GO TAIKONAUTS!

All About The Chinese Space Programme

龙腾太空

Issue 2

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Dawn of the Chinese Space Station Era

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April - June 2011

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There were two successful space launches in the second quarter of 2011.

On 10 April 2011 at 4:47:04 Beijing Time, a Long March 3A (Y19) lifted-off from Pad 3 in Xichang Satellite Launch Centre, putting the Beidou IGSO 3 navigation satellite into orbit. It was the first Chinese space launch of 2011 and the eighth operational Beidou satellite. The satellite entered its working orbit ... page 3

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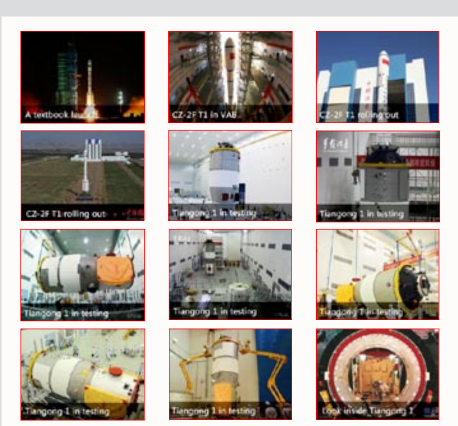

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Dawn of the Chinese Space Station Era

A Textbook Launch

History turned a new page at 21:16:03 Beijing Time on 29 September 2011, when a Long March 2F (CZ-2F T1) rocket lifted-off from Pad 921 at the Jiuquan Satellite Launch Centre in China. In contrast with other launch vehicles that took-off from the same pad on previous occasions, ... page 6

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Editor's Note

As promised, this issue is delivered as a special issue on the Chinese space station programme.

The flawless launch of the Tiangong 1 was really exciting, but it was not the most exciting moment during these days. The most exciting thing was that new details of the programme emerged almost every day following the launch. As usual, most of these details do not come from the official Chinese Manned Space Engineering Office (CMSEO). Instead, they are from an overwhelming number of media reports including interviews with space officials and scientists, stories about related people or organisations, and even reports on individual products or components for the Tiangong 1 made by specific companies. Thanks to the hard-working Chinese journalists, we are able to collect information from various sources and finish a comprehensive cover story on the Chinese space station programme. We expect it will give you a clear picture of the Tiangong 1 spacecraft, the upcoming docking mission, as well as the future Chinese space station plan.

Rendezvous and docking is the major objective of the Tiangong 1 mission. Chinese space officials, scientists and engineers, are very confident of achieving this objective with the launch of the unmanned Shenzhou 8 spacecraft that is presently undergoing final preparation. However, rendezvous and docking between people is not so easy. International space cooperation between China and the developed countries has been up and down over many years, and there still appear to be many unsolved problems. In this issue, we have an article on this topic with an historical review and analysis. Yes, it needs wisdom. Fortunately, we have seen some light at the end of the tunnel. The German SIMBOX experiment on Shenzhou 8, and the planned POLAR payload on Tiangong 2 are good signs. But why not take one giant leap forward? This is the motivation for our proposal for a China-Europe-Russia cooperation on the Space Station that is also presented in this issue. Although there must be many unexpected political and technical difficulties, they should not prevent us from exploring the possibility.

Another noteworthy piece in this issue is the article of "Touch the Chinese Space Programme in Three Days". This article was completed after attending an international space conference in Shanghai and visiting a number of local SAST facilities. This article indeed involves more personal experience than the other ones. We hope you enjoy it.

(Chen Lan)

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Chinese Space Quarterly Report

April - June 2011

Launch Event

There were two successful space launches in the second quarter of 2011.

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On 21 June 2011 at 0:13:04 Beijing Time, a Long March 3B/E (Y20) took-off from Pad 2 in Xichang Satellite Launch Centre, putting the Chinasat 10 (formally called Sinosat 5) communication satellite into the GTO orbit. On 28 June, at 17:53, the satellite entered geostationary orbit at 110.5°E after five orbital manoeuvres. On 29 June, the satellite control was transferred from Xi'an Satellite Control Centre to the Control Centre of China Satcom.

Launch Vehicle

There are no related reports in Q2, 2011 on the launch vehicle development.

Engine

After the first successful test firing in February, the 60-tonne liquid oxygen / methane engine made a further 4 test firings. It was developed under a project called "studies on key technologies of re-usable liquid oxygen / methane engine". The project recently passed an important review by the Programme 863 Expert Group.

On 2 April, the third-stage engine of the new generation launcher (supposed to be the YF-75D) passed a review that marks the starting point of the engineering model development.

Satellites

China and Venezuela signed an agreement on 27 May for the construction of the South American country's second satellite, the state-run AVN news agency reported. The VRSS-1 (Venezuelan Remote Sensing Satellite) project will cost an estimated US$140 million. The satellite will be based on the SAST2000 bus and will be launched by a CZ-2D from Jiuquan in October 2112. China Great Wall Industry is going to provide the in-orbit delivery of the satellite.

The Haiyang 2 satellite and the CZ-4B (Y14) launcher completed their shipment readiness review on 17 June in Beijing. Haiyang 2 is China's first ocean dynamic environment satellite that was in development by CAST since 2007. It was planned to ship the satellite and the launcher to Taiyuan Satellite Launch Centre on 22 June and 17 July respectively for a scheduled launch in mid August 2011.

A joint project of the China National Space Administration (CNSA) and CNES, CFOSAT (China-France Oceanography SATellite) entered its detailed definition phase in April. The future satellite's chief goal will be to measure surface wind and directional spectra of waves.

On 1 April, the HJ-1A ground station in Thailand was delivered and handed-over to the Thai authorities. The ground station was built by the China Centre for Resources Satellite Data and Application (CRESDA) according to the framework of Asia-Pacific Space Cooperation Organisation (APSCO). In March, the final testing of the station and the training of ground personnel was completed and the station started to receive nominal imagery.

On 8 April, the FY-3B completed the in-orbit testing review. FY-3B is China's second new generation polar orbit meteorological satellite. It was launched on 5 November 2010. During the more than four months of in-orbit testing, it completed 20 test programmes including the validation of 2216 parameters on 11 payloads. The test results show that functionality and performance of the FY-3B is better than the first FY-3, the FY-3A satellite that launched approximately two years earlier (27 May 2008). On 26 May, the FY-3B was formally delivered to China Meteorological Administration (CMA). The FY-3B is the first Chinese polar weather satellite in afternoon orbit, i.e. FY-3B will cross the Equator in the afternoon, which significantly enhance China's global monitoring capability.

China has recently approved the nation's first carbon dioxide monitoring satellite project. The "Scientific Experimental Satellite for Global Carbon Dioxide Monitoring" will be launched in 2014. Chinese Academy of Sciences (CAS) will be responsible for in-orbit-delivery of the satellite. Shanghai Engineering Centre for Microsatellites, CAS, Changchun Institute of Optics, Fine Mechanics and Physics, CAS, and National Satellite Meteorological Centre of CMA (China Meteorological Administration) will be responsible for the development of the satellite bus, the payloads and the ground system.

Manned Space Flight

In early April, the China Manned Space Engineering Office (CMSEO) held a special meeting on the National Space Station Project. It nominated the Chief Commander, the Chief Designer and members of the Task Planning Committee. It also confirmed the work plan for 2011 and the technical requirements of some systems for the project's approval.

Scientists and engineers of the German Aerospace Agency DLR and their Chinese counterparts from the China Manned Space Engineering Office (CMSEO), successfully concluded a dry-run of the SIMBOX flight- and engineering models in April and May in Beijing. After all parameters were met, and the simulation of the experiment was completed without any difficulties, the international team gave the go-ahead for the integration of the approximately one-tenth of a cubic metre sized incubator into the Shenzhou 8 rocket. In August, the SIMBOX facility was transported to the Jiuquan launch site in Inner Mongolia, and the launch was set for end of October 2011.

On 25 April 2011, CMSEO officially announced a public naming contest for the country's first manned space station when China's six taikonauts launched a crystal ball together. The campaign asks for the CMSEO logo, name and logo for China's manned station, names for the core module, two experiment modules and the unmanned cargo transportation vehicle. The public was asked to submit their ideas to the CMSEO web site from 25 April to 25 July (or 20 May for the cargo transportation vehicle). A review committee would select for each category 30 name proposals and logos. After that, the public can vote on the list of entries and the 10 highest-rated ideas would be short-listed. The winner will be selected by the end of September. China's manned space station is planned to be completed around 2020. The selected name and logo, at that time with the station, would fly into space.

The Tiangong 1 station prototype and the Shenzhou 8 spacecraft completed vacuum thermal tests in the KM-6 chamber in mid April and early May respectively. At the end of June, the Tiangong 1 module completed all testing in Beijing and passed the shipment readiness review on 28 June. It was then transported to the Jiuquan Satellite Launch Centre (JSLC) on 29 June.

On 23 June 2011, a delegation of the China Manned Space Engineering Project Office (CMSEO) accepted 300 flags from the International Astronautical Federation (IAF) during the Paris Air Show in France. These flags will be carried into space on board of the Tiangong 1 target spacecraft and be brought back to Earth by a taikonaut when he/she completes China's first manned rendezvous & docking mission next year. Berndt Feuerbacher, president of IAF, handed over the flags to taikonaut Zhai Zhigang. In December 2010, the same 300 IAF flags were sent to the International Space Station on board of the Russian manned spacecraft Soyuz TMA-20, and were brought back by U.S. Space Shuttle Endeavour in June 2011. When the flags return again to Earth, IAF would deliver them to each member in proper time, so as to promote the peaceful use of outer space and to develop international cooperation in the area of manned space flight, said Mr. Feuerbacher.

Lunar and Deep Space Exploration

On 16 May, a seminar on China's first asteroid exploration mission was held in Purple Mountain (Zijinshan) Observatory, Nanjing. Eight CAS subsidiaries including the Lunar and Deep Space Architecture Department, the Centre for Space Science and Applied Research, the Shanghai Observatory, the Institute of High Energy Physics, the Institute of Electronics, the Shanghai Institute of Technical Physics, the Changchun Institute of Optics, Fine Mechanics and Physics, the Xi'an Institute of Optics and Precision Mechanics, as well as the Nanjing University and Shanghai Academy of Spaceflight Technology (SAST) attended the seminar. Scientists discussed mission objectives, payload configuration and spacecraft design and target asteroid screening.

