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TIANZHOU 1

On 20 April, at 19:41 Beijing Time (BJT), (11:41 UTC) the Long March 7 Y2 (CZ-7 Y2) rocket launched from the Wenchang Space Launch Centre (WSLC) on Hainan Island with China’s first cargo spacecraft, Tianzhou 1. The freighter is 10.6 m long and has a maximum diameter of 3.35 m. Its maximum take-off weight is 13.5 t, with a payload capacity of 6.5 t (including 2 t fuel). Tianzhou (TZ) has a 0.48 ratio of cargo capacity to the total weight of the spacecraft. Chinese space craft designers used new alloys and carbon fibres to achieve the low structural weight. Reliable cargo transportation is essential for the future Chinese Space Station (CSS).

TZ-1 mission profiles included a triple docking with the orbiting Tiangong 2 (TG-2) space lab (length: 10.4 m, max. diameter: 3.35 m, weight: 8.6 t), a triple re-fuelling, conducting 10 experimental (mostly remotely operated) projects and a controlled re-entry.

TZ-1 began to approach TG-2 automatically on 22 April at 10:02 BJT and had first contact with the space lab at 12:16 BJT. The 1st automated docking was successfully completed at 12:23 BJT at an altitude of 393 km above the Earth, that corresponds to the orbital altitude of the future CSS. After the 1st docking, aerospace engineers tested the control ability of the cargo spacecraft for the two spacecraft. Docking was followed by a two-month-long joint flight, the longest tandem flight so far achieved by China.

The main task of TZ-1 is the test of the propellant re-fuelling technology. On 27 April, at 19:07 BJT (11:07 UTC), the 1st 5-day-long re-fuelling procedure was successfully concluded. China became capable of in-orbit re-fuelling, after Russia, Europe and the U.S. have demonstrated this technology before. Each re-fuelling procedure took 29 steps divided in five stages and lasted several days each time. The 1st one took five days.

The 2nd in-orbit re-fuelling was accomplished within 2 days on 15 June at 18:28 BJT.

TZ-1 separated from TG-2 on 19 June in the morning and remained 5 km behind the space lab for 90 minutes. Then, mission control sent the command to TZ-1 to fly around the space lab from behind and position itself at 5 km in front of TG-2. During that manoeuvre, both space craft turned in semi-circles. The aim of the 2nd docking was to test the docking procedure from a different direction. It was completed on 19 June at 14:55 BJT.

Current International Cargo Capabilities

<table>
<thead>
<tr>
<th>Cargo Craft</th>
<th>Capacity/Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATV</td>
<td>7.67 t – re-fuelling capability</td>
</tr>
<tr>
<td>HTV</td>
<td>6 t (1.5 of which is unpressurised)</td>
</tr>
<tr>
<td>Dragon</td>
<td>3.31 t</td>
</tr>
<tr>
<td>Cygnus</td>
<td>2-3.5 t</td>
</tr>
</tbody>
</table>

On 21 June, in the morning, TZ-1 cargo spacecraft undocked from the TG-2 space laboratory again and began a 3-month independent flight. The undocking sequence started at 9:17 BJT and took about 30 minutes. TZ-1 operated in an orbit of around 390 km.

After ground control sent the commands for TZ-1 3rd rendezvous and docking at 17:24 BJT, the manoeuvre was accomplished with a fast-docking procedure within 6.5 hours, late on 12 September at 23:58 BJT.

The 3rd re-fuelling was completed on 16 September.

TZ-1 started separation procedures from TG-2 on 17 September at 15:29 BJT and finalised the manoeuvre at 16:15 BJT.

After 5 months in orbit, the Tianzhou 1 de-orbit started on 22 September by firing the cargo craft’s thrusters twice to initiate the decay. The ground control team gave the command at around 18:00 BJT. TZ-1 re-entered and burned up in Earth’s atmosphere. The remaining pieces fell into a designated sea area over the South Pacific.

