael Moorcock, Norman Spinrad and others.

The technology and culture journal WIRED (UK) wrote about Qiufan Chen and while analysing his work, they found out there have been changes in China:

"Indeed, in the past five years, China has become a nation obsessed with its own science fiction. What was once a niche subculture with a small circle of hardcore fans has blossomed into a full-fledged 66 billion yuan ($10 billion) industry of films, books, video games, and theme parks. In 2015, Liu Cixin had become the first Chinese writer to win a Hugo Award, for *The Three Body Problem*. The next year, Hao Jingfang became the first Chinese woman to win a Hugo, for her novelette *Folding Beijing*. *The Wandering Earth*, a 2019 film adaptation of a story by Liu Cixin, earned more than $300 million in its first week after release and would become China's fourth-highest-grossing film ever. Once dismissed as frivolous children's literature, science fiction now commands the attention of all kinds of enterprises hoping to profit from its popularity: film studios hungry for screenplay fodder, universities setting up sci-fi research institutions, talent agencies eager to jump on the bandwagon, tech companies keen to borrow the genre's aura of profundity, and even government officials looking to ennoble the national project of innovation." (https://www.wired.com/story/science-fiction-writer-china-chen-qiufan/)

Then again, Qiufan Chen wrote in an essay that science fiction is no longer valid as we actually live in science fiction times. Our present times are even more SF than SF. He comes quite close to Cixin Liu in this statement. Chen continues to wonder about the influence of Artificial Intelligence on writers in the future. *(This essay has been translated into German for the afore-mentioned KAPSEL magazine.)*

AI is a big issue in astronautics. Can we only reach far planets and stars by implementing artificial intelligence in spaceships? Machines can better endure long periods of space flight. They don't react to radiation, they don't lose strength in their muscles, they don't get tired – yet they can wear out and be in need of eventual repair.

Why is it still so rare among Chinese SF writers to include (actual) astronautics? I read in an interview with the Chinese SF author Jiang Bo that he used to read older science fiction literature from China where space was one among many topics. I can only guess the reasons for this lack of taikonautics in the more prominent examples of Chinese SF literature. Liu certainly introduces outer space in his *The Three-Body Problem* novels but I find the scenarios rather far from real circumstances in current space exploration. Maybe for these science fiction writers it is seminal to reach far shores instead of describing a near future by observing current developments and actions?

When I asked Qiufan Chan in a mail interview in June 2021 if he knew any engineers from Chinese space agency and private companies, he answers: "Yes. I have a lot of friends working in the space sector, both state-owned and private. One of my friends and alumni, Astrophysics Professor Su Meng, who founded an asteroid mining company, shared a lot of interesting stories in the area. I also visited some of the most confidential research institutes on space exploration which was really an eye-opening experience." Chen even occupies himself with Chinese space exploration for his own texts. When being asked if he draws inspiration from Chinese taikonautics, he openly confirms: "There are two stories about Chinese astronauts. Short story *Space Leek* (on *Future Tense*) about how female Chinese astronauts survived from a leaking issue in the space station. (https://slate.com/technology/2019/06/space-leek-chen-qiufan-stanley-chen.html)

Link to website with Space Leek novelle

The novella *Debtless* (on *Clarkesworld*) is about asteroid mining in space. (http://clarkesworldmagazine.com/audio_04_20d/)

Link to website with Debtless novella

Both of the stories are set up on some solid scientific facts and knowledge, so took me quite some time to do the research."

So now it seems, at least one of the Chinese SF authors is interested in real-world space travel.

I suppose it is just the tip of an iceberg and if we dig deeper, we will encounter more contacts between Chinese science fiction and space exploration. In his debut novel *The Waste Tide* Chen describes an ecologically wasted territory where poor people work and wreck themselves just to find a small portion of good luck. Chen doesn't seem to be interested in displaying perfected images of a rabid Chinese economy. He delves into the deprivations of a global economy which transports waste to foreign countries. Out of sight, out of mind.

With space exploration, Qiufan Chen feels more optimistic: "I think now it's becoming a big hit in the genre. As we know the old International Space Station is going to be retired in 2024. And China now is actively building the new Station and organising an international alliance on science research. Also the future plans to build the Moon settlement, and probably plans to settle on Mars as well. So, there is plenty of space there for our imagination and narratives." With this kind of imagination, Chinese science fiction will rise in its importance for a global understanding of technology and space in the future. We will come back to the topic in later issues.


Thinking
in
visions!
E = m x rc²