China's second lunar orbiter, Chang'e 2, reached its design lifetime of 180 days on 1 April. It was launched on 1 October 2010. Up to 1 April 2011, it has obtained a complete 3D lunar surface scan with images of 7 m resolution. Chang'e 2 then entered the extended mission phase for additional polar area imaging and the second-time high-resolution survey on the Sinus Iridium area which is one of the planned landing sites for Chang'e 3. For the latter, Chang'e 2 had to lower its orbit to 15 km altitude and returned back to the original orbit after completion of the imaging process. At the closest-to-surface point, it was able to obtain surface image with resolution of nearly 1 m and elevation data of 5 points per second by the laser altimeter. By 23 May 2011, Chang'e 2 completed all these tasks.

As Chang'e 2 still had enough remaining fuel after the completion of the first two tasks in the extended mission, it was decided to fly the probe to the Sun-Earth Lagrange 2 (L2) point for the rest of the extended mission. On 8 June, Chang'e 2 raised its orbit from 100 x 100 km to 104 x 3,583 km. On the next day, Chang'e performed an engine burn from 16:50 to 17:08 and successfully left the lunar gravity zone. It was expected to take 85 days to reach the L2 point and would enter a Halo orbit around L2.

Miscellaneous

Before the Beidou IGSO-3 launch on 10 April, the Command and Control Centre in Xichang Satellite Launch Centre completed a system upgrade for improved remote monitoring capability, more stable and efficient transmission, networked management and enhanced security features.

In mid May, the first "military standard-time watch" using Beidou 2 time service completed a review held by PLA and the China Electronics Group. The watch is reported has time precision of 0.1 second and is also capable of measuring temperature, air pressure, altitude and storing data. In the next step, the watch will be enhanced with positioning and navigation functions.

The Hainan Space Park, located at south of the new Hainan Satellite Launch Centre in Wenchang, has completed a round of design optimisation and would enter the design phase for construction. The park is financed by the China Aerospace Science and Technology Corporation (CASC) and designed by the U.S. based BRC Imagination Arts. The park's total investment is 7 billion RMB (around one billion USD) and it is expected to be opened in 2014. The park includes a launch watch zone, a tour corridor through the nearby launch centre, astronomical display zone, space camp, etc. Meanwhile, it was also reported in mid-May that the Space Pavilion of the Shanghai World Expo 2010 will be relocated to the Hainan Space Park.

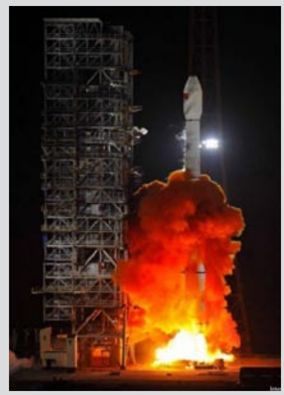
On 4 and 5 April 2011, a Chinese delegation headed by the Director of CMSEO, Wang Wenbao, together with Yang Liwei, Deputy Director and first taikonaut, visited DLR in Bonn. The delegation met with Christoph Hohage, Director of Space Management. Both sides exchanged their views on further cooperation in the field of human space flight. Wang Wenbao and Christoph Hohage briefly introduced the current situation with respect to human space flight in China and Germany, and jointly reviewed the progress made of their cooperation project SIMBOX since the Cooperation Framework Agreement between CMSEO and DLR was signed in December 2008. To further strengthen cooperation and exchanges, both sides agreed that a joint working group should be set-up based on the original Framework Agreement, so as to promote continuous cooperation. During the talks, the two sides also had an extensive and in-depth exchange on further cooperation in the construction and operation of China's space station. Both sides stressed that the SIMBOX project on the upcoming Shenzhou 8 mission, was the starting point of cooperation, and that in the future, China and Germany would have a broad cooperation in the field of space station construction technology and space science experiments.

The Chinese delegation left Germany for France to visit ESA Headquarters in Paris. The Chinese officials had friendly talks with Jean-Jacques Dordain, Director General of ESA. Jean-Jacques Dordain welcomed the CMSEO delegation and spoke about the main progress made since last year in the field of human space flight, while Chinese Director Wang Wenbao presented China's current human space missions and the construction plan on the future space station. During the meeting, the two sides engaged in an in-depth discussion on potential exchanges and cooperation for human space flight.

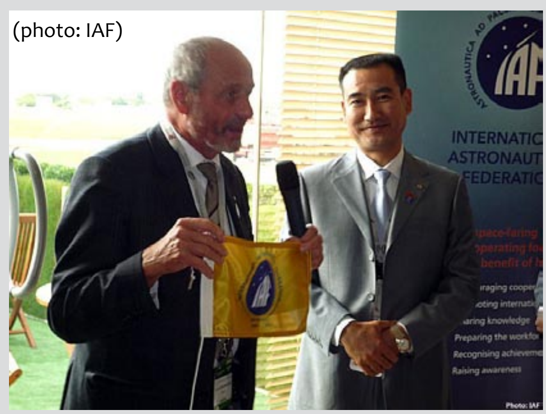
On 4 April, a CNSA delegation visited the Italian Space Agency (ASI) and discussed cooperation on the Sino-Italy Earthquake Electromagnetic Test Satellite project. In the same month, there was the tenth meeting of Joint China-France Committee on Space Cooperation held in Beijing.

(Chen Lan)

APSCO: *Asia-Pacific Space Cooperation Organisation*
CASC: *China Aerospace Science and Technology Corporation*
CALT: *China Academy of Launch Vehicle Technology*
CAS: *Chinese Academy of Sciences*
CAST: *China Academy of Space Technology*
CMA: *China Meteorological Administration*
CMSEO: *China Manned Space Engineering Office*
CRESDA: *China Centre for Resources Satellite Data and Application*
SAST: *Shanghai Academy of Spaceflight Technology*



(photo: IAF)



top left: Lift-off for Beidou IGSO-3

top right: the Beidou military standard-time watch

left: IAF President Feuerbacher and Zhai Zhigang

Shenzhou 8 during thermal vacuum test

Dawn of the Chinese Space Station Era

A Textbook Launch

History turned a new page at 21:16:03 Beijing Time on 29 September 2011, when a Long March 2F (CZ-2F T1) rocket lifted-off from Pad 921 at the Jiuquan Satellite Launch Centre in China. In contrast with other launch vehicles that took-off from the same pad on previous occasions, this CZ-2F had no escape tower and no crew on top. This was an improved CZ-2F rocket carrying China's first space station module, Tiangong 1 (TG-1) that will be the target for rendezvous and docking by three Shenzhou (SZ) spacecraft in the near future.

It was a long anticipated launch and the most important event after the SZ-7 space-walk mission. Mastering rendezvous and docking technology will be another milestone in China's human space flight programme. TG-1 is not only a docking target but also a prototype of a mini space station. It's the beginning of China's ambitious space station plan for the coming years.

China's Central Television, CCTV, provided a live broadcast of the launch. Thanks to the clear sky, the ground optical tracking equipment captured a beautiful view of the separation of the strap-on boosters and the first stage, with five bright dots like a blooming firework becoming clearly visible, and also, finally, jettisoning of the fairing. Additionally, four on-board rocket-cams transmitted video back to Earth in real-time, clearly showing each separation event and TG-1's orbital insertion. Jettison of the strap-on booster, first stage engine shutdown, first stage separation, jettison of the fairing, second stage engine shutdown and spacecraft separation took place at T+155 s, T+159 s, T+160 s, T+215 s, T+460 s and T+582 s respectively. The different timing in the launch sequence as compared with previous Shenzhou launches, was due to improvements on the launcher and the different payload carried on-board. At 21:28, TG-1's solar panels were successfully deployed. The launch was perfect.

However, just weeks before the launch, it was still surrounded by uncertainty. The TG-spacecraft arrived in Jiuquan on 29 June, followed by the CZ-2F T1 rocket on 23 July. Preparation work then proceeded smoothly. There were messages indicating the launch would take place at the end of August. But the CZ-2C SJ-11-04 launch failure on 18 August interrupted the procedure. Initial evidence pointed towards

Voices from the International Space Community

Prof. Johann-Dietrich Woerner *on the occasion of the launch of Tiangong 1, the test module for a future space station:*
"We have not been thinking about a closer partnership only since the launch of Tiangong 1. We have been working together with China for some time already. Chinese scientists have been joining our parabolic flight campaigns, and on 1 November this year German experiments of the SIMBOX Project will be launched into Earth's orbit on-board a Chinese rocket. The participation of China in the International Space Station would be a logical and welcome extension of such activities. Finally, this launch is not, as has been described by some, a demonstration of power, but a logical continuation of Chinese space research. A more intensive cooperation would not only be a win-win situation for all involved parties, but would also serve international understanding."

Manuel Valls, *(Retired) Head of Policy and Plans Department of ESA's Human Spaceflight Directorate:*
"The launch of Tiangong-1 sets off the building of a Chinese Space Station scarcely thirteen years after the launch of Zarya marked the beginning of the assembly of ISS, which is quite remarkable and a good omen for the continuation of the human spaceflight global endeavours."