Long March 5 - CZ-5

After its transport from the factory to the harbour in Tianjin, the second Long March 5 (CZ-5 Y2) carrier rocket (payload capacity for LEO: 25 t; for GEO: 14 t) left on 24 April (China’s National Space Day) by special rocket-carrying ships from the port of Tianjin for Wenchang at Hainan Island. The CZ-5 rocket arrived 6 days later, on 1 May. At WSLC it was assembled, tested and prepared for the launch.
The Tianzhou 1 mission was used for a host of scientific and technological projects, such as:

**TECHNOLOGY**
- Release of Silu 1 (Sichouzhilu 1 - Silk Road 1) 3U cubesat on mission day 104. Silu 1’s signals were received on the ground right after release.
- Testing of an advanced navigation, guidance and control device and new domestic-made components.
- In-orbit verification of the key technology for active vibration isolation for maglev.

**SCIENCE**
- Research on key technologies of the two-phase system experimental platform with the objectives to create a technical foundation for: solving the engineering difficulties of space-efficient heat transfer and research into evaporation and condensation under a microgravity environment.
- Verification of key technologies for non-Newtonian gravitational experiments, e.g. in-orbit tests of the performance of a high-precision electrostatic suspension accelerometer.
- Life science study “Effects of microgravity on cell proliferation and differentiation”. The study comprises eight sub-projects which were all remotely controlled and operated for 30 days.

Below are details about four of the set of life science experiments:

**CKIP-1 study**
School of Chinese Medicine of Hong Kong Baptist University (HKBU).
Team lead: Prof Lyu Aiping and Prof Zhang Ge.
The study aims at the understanding of the bone loss mechanism in space, in particular the effect of the CKIP-1 gene on bone formation under microgravity. The CKIP-1 gene in osteoblasts (bone forming cells) could specifically interact with Smurf1 genes in the cells to inhibit cell activity, causing the slowing or hindering of bone formation during ageing and support the development of glucocorticoid-induced osteoporosis. The process is accompanied by the mass growth of osteoclasts (bone-resorbing cells), causing bone structure to change. Osteoblasts, in which CKIP-1 genes were silenced, were taken on board the TZ-1. The researchers were monitoring remotely the effects of CKIP-1 on osteoblasts.

**Testing of medicine to treat bone loss**
Center for Synthetic and Systems Biology at Tsinghua University.
Team lead: Chen Guoqiang.
The experiment investigates the effect of 3-hydroxybutyric acid (3HB) in preventing osteoporosis. For that, osteoblast cell samples treated and not treated with 3HB were compared. Pre-cursor experiments, simulating the micro-gravity environment, have been conducted on the ground. Scientists hung up mice by their hind legs to keep them restrained, and found that those given 3HB had normal bones, while those without 3HB suffered serious bone loss. The aim is to test the effect of the medicine in a real space micro-gravity environment.

**Embryonic stem cells and embryoid bodies of mice**
Institute of Zoology of the Chinese Academy of Science.
The aim of this research is to remotely observe the process of proliferation and differentiation of embryonic stem cells and embryoid bodies of mice in space. In parallel, experiments will be conducted on the ground to compare the results. In previous ground experiments simulating micro-gravity conditions, the differentiation ability of mouse embryonic stem cells was enhanced. The key gene, responsible for this change and the molecular signalling pathway could be identified. The research team conducted a series of space life science experiments on China’s recoverable satellites SJ-8 and SJ-10 and hope to continue the study on the future Chinese Space Station. The ambition is to culture functional tissues, such as heart, kidney, liver and spleen tissues.

**Induce the differentiation of human embryonic stem cells into germ cells**
Medical Faculty of Tsinghua University.
Team lead: Prof Keh-Kooi Kee.
The experiment’s objective is to induce the differentiation of human embryonic stem cells into germ cells within 30 days. During this process, the basic development and maturation of germ cells in the micro-gravity environment, and the developmental potential of human embryonic stem cells will be studied. To what extent the human embryonic stem cell can differentiate in space is still unknown.
of the Shijian-18 communication satellite. On 26 June, the CZ-5 together with its integrated payload was transferred vertically from the assembly hall to the launch area at Wenchang Space Launch Centre. The same day, the State Administration of Science, Technology and Industry for National Defense (SASTIND), set the launch window for between 2-5 July.