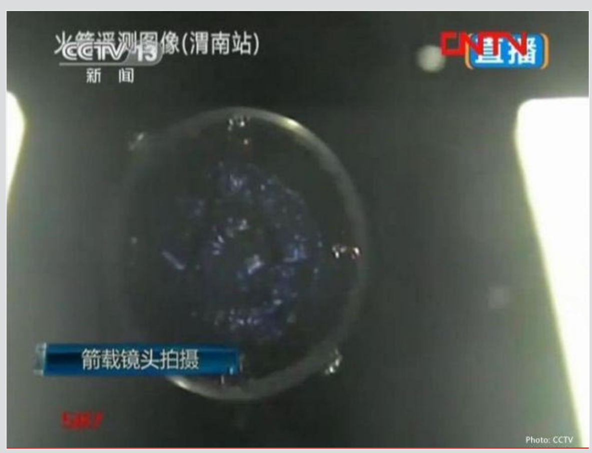
Klaus-Peter Willsch, *Member of Parliament and Chairman of the Air & Space Group in the Deutsche Bundestag (German Parliament):*
"China is a rising space nation. With the Long March rocket, China owns a reliable rocket carrier, which is - like the Ariane 5 rocket - mainly used for the transport of satellites. With the launch of Tiangong 1, the "heavenly palace", China strongly commits to human space flight, and also makes clear that it has succeeded in operating at the same level as the "classic" space nations."

left: lift-off

right: 2nd-stage engine

left: booster separation as seen from rocket

right: booster separation as seen from ground

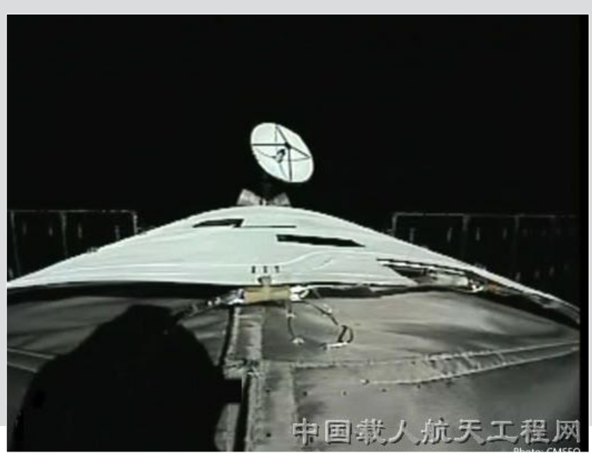


left: inside the fairing

right: spacecraft separation

left: ground telescope image

right: in-orbit image



the second stage as being the cause of the failure. As all Chinese Long March launchers have a similar second stage, the Tiangong launch had to be delayed, which was announced by a spokesman of the China Manned Space Engineering Office (CMSEO) on 1 September. On 8 September, the official result of the investigation identified the servomechanism connecting the vernier engine at the second stage as being the cause of the failure.

On 20 September, CMSEO announced that measures had been taken to avoid a repeat of the failure, and had set the launch date between 27 to 30 September. On the same day, the CZ-2F T1 launcher with the TG-1 payload on-board, was transported to the launch pad from the vertical assembly building, which took about one hour (from 9:00 to 10:07).

Due to a forecast of bad weather for 27 and 28 September, it was announced on 25 September that the launch was again delayed for a further two days to 29 September. There were a few rounds of partial and full system rehearsals at the launch site. Fuelling, lasting a total of five hours, was completed on 28 September. There were no further glitches reported before the launch, and after more than one decade of development and waiting, TG-1 was ready to go.

After the textbook launch, TG-1 entered an initial orbit of 200 x 346 km. At 01:58 on 30 September, the first manoeuvre raised its apogee to 355 km. And at 16:09 later that day, the second manoeuvre finally put TG-1 into a near-circular orbit with an apogee of 362 km, and initiated the in-orbit test and checkout. Later, on 30 September, TG-1's Environmental Control and Life Support System (ECLSS) was turned on, and switched to the autonomous operation mode. According to scientists involved in the mission, the rendezvous and docking will be at an altitude of 343 km. The initial higher orbit is designed to take advantage of natural decay to save onboard fuel that will lower the orbit to the expected altitude for SZ-8 to approach and dock with TG-1. On 12 October, the in-orbit testing was completed. At the time of writing (21 October) all operations continue to run smoothly.

It is noteworthy that on 7 October, a staff member in the Toyama Astronomical Observatory, Japan, took an in-orbit image of TG-1 using a one-metre optical telescope. The image clearly shows the spacecraft and its solar panels. It is the first publicly available image of this kind of Chinese spacecraft. The CMSEO also officially released two in-orbit pictures (one external view of the spacecraft and one in-cabin image) on 10 and 20 October via t.qq, a Chinese micro-blog site.

Long Journey to the Heavenly Palace

As early as in 1992 when the humann space flight programme was initiated, the Chinese drew up a plan consisting of three phases:

- Complete the first human space flight by 2002.
- Master technologies of extra-vehicle activity (EVA), rendezvous and docking, and launch an 8-tonne class man-tended space laboratory by 2007.
- Establish a permanent modular space station after 2010.

China has successfully completed the first phase by sending the first taikonaut into space in 2003, one year later than planned, and achieved the first objective of the second phase in 2008 with Zhai Zhigang's 16-minute historic space walk. The rendezvous and docking mission and the space laboratory have been at least 4 years behind the original schedule, which indicates the difficulties the Chinese engi-

Voices from the International Space Community

Karl Bergquist, *Administrator at International Relations Department at ESA-Head Quarters in Paris in an interview with CCTV on 29 September 2011:*
"I think the Tiangong mission is, of course, a very important step in view of the building up of the space station. Because with Tiangong, China will be able to test different technologies, such as life support, docking mechanism and so on. The European Space Agency has a long-standing cooperation with China since now almost 20 years. When it comes to space science we even have developed joint missions. ESA, for example, participated on the Chinese Double Star mission. ESA by itself is an organisation which is based on international cooperation. We are very much keen to enlarge the cooperation and to look into new areas of mutual interest when it comes to space science and applications."

John Logsdon, *Founder and long-time Director of George Washington University Space Policy Institute in an interview with CCTV on 29 September 2011:*
"It is a very important step for China in its very careful, slow paced but very steady development of human space flight capabilities. It is an important step forward in getting rendezvous and docking technology which is crucial for the future. ... I think this is an addition to the human capability to exploit the space environment for human benefit. ... The United States looks with great interest on China's plans. There are some here that would like to create the kind of space race that took the United States to the Moon in the 1960's, but I think the situation is so different that that is not really a relevant comparison… I hope that our two countries can develop a political relationship that would allow very visible cooperation, like human space flight, to move forward."

Kathy Laurini, *NASA/Senior Advisor, Exploration and Space Operations:*
"I wish to congratulate the Chinese on their launch of the Tiangong-1 experimental module and test bed. It will open a lot of doors for their activities in low Earth orbit. The live video of the launch was remarkable."

neers encountered. As all the technologies in this phase are essential to the future space station and to operate a meaningful human space programme, it becomes a key phase.

Pre-studies and key technology development of both the 8-tonne space laboratory and the docking mechanism started very early. It was in 1995 that SAST started the study on the docking mechanism. It completed a demonstrator in 1999. In early 2004, it was reported that SAST has made a "breakthrough" in docking mechanism development. Planning of the space laboratory was initiated in the late 1990s, and the preliminary design review completed in 2002. The project was then subsequently formally approved and entered full-scale development around 2004. Besides the docking mechanism, SAST continued their same role in the Shenzhou programme responsible for the development of the resource module (propulsion module), the power system and the communication system, while CAST was responsible for the overall development and the rest of the hardware. Zhang Bainan was named as Chief Designer of the space laboratory. In 2006, development of the engineering model started and the space laboratory was named as "Tiangong" (meaning "heavenly palace" in Chinese). In 2009, the flight model development began.

There was then a major change in the planning of the docking mission. The originally planned rendezvous and docking, using a Shenzhou vehicle and the orbital module of a previous Shenzhou, would happen earlier than the EVA mission. But the docking mechanism development took longer than expected, so that it was decided to fly the EVA mission first – it was shifted to 2007, and actually flew in 2008, with the docking mission delayed to around 2010. As the space laboratory could be ready by then, docking with an orbital module was abandoned and the docking tests were combined into the laboratory programme. This is what we see today as a multi-year plan with three Tiangong laboratories and at least seven Shenzhou spacecraft. It was unfortunate that the unique Chinese design of the Shenzhou orbital module that was conceived as a satellite, a docking target and more, does not realise its full value. It will be hard to see a Shenzhou with two pairs of solar panels in the future.

To launch the TG-1 that has different requirements compared with the Shenzhou vehicles, a new launcher model was designed. It was originally named CZ-2F/G (G meaning "improvement") and was given the final designation CZ-2F/T. The new launcher has as many as 170 improvements, including:

- The fuel capacity of the strap-on boosters has been increased, by changing the fuel tank's cap from a sphere-shape to a cone-shape. As a result, the launcher has about 450 tonnes of fuel, 493 tonnes of launch mass and its LEO capability is increased to 8.6 tonnes.
- The launch escape system is replaced with a new, larger fairing with a length of 12.7 m and a diameter of 4.2 m. It uses the Von Karman Ogive to improve aerodynamic performance.
- Two sets of laser inertial measurement units (IMUs) replace the gas-bearing gyroscope to improve the launcher's manoeuvring capability.
- The original perturbation guidance system is replaced by a new, interactive guidance system providing better orbit insertion precision.

TG-1 completed assembly in August 2010, and started a series of tests. The flight model of the docking mechanism was completed and delivered in November 2010. And in April 2011, the TG-1 flight model completed the crucial thermal

Voices from the International Space Community

Dr Shufan Wu, *Senior Spacecraft Control System Engineer contractor for ESA:*
"Tiangong-1 marks the solid step forward of the Chinese manned space program towards a manned space station or large space structure construction in the near future. It is a very necessary step to test and acquire the in-orbit automated or autonomous rendezvous and docking technology of spacecraft, which forms the basis for in-orbit assembly and construction. It opens also the door for Chinese manned space program to cooperate with international players in space station constructions and applications."