**Air Launch**

The Airspace Industry Corporation of China (AICC) signed an agreement with the Ukrainian aeroplane manufacturer Antonov Airlines in May to use the world’s biggest airplane, the AN-225 Mriya for air launch activities. AICC intends to modernise the AN-225 in order to carry heavier satellites on the back of the aeroplane and launch them from a height of 12 km to space. The first contacts with Antonov started already in 2011.

China’s Landsat network of remote sensing satellite ground-stations that cover all of China’s territory and 70 percent of Asia passed its final acceptance test on 31 May. The network’s data receiving centre is headquartered in Beijing and is connected to 3 ground stations to where the Landsats transmit their data: one in the Miyun district, a suburb of Beijing, one in Kashgar in Xinjiang Uygur Autonomous Region and one in Sanya in Hainan Province. The network will be used to support various remote-sensing systems, especially for the western part of the country and the South China Sea.

**Manned Space Flight**

**Astronauts**

At the beginning of June, Yang Liwei, China’s first astronaut and Deputy Director of China Manned Space Agency (CMSA) announced for late 2017 a new taikonaut selection of 10 to 12 recruits - including two female candidates. The new phase of China’s space exploration programme is calling for the next generation of astronauts. According to Yang Liwei, more consideration will be given to aerospace engineers and other experts from the civil sector. In the future, taikonauts will be selected every four years. Yang Liwei confirmed that preliminary studies for a manned lunar programme are ongoing and that it will not take long to get official approval and funding so that potentially, Chinese astronauts could land on the Moon by around 2030.
Traditions can come a long way: in 1962 – one year after Yuri Gagarin accomplished mankind’s first flight into the cosmos – the Soviet Union declared 12 April as “Cosmonautics Day” with opulent galas and commemorative events taking place annually. In 2011, the United Nations joined in the Russian celebration and made Cosmonautics Day the world-wide festival of “International Day of Human Space Flight”. Earlier though, in 1999, as a result of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space UNISPACE III in Vienna, the most prominent space event on Earth has been introduced. Since then, the week from 4 October to 10 October each year is known as the World Space Week.

And now China has got it right as well: On 24 April 2016, for the first time, China celebrated its National Space Day. This day is the reoccurring anniversary of the launch of the People’s Republic of China’s first satellite - Dongfanghong 1 - into Earth’s orbit on 24 April 1970.

In remembrance of this milestone achievement, on 23 April 2016 the China Manned Space Programme Office held a symposium in Beijing, for which more than a hundred space experts were invited. The conference participants reviewed the development of the countries manned spaceflight activities and looked ahead into the future.

On the sidelines of this gathering, Zhang Yulin, Vice Minister of the Armed Forces Equipment Development Department and Deputy Commander of China’s Manned Space Programme gave a rare interview to Chinese media. He spoke about the status of China’s manned space programme and about plans for innovation and development for the future.

Zhang Yulin stressed that the decision taken by the Central Committee of the Communist Party of China and the State Council to establish the China Space Day reflects clearly the importance China’s government attaches to space and space affairs. The decision for a National Space Day comes rather late in China’s 60 years of industrial aerospace development but it comes at the right time when China is heading into a science and technology-based future.

The Vice Minister explained that the manned space programme had used up moderate financial means but the 10 astronauts flown to space until April 2016 have put into action the Chinese dream of flying to space. This has greatly inspired the people and effectively raised China’s overall national strength and enhanced significantly China’s international image.