Prof. Dr. Berndt Feuerbacher, *President of the International Astronautical Federation:*
"We congratulate our Chinese partners on the successful launch of the space module Tiangong-1 on 29 September 2011 with a Long March 3F rocket from Jiuquan Launch Center. This is the first step towards a Chinese space station, which is planned for assembly within the 2016 – 2022 timeframe. China is building-up its ambitious space programme in a long-term, consistently planned, step-by-step sequence. After the first human space flight by taikonaut Yang Liwei in 2003 and several subsequent flights of increasing complexity, the small space laboratory Tiangong-1 has now been placed unmanned into orbit for conducting the first docking manoeuvre. With the successor modules Tiangong-2 and -3, a manned space laboratory for scientific and technological experiments will be established, that will finally lead to an independent 30 tonne space station. In combination with the scientifically-oriented Chinese programme for lunar exploration, China is developing into a space nation comparable with the US, Russia and Europe. With that, China is an interesting partner for international cooperation. Russia, France and Germany have been starting partnership cooperation with China in different areas. In view of ever more challenging future goals for space flight, in particular in the frame of exploration with possible manned flights to Mars, a better incorporation of China into international partnerships would be desirable."

left: TG-1 interior (port facing)

right: TG-1 interior (resource module facing)

left: the flight module and back-up

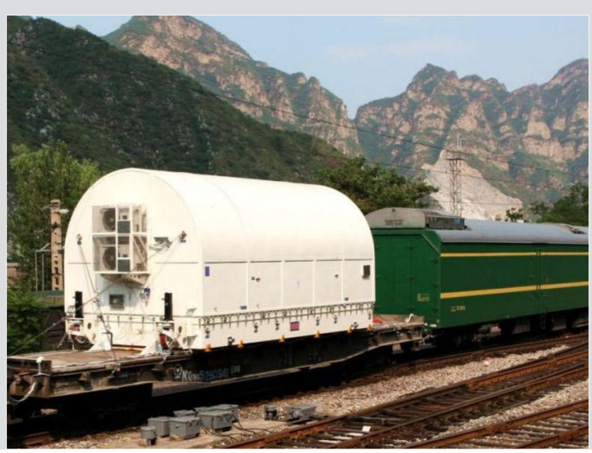
right: TDRS antenna close-up

left: early mock-up

right: thermal vacuum test

left: TG sealed in a container

right: during transport



vacuum test in the KM-6 test chamber. After a flight readiness review (FRR), it was transported to Jiuquan and arrived on 29 June. It was the last stop on its way to its destination - space, or heavenly palace, as its name unveils. It is also a long journey taking almost 20 years from concept to reality.

A Man-tended Mini Space Station

TG-1 is developed on the basis of the Shenzhou manned spacecraft. It has two cylindrical sections that are officially called the "experimental module" and the "resource module". They can be easily distinguished by their different diameters. The pressurised larger diameter section is the experimental module that is essentially an enlarged Shenzhou orbital module, while the unpressurised smaller diameter section is the resource module, an improved Shenzhou propulsion module. They play similar roles to their predecessors. With a docking port at one end of the experimental module, TG-1 can be visited periodically by Shenzhou vehicles, and can host the three-man crew for about 20 days or one taikonaut for 60 days, which makes it comparable to early Soviet Salyut or Almaz stations. Although China officially calls TG-1 the "Target Vehicle" and it is just an 8-tonne class spacecraft, it is truly a space station by any definition of space station. Of course, it is just a "mini space station" and is the smallest space station in history.

TG-1 has a length of 10.4 m, diameter of 3.35 m, and mass of 8,506 kg – the heaviest spacecraft China has ever launched. The experimental module and the resource module have lengths of 4 m and 3.2 m, and are connected by a 1.6 metre-long truncated cone. The resource module has a diameter of 2.8 m, with a usable interval volume of approximately 15 cubic metres, with a volume of 4 m long, by 2 m tall and 1.8 m wide. The mini station has two 490 N engines at the rear of the resource module and 24 thrusters on its exterior. Compared to the Shenzhou spacecraft, its solar panels have been re-designed by replacing the base-plate with a semi-rigid carbon-fibre made frame-grid structure, which reduces the overall weight significantly. It is able to generate 7 kW of electricity and supply the spacecraft through a high-pressure bus bar at 100 V. TG-1 is equipped with S-band and Ku-band communication systems. A one-metre diameter antenna is used to track the Tianlian Data and Relay Satellites.

TG-1 was designed from the beginning as a test-bed for space station technologies, so it is very natural to see so many new technologies, all for the first time in China, on the spacecraft. They include:

- **Centralised altitude control, power, communication, data management and environment control systems.** When a Shenzhou spacecraft docks with TG-1, the latter will take over the responsibility of all these controls for the docked complex. Such a system is critical for the future modular space station.
- **An improved environment control and life support system (ECLSS) with two technology demonstrators of water vapour separation and water electrolysis.** They are essential for a regenerative ECLSS planned for TG-3, and the future permanent space station.
- **Micrometeoroid shield.** This shield protects the spacecraft with an average interval without penetrating damage of more than three years. The total mass of the system is less than 50 kg, which took a few years to design, test and improve. It was tested in an ultra-high velocity impact device capable of firing and detecting sub-millimeter-sized particles.
- **A large flexible bellows-type metal propellant tank.** This cylinder-shaped accordion-like tank is able to push propellant into the engine under zero gravity, which is necessary for long-term operation of the space station. It is also ready for in-space refuelling by cargo transportation vehicle, although such an operation is not planned for the two-year long TG-1 mission.
- **Six single-frame control moment gyroscopes (CMGs) in the resource module.** It is the first time that CMGs have been used on a Chinese spacecraft. CMGs have advantages of a larger output moment, higher precision, and no requirement for a working substance, so that it is a good choice for implementation on a space station. Previous Chinese spacecraft all used attitude-control thrusters and momentum wheels.
- **Upgradable software.** To explore future software upgrading in long-term station operation, the control software of a subsystem on the TG-1 is designed to be upgradable from ground control.
- **Habitation facilities.** To support longer duration space occupation, TG-1 is equipped with a mini kitchen, a sleeping space with sleeping bags for two crew members, exercise bicycle etc. There is also additional food and other supplies on-board in preparation for the upcoming manned Shenzhou flights.

TG-1 also has experimental equipment, the most noticeable of which are two telescope-like cylinders located at the joint section between the two modules. One of them is reportedly a hyper- spectral imager with a ground resolution of 10 m. It was reportedly developed jointly by the Changchun Institute of Optics, Fine Mechanics and Physics, and the Shanghai Institute of Technical Physics. The former was responsible for the visible light spectrum device and final integration, while the latter developed those of the shortwave infrared spectrum. Other experiments include a composite gel crystal-growing device, and space environment survey equipment. There is also a student experiment – the exposure of seeds of endangered species in space. This experiment was selected from a nationwide competition in schools earlier this year. It is also believed that a certain amount of stamps, envelopes and artistic works were carried in the spacecraft, which has become a Chinese space tradition. The most interesting "payload" being 300 flags from the International Astronautical Federation (IAF) that have already flown on the ISS, Soyuz and Shuttle, and will be brought back to Earth by a manned Shenzhou next year.

Dragon's Kiss in Space

The main objective of China's human space programme in phase 2 is to test space vehicle rendezvous and docking technologies. According to the plan announced to the public, there will be 3 Shenzhou missions to experiment and verify related technologies using TG-1 as the target spacecraft. The first mission is an unmanned SZ-8 mission to perform China's first-ever rendezvous and docking operation, and to test the multi-module complex control and management system, and most importantly, to verify its reliability and safety in preparation for the manned mission later on.

SZ-8 is scheduled to be launched by a CZ-2F rocket (Y8) on 1 November 2011. Before the launch, TG-1 will gradually lower its orbit to a 343 km near-circular orbit through natural decay. It will make a 180-degree turn-around before the SZ-8 launch, aligning its docking port backward and ready for the docking - the dragon's kiss in space. According to the reports by Chinese media, the first docking will take place 2 days after launch. The SZ-8 will start the rendezvous sequence around 50 km from TG-1. It has 4 planned location points at 5 km, 1,400 m, 400 m and 30 m respectively from TG-1, where the SZ-8 will stop for a short period of time to verify that everything is going well before continuing the approach.

Once SZ-8 docks with TG-1, TG-1 will take over the flight control of the complex and will even supply an additional 500 W of electric power to SZ-8, since it only has one pair of solar panels. This might be necessary to support the experiments on board of SZ-8. The TG-1/SZ-8 complex will remain in this orbit for about 12 days until SZ-8 undocks from TG-1, and prepares for the second docking experiment. Following the second docking, SZ-8 will return to Earth and TG-1 will be raised to the orbit it was in prior to the docking.

Besides its space technology test mission, SZ-8 also has scientific and other payloads including a German biological and physiological experiment facility called "SIMBOX", a chip named "Dream" which contains more than 40,000 literary and artistic works collected from the public, and also some plant seeds

Another noticeable and interesting change is that SZ-8 reportedly will have a "more comfortable and human-friendly interior design". This might indicate that China is not completely satisfied with the original Shenzhou versions that may have too strong an influence from Russian designs. It is likely that future Chinese space station(s) and spacecraft will try to reach Western standards in all aspects.

Over the last 12 years, China has launched 7 Shenzhou spacecraft, each one an improved version over the previous one. With this incremental improvement approach, China is gaining technology maturity for a manned spacecraft while keeping both risk and cost relatively low. After the docking capability is added to SZ-8, the final building block is in place, and the design of the Shenzhou spacecraft will be finalised, becoming the standard crew ferry vehicle for the future.

The following SZ-8, SZ-9 and SZ-10 are planned to perform further tests with TG-1. As TG-1's primary task is to test and verify its rendezvous and docking capability, SZ-9 and SZ-10 will continue these tasks, but with both automatic and manual operations.

Wu Ping, the CMSEO spokeswoman disclosed in the news conference at Jiuquan prior to the TG-1 launch, that the first crew has already been selected, and under the current plan, SZ-10 will be a crewed mission. Whether SZ-9 will be crewed or not will depend on the result of the SZ-8 flight review. SZ-10 is getting more public attention in China because, as reported by the Chinese media, it will carry the first female taikonaut.

There is no indication of how long the crew will remain on TG-1. However, SZ-8 mission's 12-day timeline with TG-1 may suggest the crewed mission would likely have the same duration. 12 days is well within the 60-man-day limit for human inhabitants on a TG spacelab without a regenerative ECLSS.

Evolution to a Chinese Mir

While TG-1 is designed as a space station test-bed and a docking target, TG-2 and TG-3 are officially called space laboratories. This could mean that TG-2 and TG-3 will operate with full functionality designed for a space laboratory. Similar to TG-1, the service life for the space laboratories is reportedly only two years. It is reported that TG-2 will be launched in 2014 and TG-3 before 2016. Throughout approximately 7-8 years of combined operation of the space laboratories, China could test key technologies and build up the experience necessary for designing, building and operating the upcoming space station.

According to various media sources, TG-2 will be almost identical to TG-1 and will be launched with a CZ-2F/T rocket. What makes TG-2 different from TG-1 is that it will be an operational space laboratory that may accept on-board experiments from various research organizations and other users. Its mission objectives will be focused on Earth observation, medical (space flight) and other space application technologies, according to the CMSEO web site. It is also planned for a small satellite to be released from TG-2, and it is reported that the China-ESA joint experiment POLAR, a Gamma-Ray Burst Polarimeter, will be carried and tested on TG-2.

TG-3 would be a major upgraded version of TG-2. CMSEO states that it will test regenerative ECLSS, mid-term manned occupation and cargo transport vehicle rendezvous and docking on TG-3. The cargo transport vehicle is the most interesting among these, suggesting that TG-3 may include a second docking port. A possibility corroborated by a Tiangong model on display at the 2008 Zhuhai Airshow. This model had two docking ports and looked as though it was of larger diameter than TG-1. However, the aft docking port may require a bulkier resource module to contain a transfer tunnel inside, resulting in greater mass. The Chinese media suggest that TG-3 will be launched by the CZ-7, the successor of CZ-2F, and will be as heavy as 13 tonnes. If this is true, TG-3 will be clearly not just a simple upgrade of the 8.5-tonne TG-2, but a significantly redesigned version of the space laboratory. It is reasonable to have a transitional version between the early TGs and the future modular station. And it is possible that some major components of TG-3 hardware could be partially shared with the modular space station.

Besides the TG space laboratories and SZ spacecraft, the cargo transport vehicle is another important piece of hardware to be developed and tested during the TG spacelab programme. The official CMSEO website has revealed that the cargo spacecraft will not be heavier than 13 tonnes and its maximum diameter will be 3.35 m. This indicates it will likely be launched on CZ-7. From reports in the Chinese media, the cargo transport vehicle is based on the TG-1 vehicle and will have a 5.5 tonne cargo upload capacity.

Following completion of the TG-3 mission, China's human space programme will move on to the next stage, the construction of a long-term human occupied modular space station. By around 2020, a core module and two experimental modules will be launched and assembled in orbit to form a 60-tonne space station complex.

The plan is to launch the core module first after 2016, to which other modules and spacecraft would attach later. The core module is 18.1 metres in length and 4.2 metres in diameter, with a total mass of about 20-22 tonnes. Similar to the Mir core module, it consists of three sections, namely the node module, the life control cabin and the resource module. The node module has 5 docking ports according to the artistic rendering released from the official source. At the aft side of the resource module, is the 4.2 m diameter life control cabin with a built-in docking port. In most of the renderings, this aft port is shown in docked configuration with a cargo transport spacecraft. As the first and central module of the space station, the core module provides the life support environment for its long-term inhabitants, and serves as a control centre for the space station complex. There are reports suggesting that the core module could support 3 taikonauts for a long-term stay.

The experimental modules I and II are both 4.2 m diameter pressurised modules for space application experiments. While module II is mainly for experimental purposes, module I has built-in control systems, thus serving as a back-up control system for the core module. The two modules will be connected to the node module head-to-head and vertically aligned with the core module making the complex T-shaped. Both modules are 14.4 m in length and weigh about 20-22 tonnes at launch. They will dock with the forward port at the node and later be relocated to the starboard and port location ports by a robotic arm installed on the core module. To accumulate experience for the building of a space station, China has already started development of an experimental space robotic arm to be launched into space for testing within the next few years.

The basic configuration seems to be the T-shape permanent complex with a SZ spacecraft docking to the forward port at the node module in line with the core module, and a cargo transport vehicle at the aft of the station. There are also renderings on the internet showing as many as two crew vehicles and two cargo transport vehicles docked to the zenith, nadir, forward and aft ports of the station, making all docking ports fully-occupied and the space station a 100-tonne complex, very close to the Mir space station in weight, size, building approach, functionality and operational mode.

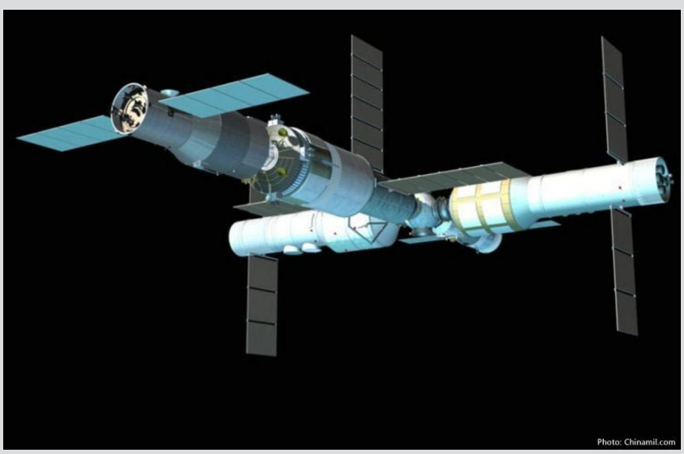
The space station programme was officially approved by the Chinese government in October 2010 which means it will be funded through the coming years. CAST is responsible for the core module and one experimental module and SAST for another experimental module. Due to the over 20-tonne mass and 4.2 m diameter, the core module and two experimental modules can only be launched on CZ-5 from the Wenchang Satellite Launch Centre in Hainan province currently under construction. Transportation of the modules will likely be by land and sea from Tianjin to Hainan.

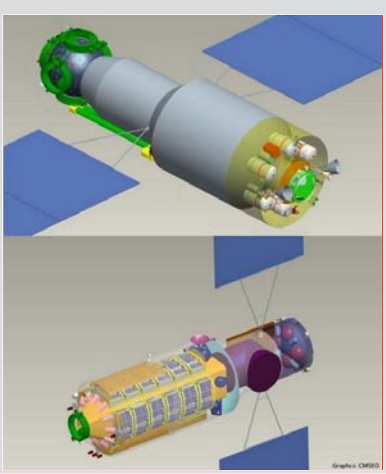
According to Wang Wenbao, Director of the China Manned Space Engineering Office, China's space station will have a service life of about 10 years.

Emerging of a New Player

It took the former Soviet Union and the United States 10 years and 11 years respectively from their first manned space flight to the first manned space station mission. If China successfully completes a manned Shenzhou mission visiting TG-1 in 2012, it will be just 9 years. Although TG-1 is only 8.5 tonnes and has a shorter duration capability for human occupation, it has similar capabilities supporting visiting crews and long-term un-manned operation. If we consider that China may achieve its objectives on only its fourth manned mission (18th and 26th for the Soviets and the Americans) and TG-1 adopts a lot of advanced station technologies that Salyut 1 and Skylab did not have, it is very impressive how rapidly and cost-efficiently the programme has been implemented.

China's objective and strategy on human space flight were set almost two decades ago, and they have never altered since then. China's strategy is to maintain a moderate-scale human space flight programme with limited investment and limited number of missions but with a large span in technology advancement. Such a strategy is also





top: the alleged TG-3 model

second top: the modular space station

third: artistic rendering

bottom: the core module (top) and the experimental module (bottom)

called by the Chinese, "fast move with big paces". It has proven a sustainable strategy and is appropriate for China. China has achieved about half of the stated objectives, and no-one doubts its capability to finally complete the plan with a 60-tonne class permanent modular space station in low Earth orbit. It is certain that a Chinese space station will be in space after 2020. Meanwhile it's quite uncertain for the existence of the ISS beyond that time, although from a technical perspective, the ISS could remain in orbit until 2028.

Similar to the situation during previous manned space launches, Chinese media had extensive coverage of the TG-1 mission. There were overwhelming reports providing a large amount of information on the mission, its history and technical details, exhibiting a more and more open China and its space programme. Of course, almost all reports are positive and there is no criticism of the programme. However, China is now in the internet era. People have a greater freedom to express their views in cyberspace. On Sina Weibo, the Chinese counterpart of Twitter, a poll for the question "Are you proud of the TG-1 launch?" showed that only 41% of more than 8,000 netizens voted for yes, and 45% said "No, it has nothing do to with me". Considering the increasing social tensions in China in recent years, and young people's revolt against the traditional propaganda, the figure is not low. Undoubtedly public views will influence the Chinese space programme more and more, and also undoubtedly it will never change the course of the human space programme set nearly two decades ago.

On the other side, mainstream media in the West quickly picked up the launch news and mostly gave positive comments. It is interesting to note that there seem fewer reports than on previous occasions connecting the launch to the military and China's human rights issue. It was common when Shenzhou 5 was launched in 2003. Does this reflect a trend that Western people have started to change their views on the Chinese space programme? The newly confirmed fact that the docking mechanism on TG-1 is ISS-compatible shows that China remains willing to join the ISS programme. There were two reasons when the U.S rejected previous cooperation proposals from China. One was the political reason that we all know, and the other was that Shenzhou is not "mature" enough to visit the ISS. The latter will be cleared soon after the upcoming rendezvous and docking demonstration. Will the political issue be resolved? Sometimes sudden change is triggered by a gradual and unnoticeable transformation that may happen, or may have already happened in both China and the U.S. Nothing is impossible.

We are unable to predict the future. But of one thing we are sure, China has entered the space station era and it will write a new page in the history of human space flight.

(Chen Lan, Dave Chen, Jacqueline Myrrhe)

Please, go to the Gallery for more photos.