Zhang Yulin then listed the tasks for 2016: launch of Tiangong 2, Shenzhou 11 mission, test of key technologies, and first flight of Long March 7. The efforts in 2016 are crucial key steps within the second phase of China’s manned space project before the third phase – the construction of the space station – can start. “This year’s tasks are difficult, challenging and of great responsibility. But we have the confidence to win, and we will turn the confidence into victory”, he stressed and added that the pillars for succeeding are the support by the government, the accumulated experience from Shenzhou 1 to Shenzhou 10 and Tiangong 1, as well as the talented and creative workforce. Nevertheless, it also requires to take carefully chosen steps, attention to quality and good planning to make 2016 a success.

However, what are the plans for the time after the completion of the Chinese Space Station? Zhang Yulin gave a glimpse of that when he said that the completion of the space station will become the starting point to plan a new innovative goal. The research on that is still in the study-phase. But in general, he emphasised, the manned lunar exploration of the Moon and the expansion of that research to the Moon-Earth space is a realistic choice. Such a project would elevate the manned spaceflight programme to a higher ground, in line with the national situation for the great rejuvenation of the Chinese nation. In accordance with President Xi’s demand for innovation and the five development concepts (see: next page) introduced by the government and the party, a new manned spaceflight strategy will be worked out, one that will fit in the “Two Centenaries” goal (see: next page) and will be based on the previous achievements, Zhang Yulin added.

In parallel with those efforts, there is a need for holistic innovation which includes the innovation in all aspects of space engineering management and engineering-related key technologies. For that, innovative people are a prerequisite. Zhang Yulin drew attention to the fact that the most precious thing is to train a large number of outstanding talents for the development of science and technology in China. Innovation and development of new manned spacecraft are one side of the medal, the other side is to make great efforts to train innovative talents. And for that, the China National Space Day is a good foundation since its main objective is inspiration and encouragement about space.

Last but not least, Zhang Yulin also touched on the point of commercial activities in the area of manned space flight. He referred to space as the new area for the development of mankind, the new place to work and live. He also made explicitly clear that the meaning of astronautics is to explore new places and to aim for technological break-throughs: “Whether it’s a space station or a satellite, we ultimately do these things in order to exploit space resources. Do you want to industrialise? Do you want to support civil-military integration? Do you want to support the development of private economy in space? This is certainly self-evident. For example, satellites - commercial applications are now in the making, and communications, remote sensing and navigation satellites are in commercial use. For the space station, it is necessary to achieve breakthroughs in the manned spaceflight technology, but also to carry out space science applications. In addition, we also need to make...
full use of space stations to support mass entrepreneurship and innovation. At the moment the “Internet of Things” is much talked about. Our space station can also be seen as a node in a large network in Earth’s orbit. However, this is not the main task for China’s manned space project. China’s space station is still about to be assembled with an early exploitation phase to follow where the technologies for long-term stays in space will be developed. After maturity, the commercialisation of some applications is possible, although not the subject of the current project, but it can be one direction that we must strive to promote.”

(GoTaikonauts! wishes to thank Yunxia Liu, Cologne, for her help translating the article with the Zhang Yulin interview.)

The five development concepts: innovation, coordination, green development, opening up, and sharing are designed to facilitate building a “moderately prosperous society in all respects” by 2020.

The five development concepts were mentioned for the first time by the end of October 2015 in the “Proposal for Formulating the 13th Five-year Plan (2016-2020)” which was adopted at the Fifth Session of the 18th CPC Central Committee.

The term “Two Centenaries” refers to two 100-year anniversaries: the founding of the Communist Party of China in 2021 and the founding of the People’s Republic of China in 2049.

The “Two Centenaries” is a set of goals advanced by the General Secretary of the Communist Party of China, Xi Jinping, following the 18th National Congress of the Communist Party of China held in 2012. It is the basic foundation for achieving the “Chinese Dream” - a moderately well-off society by doubling the 2010 capita income until 2021 and of becoming a “strong, democratic, civilized, harmonious, and modern socialist country” until 2049.
Qian Xuesen’s work laid the foundation for China’s civil space programme. In this exhibition room, the efforts for launching Dongfanghong 1 (hanging from the ceiling) are explained. credit: GoTaikonauts!