Touch the Chinese Space Programme in Three Days

Report from the 4th CSA-IAA Conference on Advanced Space Technology in Shanghai

left: the conference
right: Mr. Zhu Zhisong

An Open and International Conference

To the Chinese space programme and people paying attention to it, early September is a month full of uncertainties. The long-awaited Tiangong 1 rendezvous and docking mission was only less than a month away, when a Long March 2C rocket, the workhorse of the Chinese launcher fleet, experienced its first failure just over two weeks earlier. This event interrupted the consecutive run of successful launches since 1996, and the highest density of launches in history (7 launches within 1.5 months). What happened in the launch? Is it a low probability event or a systematic problem? Would the Tiangong 1 launch be delayed? That's why it was so interesting for the author to participate in the 4th CSA-IAA Conference on Advanced Space Technology held on 5-8 September 2011 at Grand Soluxe Zhongyou Hotel in Shanghai.

The China Society of Astronautics (CSA) and the International Academy of Astronautics (IAA) jointly hosted the conference. As a reporter representing the German magazine Raumfahrt Concret, the author registered for the conference via its web site smoothly. On-site registration was also very smooth and easy. Although only about 10% of participants were from other countries, there were still well prepared materials in English, a simultaneous interpretation facility, and friendly English-speaking staff. There were no limitations for foreign and Chinese participants to communicate, though most Chinese people seemed not interested in such kind of communications, but this could just be a result of the language barrier. With a Chinese face, the author, probably the only journalist working for a foreign media at this conference, was able to talk to many people from low-level engineers, to high-ranking officials and to other Chinese journalists. The conference was truly international and very open. This may have come as a small surprise to anyone coming with the impression that the Chinese space programme is closed, clouded in mystery, and strongly military related.

All the important Chinese space organizations were present at this conference. Officials and senior scientists from the China National Space Administration (CNSA), China Academy of Space Technology (CAST, or the 5th Academy), China Academy of Launch Vehicle Technology (CALT or the 1st Academy), Shanghai Academy of Spaceflight Technology (SAST or the 8th Academy), Academy of Aerospace Propulsion Technology (AAPT or the 6th Academy) and China Academy of Sciences (CAS) attended the opening ceremony or made keynote speeches. Dr. Jean-Michel Contant, General Secretary of the IAA, also made a keynote speech. The conference lasted for three days (5 September was for registration only). After the opening ceremony and keynote speeches on 6 September, the whole day of 7 September was devoted to technical sessions. On the last day, 8 September, the conference arranged a technical visit to the SAST launcher vehicle and satellite manufacturing facilities. It was actually a rare and unique opportunity to peek inside the Chinese space facilities. For this author, this was the first occasion to visit such facilities in China.

It was worthy to note that most Chinese participants in this conference are quite young, with most of them looking below 40 years of age, and with many of them holding a master or doctor degree. When talking, they all showed themselves to be very self-confident and proud of their profession. Is it symbolic that the Chinese space programme has a bright future?

Ambitious Deep Space and Scientific Missions

In the keynote speeches, Chinese space officials outlined China's space plan for this decade. There were not many new details given for these programmes, but overall it was still very impressive. China will develop a new family of launcher vehicles using kerosene and liquid oxygen (Long March 5, 6, 7) to replace the current toxic and polluting

Long March 2, 3, 4 vehicles. China will continue its lunar exploration programme by sending a lander and a rover to the Moon (Chang'e 3/4 from 2013) and return samples from the Moon (Change 5/6 later this decade). There are also plans for a methane-fuelled launcher, an air-launched solid small launcher and the HTHL (horizontal take-off and horizontal landing) RLV. But judging from the PowerPoint slide, the RLV looked more like a concept rather than a tangible engineering project. In the area of human space flight, followed by the Tiangong 1 and Shenzhou 8, 9, 10 rendezvous missions, China will launch more Tiangong laboratories and Shenzhou manned vehicles, and also a Tiangong-derived cargo ship, which will eventually lead to the assembly of a 60-tonne modular permanent space station around 2020.

It was very interesting to see a slide on the plan of China's deep space exploration programme. The slide, presented by Liu Qiang, Division Director of Research and Development of CASC, showed the following schedule (text in brackets are comments by the author):

- 2015: Mars global remote sensing (presumably an orbiter launched independently by China, as the successor of the Yinghuo 1 that is launched by a Russian vehicle).
- 2017: Asteroid rendezvous and touchdown.
- 2018: Deep space solar observatory.
- 2021: Venus global sensing (presumably an orbiter) and atmosphere floating (presumably a balloon).
- 2022: Mars rover.
- 2023: Polar orbit solar probe.
- 2024: Asteroid sample return.
- 2025: Jupiter orbiter.
- 2028: Mars sample return.

Wu Ji, Director of the National Space Science Centre, CAS, also presented an ambitious plan on China's space science missions. He outlined following mission, planned and to be developed by CAS in the next 5 years (the 12th 5-Year Plan):

- The **Hard X-Ray Modulation Telescope (HXMT)**: This telescope will perform a full-sky hard X-ray survey at an orbital altitude of about 550 km. The long-awaited telescope is planned for launch in 2013-2014.
- The **Space multi-band Variable Object Monitor (SVOM)**: The major scientific objective of which is to detect and locate various Gamma-Ray Bursts (GRBs). It is a Sino-France joint project. The satellite is to be launched in the timeframe of 2013-2014 by France.
- **Shijian 10 scientific satellite**: A recoverable satellite specifically for microgravity and space life experiments. It has 9 experiments aboard the orbital module and 11 inside the re-entry module. The launch date of the satellite was not revealed.
- The **Earthquake Electromagnetic Monitoring Satellite**: The 500 kg, CAST-2000 bus-based satellite will be sent into a 500 km polar orbit. Launch date was unspecified.
- **Quantum Experiments at Space Scale (QUESS) Satellite**: This satellite is to test for the first time satellite-to-ground quantum communication. The 300 kg small satellite will be sent to an 800 km polar orbit.
- **Dark Matter Particle Detection Satellite**: This satellite is designed to carry a Track Detector, a BGO Detector and a Neutron Detector to find and study dark matter particles through the high-resolution observation of high-energy electrons, gamma-ray spectrometry and its distribution in space.
- **Project Kuafu**: This consists of three satellites to observe the solar wind. The first satellite, Kuafu-A, carrying six payloads, will be sent to the Sun-Earth Lagrange 1 point.

Wu Ji also presented a medium plan till 2020. It includes the X-Ray Timing and Polarization Telescope (XTP), the Space Millimetre Wave VLBI Telescope, the Solar Polar Orbit Radio Telescope (SPORT), the Magnetosphere-Ionosphere-Thermosphere Coupling Exploration Project, Near Space Atmosphere Research Satellite, as well as experiments on the Chinese space station.

Chinese Docking Mechanism Compatible with the International Standard

During the conference, there were some opportunities to communicate with Chinese space officials and other participants. Undoubtedly, the hottest topic in casual talking during the conference was the CZ-2C SJ-11-04 launch failure and its impact on the upcoming Tiangong 1 launch. But to this author's surprise, many people inside the space industry were fully aware of the conclusion of the investigation of the launch accident, released just when the conference was opened, from the internet instead of internal "official" channels. All agreed that the internet had become one of their major sources for information and even for coverage of space events in China. It is faster and accurate. Some people said they were surprised that the result of the investigation was released so quickly and in such an open way, considering the payload of this launch was sensitive and secrete. The CZ-2C accident was blamed on a failure of the servomechanism connecting a vernier engine on the second stage. This then led to attitude loss and eventually destruction of the rocket. As all Long March launchers share a similar second stage design, many people were concerned that the Tiangong 1 launch would be delayed indefinitely. While some people were quite confident that as long as the cause was identified, and was not a complicated issue, measures could be taken easily and quickly to avoid a long delay.

The most interesting and unexpected encounter was with Mr. Zhu Zhisong, Head of SAST. It was shortly after the lunch on the opening day. Mr. Zhu was just awarded the IAA correspondent academician in the opening ceremony. He was quite excited when talking about the ambitious Chinese space plan and jobs SAST is responsible for. Asked by the author and the other Chinese journalists, Mr. Zhu revealed the following interesting facts that were never reported before:

• The Chinese docking mechanism used by the Tiangong 1 and Shenzhou 8/9/10 docking is fully compatible with the "international standard". It was developed by SAST and has been identified by observers as of APAS type since a photo of the space laboratory mock-up appeared in early 2003. Zhu did not reveal however, whether the Chinese docking mechanism uses the Russian APAS-89 design as used on ISS, or the extent to which Russia was involved in the development.

• SAST is responsible for development of the strap-on boosters of the Long March 5 (CZ-5) new generation launch vehicle. There are two types of boosters, one has diameter of 3.35 m and the other has 2.25 m. They will be equipped with one or two 120 t thrust YF-100 kerolox engines respectively. The core stage of the CZ-5 is developed by CALT.

• SAST will develop one of two experimental modules of the future 60-tonne class modular space station. CAST will develop the core module and another experimental module.

From Water Engine to Near-Space Hypersonic Vehicle

The conference received a total of almost one hundred research papers, most of which were from Chinese authors and some of which are very interesting indeed. For example, there are multiple papers in the area of near-space hypersonic vehicles and related engines, and thermal protection systems, showing China's focus of attention on advanced space transportation systems.

A paper presented by researchers from the Science and Technology on Space Physics Laboratory, Beijing, showed the conceptual design of a re-usable near-space hypersonic vehicle capable of reaching Mach 5.5 at altitude of 35 km. The vehicle is powered by four air-turbo ramjet expander-cycle (ATREX) engines with a total ground thrust of 560 kN and cruise thrust of 178 kN. Its take-off mass is 84.6 t including 35 t of liquid hydrogen. It has a delta wing with a sweepback angle of 75 degrees, a length of 57 m and a wing-span of 23 m. The vehicle is envisioned as the first stage of a TSTO (two-stage-to-orbit) space launch system or a hypersonic aircraft for both military and civil uses. Another paper by Northwestern Polytechnical University and Xi'an Aerospace Propulsion Institute studied the broad flight envelope of the ATR engine. As China has completed the first successful test firing of an ATR engine early this year (2011), it will not be a surprise if such a hypersonic vehicle actually takes off within a few years from now.

There were also some innovative and interesting papers from Chinese researchers. Here are some examples:

• A proposal for a light pressure-impelled gasbag spacecraft. In comparison to the traditional solar sail design, the gasbag design has a better flight capability and reliability.