In the basement (or ground floor), the panoramic picture shows a scenery from the launch site in the Gobi Desert, which will later become the Jiuquan Satellite Launch Center (JSLC). The ground floor also shows a replica of the control room for missile launches. credit: GoTaikonauts!

Many modern and fancy installations introduce the visitors to the academic work by Qian Xuesen. credit: GoTaikonauts!

The liquid-fuelled, 2,500 N twin-engine developed by the 6th Academy of China Aerospace Science and Technology Corporation (CASC) is used for the Shenzhou spacecraft in case of emergency escape, orbital and return manoeuvring. credit: GoTaikonauts!

Qian Xuesen was honoured and respected up to the end of his life. China’s taikonauts showed him their reverence while visiting. credit: GoTaikonauts!

Never too old to learn! Keep learning! This is the message to the students and young visitors of the museum: pass on the flame! credit: GoTaikonauts!
It was for French catholic Jesuits that China inherited a unique scientific sky observation facility, which became the starting point for a wider telescope park supporting today China’s unfolding deep-space efforts.

The story starts around the year 1900 when the Jesuits missionaries founded on the picturesque West Sheshan hill top, the highest of a 13 km long hill range, 40 km away from the vibrant port city of Shanghai, the Sheshan Observatory. The West Sheshan Mountain is just 97 m high but it clearly sticks out of the very flat surrounding territory south-west of Shanghai, making it an ideal place for sky observation but also as a befitting, unique religious place: between 1925 and 1935 the Sheshan Basilica of Our Lady of Sheshan was built on the uppermost spot of the hill, just a little bit higher and a bit more central than the earlier established observatory. The observatory with its 40-cm binocular refraction telescope, has been for long the biggest in East Asia. The historic refractor and the old observatory building are now the Sheshan Astronomical Museum, open to the public.

Over the years, the old observatory was rebuilt, modernised, and equipped with a 1.56-m optical telescope which is still operational until today. From 1951 until 1981 is has been China’s central time keeper. Only in 1962, Sheshan Observatory, and Xujiahui Observatory - located in a town district in central Shanghai - merged to operate now under the newly founded Shanghai Astronomical Observatory (SHAO). Since 1999, SHAO’s administrative headquarters is housed in a modern building in Nandan Road Xujiahui (also called: Zikawei) District, not far from Shanghai Jiao Tong University (SJTU).

But not only this was changed over time: Also, the research facilities of the Sheshan campus saw, under the care of the Shanghai Astronomical Observatory, and being part of the Chinese Academy of Sciences, an impressive growth throughout the recent decades.

Presently, it comprises not only the 1.56-m optical telescope, but also a 60-cm satellite laser ranging (SLR) telescope – both located on the Sheshan hill – and: two state-of-the-art radio telescopes in the close neighbourhood of West Sheshan Mountain.

One of these radio telescopes is the Sheshan 25-m radio telescope (SH25), a landmark in the green countryside east of Sheshan. It was China’s first VLBI (Very Long Baseline Interferometry) station when it saw its first light in 1986. The Sheshan 25-m radio telescope is a Cassegrain beam waveguide type antenna, equipped with six receivers at 1.3, 3.6/13, 5, 6 and 18 cm wavelengths and a complete VLBI system.

Its main tasks are data acquisition for high-resolution VLBI astrophysics and high-precision astrometry observations – on national and international level - and playing an integral and significant role as part of the European VLBI Network (EVN) since 1993, contributing to its longest baseline. 13 years ago, the EVN correlator, situated in Dwingeloo, The Netherlands, was connected with Shanghai via high-speed fibre, capable of a maximum data rate of 1 Gbps in real-time mode. The 25-m dish was also used for all four Chang’e lunar missions for VLBI orbit determination.

The latest addition to the Sheshan campus of SHAO is the divine winged horse “Tianma” or “Pegasus” as it would be...
called according to the terminology of Greek Mythology. A few kilometres away from Sheshan hill, in the middle of fertile farmland, the giant among China’s antennas is scanning the skies. Tianma 65-m radio telescope has been operational since 28 October 2012, the 140th anniversary of the Shanghai Astronomical Observatory. The inauguration at the end of October 2012 was also just in time to support the Chang’e 2’s close fly-by of asteroid Toutatis on 13 December 2012 at a distance of 7 million kilometres.

Tianma’s total height of 70 m makes it Asia’s largest radio telescope and with its 2,650-t weight certainly also the heaviest. It is able to rotate around all its axes. The 1,104 panels of the main reflector are equipped with actuators for adjusting the dish surface via the active surface system. Its operational frequency is between 1 and 50 GHz. Tianma receives radio waves in the L, S, X, C, Ku, K, Ka, Q-band and it is equipped with the Chinese VLBI Data Acquisition System (CDAS). The research with Tianma comprises single-dish observations of radio spectral lines and pulsars to accumulate observational data for the establishment of a pulsar time standard and deep-space automatic navigation. But also, Tianma is part of the European VLBI Network (EVN).

Both radio telescopes, the 25-m telescope and the 65-m telescope, can be operated together as if it were a single dish telescope, improving their performance.

Tianma’s construction was a pretty quick feat. The project was approved in October 2008, the foundation laid one year later, construction started in 2010 with the official operations beginning at the end of October 2012. Its main reflector was installed aided by China’s first active surface control system which was an in-house development by the SJTU School of Mechanical Engineering.

Looking from afar or from near: The appearance of this white titan is majestic, indeed. Visitors can get close to the parabolic dish and might be able to experience live the antenna’s operation when a buzz starts filling the air and the dish slowly starts rotating for pointing onto a new position up in the sky. Standing next to the technical construction made of steel, concrete and metal, and watching it moving, one wonders and is fascinated as to why this mechanical apparatus can see better than the human eye – which does not see anything where the telescope is directed to. It is worth visiting the Tianma radio telescope to get connected with science and technology and to feel a bond with the heavens. Maybe, SHAO will take the effort to offer guided tours soon, to explain its important work with the several telescopes in Sheshan and to inspire many more people. The public outreach potential of Sheshan as an important location for historical and leading current radio astronomy is big. And no study – how intense as it might be – can replace the experience of getting to know the real thing, of seeing a beast like Tianma with your own eyes and touching it with your own hands.

In Sheshan, the infrastructure for more than sporadic visits by space fans on the National Space Day is already in place. It belongs to the Songjiang District of the city of Shanghai. The 40 km distance from Shanghai city centre can be easily bridged with the Shanghai metro Line 9. Sheshan’s pleasant
green countryside with its smooth hills became the highly popular Shanghai Sheshan National Tourist Resort with amusement parks, botanical garden, generous hotel complexes, sculpture gardens, replica of a typical English old town as shopping area and for just going out. The variety of things to see and to do is enormous. And so, Shanghaiese take advantage of the facilities – but so far – know little about Tianma and its 25-m companion.

Sheshan is perfectly suited for a full day excursion to the locations of the radio telescopes but definitely also to the astronomy museum on the West Sheshan Mountain. It does not need to be National Space Day to make you go.

China’s Deep-Space Network

main antennas:
- 66-m Jiamusi, Heilongjiang
- 35-m Kashi, Xinjiang
- 35-m Nuequén, Argentina

4 "receive-only" VLBI stations for orbit determination:
- Beijing-Miyun (50 m)
- Shanghai-Sheshan (65 m)
- Nanshan, Urumqi (25 m)
- Kunming, Yunnan (40 m)

also see GoTaikonauts! issue no 16, p. 22

Note: FAST is not yet ready for deep-space tracking as it is still in its test phase, focusing on astronomical observation. All 18-m dishes, used in the Chang’e 1 and other missions, were not built for deep-space tracking and not considered part of the “deep-space network”.