• Water-based rocket propulsion system that combines the electrolyser, unitised regenerative fuel cell and thrusters.
The paper concludes that its specific impulse is greater than 400 seconds, and it has many advantages over traditional in-orbit propulsion systems.

• An inflatable aerodynamic decelerator designed for a Mars atmosphere entry.

• An experiment to investigate atomisation characteristics of gelled hypergolic propellant.

• The design of a new type of superconductive magnetorquer. Even with the cryocooler, the total weight of the design is less than 100 kg. In comparison, the weight of a traditional magnetorquer with the same magnetic moment is about 520 kg.

Although most of these studies are theoretical, and some of them were not proposed first by the Chinese, they are still quite interesting. It is worth noting that government bodies such as the Natural Science Foundation of China funded some of this research.

Exclusive Visit: No Camera, No Mobile Phone

The technical visit on 8 September was the most interesting activity during the conference. Although there were a few hundred participants at the conference, less than a single busload of visitors participated, most of them foreigners. It seemed that most Chinese participants were from the space industry, and not interested in visiting their own facility. The visit took only half a day at three locations. There were many limits during the visit and only a few items of hardware were shown to the visitors. The most anticipated Shanghai developed hardware like the docking mechanism, the Shenzhou propulsion module and elements of the new generation launch vehicles were out of the scene. However, even with such disappointments, it was still an impressive visit.

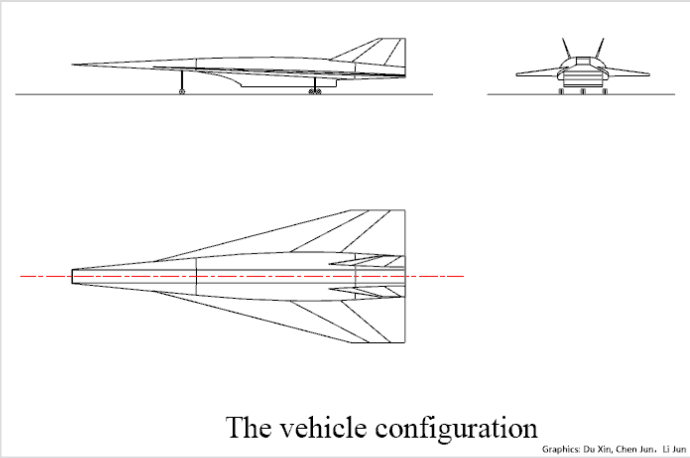
The first location was the Shanghai Solar Energy Research Centre, a subsidiary of SAST that develops and manufactures space and non-space civilian solar photovoltaic (PV) products. The latter now occupies most of its investment and revenue. The centre is located in Zizhu Science Park, Minhang District at east of the Minhang downtown area, and very near to the north bank of the Huangpu River. It is only a few hundreds metres away from the Intel Research Centre in Shanghai. The newly-built building of the Centre is mostly covered by solar panels of various types that generate more than 400 kW of electricity. Although there was no security check and no limits for personal equipment, what was shown here was mostly irrelevant for space, and thus a less interesting visit.

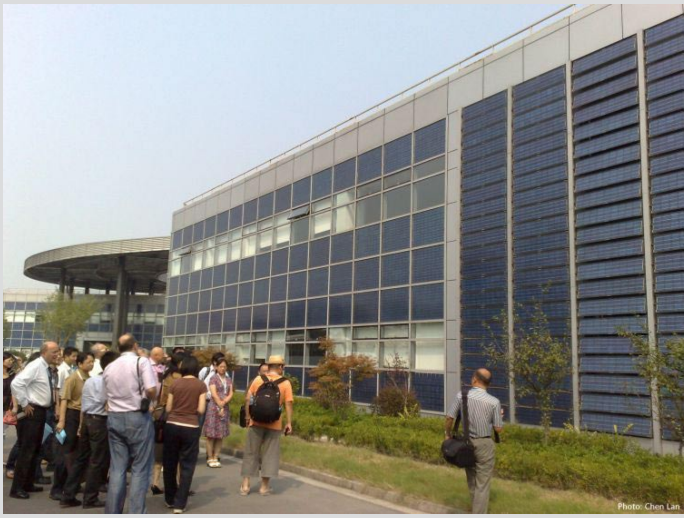
The next stop was the Shanghai Aerospace Equipment Manufacture Factory, located west of the Minhang downtown area, and also very near to the Huangpu River. This is the birthplace of the Long March 4 and 2D launchers. The gate of the factory is very unnoticeable if there are no soldiers standing there. When the bus drove in, you could feel that the atmosphere became quite different. There are a lot of slogan boards reminding people to be aware of security rules. There are railway tracks and special trains that look obviously designed to transport rockets and supporting personnel. Most of the factory buildings there look quite old, a sharp contrast to the modern buildings of the Solar Energy Centre, and of the new SAST headquarters shown in the SAST brochure. When the bus stopped at a building, the SAST guide on the bus announced that all cameras and mobile phones have to be left on the bus. It was not unexpected, but still a disappointment.

Wearing clean room clothing, including hat and shoe covers, all the people from the bus entered a large hanger, with first eyes seeing a CZ-2D and a CZ-4B launch vehicle, as well as a transportation train at the side. The hanger was quite long, that is long enough to lay two launch vehicles head to head. There were a few workers working on the rockets. At the side of the hanger, a row of scale-models were displayed - a complete set of the launchers that SAST are involved in. They are the FB-1, CZ-2D, CZ-3, CZ-4A, CZ-4B, CZ-4C, CZ-5 and CZ-6. The latter two are still in development, and SAST is responsible for the CZ-5 strap-on boosters and the CZ-6 small launcher. In comparison with its brothers, the three-stage CZ-6 looks so short and small in the row. The maiden launch of the YF-100 powered small launcher is reportedly scheduled for 2013. A young engineer guided the visitors, walking through the space between the rockets and the train, and gave brief introductions about the SAST products and answered questions from the audience – of course, what he said was all general information. It was a really good opportunity to closely observe all these flight hardware items. The paper stuck on the CZ-2D showed its manufacture number was Y21, and on the CZ-4B, it was Y17.

The last destination of the day was the Shanghai Institute of Satellite Engineering. It was located just a few blocks north of the launch vehicle factory. As expected, the guide announced again the policy for cameras and mobile phones. The area open to visitors was only a small display room, but was however, within a large Class 100,000 clean room area. The largest display item in the room was the FY-3 engineering model. There was also the engineering model of the YH-1 Mars probe, mock-ups or scale models of the FY-1, FY-2 and FY-4, as well as an air-bearing table in the room. All FY satellites are meteorological satellites developed by SAST. It was great to see these well-known satellites, but to a space fan, the visit was too short and there was too little to see. Interestingly, the last activity of the visit was a group photograph in the display room – by a SAST camera.

(Chen Lan)





top:
the hypersonic near-space vehicle concept

bottom:
the Shanghai Solar Energy Research Centre

Proposal for Mutual Rescue Operations Between the Tiangong and the ISS

Background

The ISS began six-crew member operation in 2009, and the U.S. shuttle retired in July 2011. Crew transportation and emergency rescue now totally depends upon the Russian Soyuz vehicle. The recent Progress launch failure and the aftermath plan to temporarily abandon the ISS show how fragile the ISS is, and how risky the current dependency on Soyuz. If an accident damages the station and one of the two Soyuz spacecraft docked to the ISS is unable to operate normally, or the accident blocks the way to one of the Soyuz, the crew will be in danger immediately, and three of the six crew members will have neither lifeboat nor shelter (assuming the other Soyuz is accessible and working well). For example, if the Zarya module loses power and pressure, the Soyuz docked to the Rassevet module immediately becomes inaccessible. In such a case, three crew members could leave the station in one Soyuz, but the other three would have to stay in the station that may become uncontrollable within a short time. Even after the planned 7-seat U.S. commercial crew vehicle enters service in the middle of this decade, it still lacks enough rescue capability if a serious accident hits the Harmony module, which the commercial vehicle docks to when there is a visiting crew onboard.

China has just launched its first small man-tended space station prototype, the Tiangong 1 docking target, which will be followed by another two within the next five years. At least five manned missions are planned to visit the three Tiangongs from 2012 to 2016. If there is an accident damaging the Shenzhou spacecraft, the crew will be stranded in the station. The Tiangong station is designed to support only short periods of manned stay onboard, and a Shenzhou vehicle will take two years to be built. If a new Shenzhou is unable to be launched within a short time, it could lead to a disaster.

It could be reasonable to coordinate the two parallel space station programmes so as to provide a mutual rescue capability. It would benefit both sides. However, the political barrier between China and the U.S. does not allow Chinese spacecraft or Chinese taikonauts to access the ISS. This article is proposing a solution to enable mutual rescue capability without Chinese access to the ISS.

Mutual Rescue Concept

Technically, both the Tiangong and the ATV have the capability, or partial capability, to act as a temporary shelter for a crew in an emergency. The Soyuz, Progress and ATV are able to transfer cargo and crew between the two stations. The only missing link is the incompatible docking system between the Tiangong (an APAS-89 compatible one) and the Soyuz/Progress/ATV (probe and drogue). Through Sino-Russian cooperation, it would be possible to add the passive part of the probe and drogue system and the Kurs approach system to the Tiangong, which could pave the way for the following rescue scenarios.

Scenario 1:
ATV as a shelter for the Tiangong crew

If the Shenzhou spacecraft encountered severe problems during a crew visit to the Tiangong station, the crew would be stranded in orbit until a new Shenzhou was launched to rescue them. However, the Tiangong station is not designed for long-term manned occupation, and the next Shenzhou may take many months to lift-off. In this case, the Tiangong would need to approach the ISS to a close but safe distance. Then a Soyuz, or Progress, or ATV already on the ISS could become a transfer vehicle to re-supply Tiangong, Loaded with a certain amount of water and food, it could undock from the ISS, manoeuvre to the Tiangong station, and dock with it. Once supplies are transferred to Tiangong, the transfer vehicle leaves the Tiangong and returns to the ISS. This would allow the Tiangong crew to survive for a longer time. This scenario depends upon spare supplies being available on the ISS, and the ISS re-supply schedule, as long as there is sufficient fuel in the transfer vehicle. Considering the planned frequency of ISS re-supply missions by Progress, ATV, HTV and commercial vehicles, it should be possible to carry additional emergency supplies for the Tiangong crew. Multiple re-supply flights would even be possible to enable the Tiangong crew to survive much longer.