Shanghai Astronomy Museum

Location: on the peak of West Sheshan Mountain, Songjiang District, Shanghai,

business hours: 8:30-16:00 / duration of visit 1 - 2 hours

China’s Lunar Exploration Programme - touchstone for China’s Deep-Space Tracking network

Compared to matured spacecraft and launcher technologies, deep-space telemetry and communication has been a major challenge for China for a long time.

For its first lunar mission, Chang’e 1, launched in 2007, the Unified S-Band (USB) system was still used as the primary TC&C system. Besides tracking stations within China and those in Karachi, Pakistan and Swakopmund, Namibia, as well as the Yuanwang fleet of tracking ships, China’s space programme was in urgent need of more overseas stations to have better coverage. Through collaboration with ESA, Chang’e 1 received support from ESA’s ESTRACK ground station network including the 35-m station at New Norcia, Australia, the 15-m station in Maspalomas, Spain, and the station in Kourou, French Guiana. But this was still not enough for deep-space tracking. China had to build its own deep-space communication infrastructure from the beginning. The plan was to build a VLBI deep-space network consisting of two existing 25-m antennas in Shanghai-Sheshan and Urumqi, Xinjiang, a newly-built 50-m antenna in Beijing-Miyun and another 40-m antenna in Kunming in southwest Yunnan Province. This was done until 2006. In January 2005, the Shanghai receiver participated in the international joint VLBI observation of the Huygens landing on Titan, which gave Chinese scientists useful experience.

In April 2006, the newly established VLBI network consisting now of the existing antennas of Sheshan-Shanghai, Urumqi, and the newly completed antennas in Beijing and Kunming made a successful rehearsal using Europe’s Smart 1 lunar orbiter, with support from ESA.

The next lunar mission, Chang’e 2, launched in October 2010. Already before, China started to extend and strengthen its deep-space tracking and communication network. The plan was to complete the projected domestic stations in late 2012 and the overseas stations by 2016. In 2011, China had to use its existing domestic and overseas tracking stations with a maximum antenna diameter of 18 m, supplemented by four VLBI stations for precise angle measurement during the Chang’e 2 lunar mission. Also, the TC&C system had to run at its highest power for the uplink channels. It totally relied on orbit prediction for directing the ground antennas at the spacecraft. Surprisingly, such a system worked well, not only in the 1.5 million kilometres Sun-Earth-L2 mission in 2011 but also in the 7 million kilometres Toutatis fly-by on 13 December 2012.

The success of the Toutatis fly-by was also owed to the newly completed deep-space tracking network. Two large tracking antennas in Kashi and Jiamusi, with a diameter of 35 m and 66 m, and the 65-m Tianma radio telescope for VLBI tracking in Shanghai-Sheshan, entered service ahead of schedule in October 2012. Four telescopes in Shanghai-Sheshan, Beijing-Miyun, Urumqi and Kunming joined the VLBI observation from 26 November to 14 December 2012. It is estimated that VLBI data helped to increase the orbit determination accuracy from 55 m to 11 m. Also, optical observation by three domestic telescopes and two in Hawaii and Chile helped to increase the accuracy of the orbit prediction as well.

So far, the VLBI tracking system has been successfully applied for all four Chinese lunar missions to date: Chang’e 1 in 2007, Chang’e 2 in 2010, Chang’e 3 in 2013 and Chang’e 5T1 in 2014.

However, deep-space missions to Mars or polar Sun orbit require more capabilities. On 10 July 2007, the Chinese government approved the plan to build the world’s largest radio telescope, the Five hundred metre Aperture Spherical Telescope (FAST). This huge telescope became operational in September 2016. Since it is focusing on astronomical observation during its testing phase, its capability for deep-space tracking will enhance China’s deep-space projects of the future. Other proposals included five new overseas tracking stations in North America, South America, Northern Europe, Australia and Antarctica, and to establish a space-based VLBI network by launching a constellation of tracking satellites.

Chen Lan
Exciting prospects for the future

The Shanghai Astronomical Observatory, in cooperation with national and international partners, undertakes efforts in defining the scientific goals and key technologies of the first space-based Low Frequency Radio Astronomical Observatory and the first space-based VLBI array project in the world.

Also, Tianma will soon be downgraded to become the 2nd largest radio telescope in China. The lead, on a national and international scale, will then be taken by the Steerable 110-m Aperture Radio Telescope (SmART), also known as QiTai radio Telescope (QTT) – currently under construction near the town of Banjiegou in Qitai County, in China’s north-western Xinjiang Uyghur Autonomous Region, bordering with Mongolia, Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan and India. The site for the new radio telescope was chosen in 2010. It is located in a natural basin, surrounded by 1,900 m high mountain tops, 202 km away from the Nanshan Base with its 25-m radio telescope and 46 km from Qitai town. 2012 was the groundbreaking ceremony and because the project is part of the “13th five-year plan of the Central Government supports for Xinjiang economic and social development planning and construction project”, the completion can be expected within the next four years. Like the Nanshan Base, and the Kashi satellite ground station, the Qitai 110-m radio telescope will be operated under the responsibility of the Xinjiang Astronomical Observatory (XAO).

On 6 February 2018, the final prototype dish for the Square Kilometre Array (SKA) project was revealed in Shijiazhuang, China, by the Vice Minister of the Chinese Ministry of Science and Technology. The 54th Institute of China Electronics Technology Group Corporation (CETC54) was responsible for the structural assembly of the first SKA dish, complemented by components from China, Germany, and Italy. SKA is an international effort to build the world’s largest radio telescope. Africa and Australia will host a vast quantity of radio telescope dishes and low frequency aperture array antennas, with a combined collecting area of one square kilometre. However, 100 organisations from all continents will participate in SKA with the headquarters at Jodrell Bank, UK.

With respect to antennas in China, it remains interesting, seeing intriguing developments unfolding in the future.

TianMa’s creator: CETC54 - The 54th Research Institute of China Electronics Technology Group Corporation

CETC54 was the first telecommunications research institute founded by the Chinese government, back in 1952. The institute is located 300 km south-west of Beijing, in Shijiazhuang, the capital of Hebei Province. Over its more than 60 years of development, the institute did not only grow into a facility covering an area of 2 km² and employing 6,000 staff, but has also grown into one of the leading comprehensive research institutes in the field of electronics and information.

CETC54 runs an educational college with master’s degree courses, and it also possesses the largest postdoctoral research centre in Hebei Province. Its establishment in Shijiazhuang comprises research and development centres, a laboratory, manufacturing factories, and a composite materials processing centre.

CETC54 researches, develops, and manufactures equipment for telecommunication, and electronics and information industries. It offers systems, such as emergency command dispatch communication, satellite communication, spectrum monitoring, and public security systems; equipment, including private network switches, satellite communication equipment, and satellite navigation equipment, as well as antenna-, feed-, and composite materials; and components, such as frequency control, precision machining, and customised components. The company also provides technical development and consulting services.

Compiled from content of CETC54 website: http://www.cti.ac.cn/en/
In December 2015, the People’s Bank of China issued 300 million 100 RMB commemorative banknotes and 100 million 10 RMB coins to celebrate China’s success in its space programme. Both means of payment show as the main feature the docking of Shenzhou 9 with the Tiangong 1 space laboratory. In the background, China’s lunar mission, Chang’e 1 is depicted, while the coin is also illustrated with DFH-1, LM-2F, Yutu and the Moon goddess Chang’e. The graphics on the backside of the banknote symbolise human’s technological achievement from bird’s flight, via aviation, up to the establishment of a space station. In total, 2.5 million commemorative albums, containing the banknote and the coin, were released by the People’s Bank of China.
Thinking in visions!

\[ E = m \times rc^2 \]

The German space magazine: Features, History, Fictions
www.raumfahrt-concret.de