Scenario 2:
Soyuz to rescue the Tiangong crew

If there would be a Soyuz on the ground, ready for launch within a short time when the Tiangong crew encounters an emergency as described in the Scenario 1, it would be possible to rescue the crew in a short time. The Soyuz could be launched unmanned with food, water and oxygen on-board. It would dock with the Tiangong, and bring back the Tiangong crew back to Earth. The whole flight could be fully-controlled from the ground. If an unmanned launch would not be feasible, it could be a piloted launch, by a cosmonaut, to bring back two of three Tiangong crew. The remaining Tiangong crew member would have to stay on orbit, and wait for a new Shenzhou or Soyuz to arrive. With enough supplies brought up and reduced consumption and even possibly re-supplied by the ISS as described in Scenario 1, he/she would be able to sustain a much longer time, until being rescued by the next Shenzhou or Soyuz.

Scenario 3:
Tiangong-ATV as a shelter for the ISS crew

If the ISS is in an emergency situation, with one of the Soyuz vehicles damaged or inaccessible, and the crew has to be evacuated within a short time, there would be only one available Soyuz to return three of the six crew members to Earth. The remaining three would enter the ATV, together with enough supplies and undock from the ISS. In the case of critical module damage, such as Zarya failure, astronauts remaining inside the U.S. segment at the time of the failure would have to transfer by EVA from the Quest module to the Pirs or Poisk module on the Russian segment. This would be possible as long as the ISS would keep stable for several hours. At the same time, the Tiangong would need to manoeuvre to the ISS, as close as possible, in order to shorten the transfer flight time. The ATV has no fully-functional ECLSS (Environment Control and Life Support System) or crew communication system to support long-duration independent manned flight, but it would be possible for the crew to survive for several hours, relying on air inside its large 45 cubic metre cabin, and its own or additional oxygen supply (such as oxygen candle). Once the ATV completes rendezvous and docking to the Tiangong, the latter would play the same role as the ISS to provide fresh air to the ATV, and make it a long-term living quarters. Once a Soyuz is ready, it would be launched unmanned and automatically dock to the Tiangong after ATV un-docking. Then the Soyuz could be piloted by a cosmonaut of the ISS crew, and return to Earth.

Scenario 4:
Shenzhou to rescue the ISS crew

If a Shenzhou on the ground is ready for launch within a short time when the ISS encounters emergency as described in the Scenario 3, it would not be necessary to perform the Scenario 3 operations. The Shenzhou could be equipped with a drogue port within a short time and launched unmanned to the ISS orbit. The ATV carrying three people would rendezvous and dock with it, and transfer the three crew members to the Shenzhou. The transfer could be done within a few hours with ATV's limited life support capability. Finally, the Shenzhou would land automatically, guided by ground control.

Implementation
To enable such mutual rescue operations between the ISS and the Chinese Tiangong station, it is necessary for China to have the passive part of the Russian probe and drogue docking mechanism and the Kurs system, and to slightly modify the Tiangong Spacelab hardware and flight profile as follows:

- A future Tiangong station (probably the Tiangong 3 in the middle of this decade) should be launched into the ISS orbit with an inclination of 51.6°, and positioned as close as possible to the ISS, as long as a safe distance is kept. All Shenzhou vehicles intended to dock with Tiangong would also need to be launched into the ISS orbit.
- It is speculated that the Tiangong 3 will be equipped with two docking ports, at its forward and aft ends, but both are of the APAS type. A better solution for the Tiangong station would be to be equipped with a dual-port docking node at the top of its pressurised section. The node would be almost the same as that of the ISS Zarya module. Its forward port would be the Chinese APAS port for normal docking operation while the lateral port would be a Russian drogue port equipped with the Kurs docking system, so as to be compatible with Soyuz and ATV.
- The Shenzhou spacecraft is supposed to have the capability for fully automatic or ground controlled rendezvous, docking, re-entry and landing. But if necessary, it may still need some kind of upgrading. For example, in Scenario 4, it needs to open the inward hatch cover towards the inside of the orbital module and the re-entry module from outside or by ground control, like the Progress and ATV have. It is not certain if Shenzhou has this capability.
- Higher inclination and additional mass of the node would require a little more launch capability. This could be achieved by either enhancing the launcher, or shortening the pressurised section of the station to keep the whole mass unchanged. If the Tiangong 3 is designed to be launched by one of the new generation Long March 7 rockets, the launch capability may not be an issue.

Mutual rescue would also need the European and Russian sides to carry out some limited upgrading of their own vehicles:

- The ATV would need to upgrade its Kurs system, to enable performing actual approaching and docking instead of being just a monitoring system as it is now. It would also be necessary to extend ATV's duration docked with ISS to increase working time acting as a transfer vehicle in the case of an emergency.

• Like the Shenzhou, the Russian Soyuz is also supposed to have fully automatic capability from launch to landing, but it may still need some minor upgrading.

It is worth noting that in the ATV Evolution plan ESA drew up several years ago, there was a scenario of a safe-haven / free-flying laboratory. This concept fits very well with the mutual rescue proposal. If ATV is upgraded with a fully-functional ECLSS and a crew communication system, it will not only be a safe-haven for ISS, but also for Tiangong crew. It would also become a better and safer transfer vehicle for Scenarios 1, 3 and 4 of this proposal. However, ESA is reportedly planning to cooperate with NASA on the MPCV (Multi-Purpose Crew Vehicle) project, in which ATV will become the service module of the future exploration vehicle. It is expected that the start of the cooperation project would suspend the ARV (Advanced Re-entry Vehicle) project, a major part of the ATV Evolution plan. The safe-haven would also likely be on-hold too. As a result, the mutual rescue proposal has to assume that the ATV Evolution plan is dead, and depends on the current version of ATV.

There is also a non-technical issue that may affect this proposal. If ISS partners do not wish that the Chinese crew would enter the unmanned Progress or ATV, or the Chinese would not wish the ISS crew to enter the Tiangong and Shenzhou without a taikonaut monitoring, then most scenarios in this proposal would be affected. In Scenario 1, the Soyuz would be the only option as the transfer vehicle. In such a case, one cosmonaut must be in the Soyuz to perform such an inter-station re-supply mission. In Scenario 2, if the Soyuz has to be piloted by a cosmonaut, one Tiangong crew needs to be left in the station and stay longer in orbit. In Scenario 3 and 4, it may become impossible to perform the rescue at all. But even in such a situation, the rescue capability described above in the Scenarios 1 and 2 still has great value to both sides.

It is very important to build trust between China and the European and Russian partners. With good will from all sides, the problem can be solved step-by-step with increasing mutual understanding in the cooperation. Proper technical measures would also help. In fact, Shenzhou, Soyuz and ATV are only transportation vehicles. There is not much sensitive information that can be easily collected by only staying in the cabin. The Tiangong may contain some sensitive experiments in its pressurised section, but China has already announced that the future Tiangong would be open to international partners. It is not impossible for China to accept opening the Tiangong to a foreign crew, when there are enough technical measures to protect its sensitive equipment.

Joint Demonstration Flight

The major objective of the demonstration flight is to verify rendezvous and docking operations between the Chinese and Russian/European spacecraft, spacecraft interface, and tracking and control coordination between the three sides. This mission involves a modified Chinese Shenzhou, a European ATV with upgraded Kurs system and optionally, a Russian Soyuz. The latter two are not necessarily dedicated to this mission. Instead, they could be the ones originally planned for ISS missions.

The mission may start with the launch of a dedicated Shenzhou into the ISS orbit, before the end of one of the ISS resupply ATV missions. The Shenzhou would be equipped with a drogue docking port. It may carry a two-man crew consisting of a Chinese and a European. After the ATV undocks and ends its ISS mission, it could manoeuvre to the Shenzhou and dock with it (in the current planning, the ATV would re-enter and burn-up in the atmosphere). Then the Sino-European Shenzhou crew enters the ATV and performs joint experiments. After one day of joint Shenzhou-ATV flight operations, the ATV undocks and re-enters/burns up in the atmosphere. As this Shenzhou carries only two persons, it is possible to return payload from ISS via ATV of more than 100 kg. It would be an additional reward of this mission.

If the ATV docking completes successfully within the first three days, one of the Soyuz vehicles docked with the ISS could also manoeuvre to the Shenzhou, and dock to it. The Soyuz has three crew members onboard. One of its members may be swapped with the European astronaut launched in Shenzhou. The Shenzhou then returns to the Earth with the Chinese taikonaut and an ISS crew member, and the Soyuz moves back to the ISS or returns to the Earth, too. The demonstration flight does not require the Chinese to access the ISS or any U.S. technologies and hardware. The Soyuz crew visiting the Shenzhou could all be non-Americans. It however, needs Russia to provide the passive part of the probe and drogue docking mechanism and the Kurs docking system to China, with support for hardware integration, rendezvous operation, tracking and communication, etc. As China and Russia have technical exchanges on manned space technologies since early 1990s, it may not become a big issue. Minimum U.S. involvement makes such a China-Europe-Russia demonstration flight politically feasible.

Conclusion

The most important factor for space cooperation between China and the West is the political barrier. There are also financial and technical difficulties. This proposal overcomes all these difficulties. Politically, it does not require China to access the ISS or any U.S. technologies. A good Sino-Russian relationship makes it possible to install the Russian docking system on Chinese spacecraft. Financially, the European and Russian sides need only very little investment (no hardware development and no significant changes to their original plans). Technically, all involved technologies including the Russian docking system, orbital plane and mass change, modification on the Tiangong station, etc. are proven or within China's technical capability.

If this proposal is accepted by all sides, it may take several years to discuss, plan, design and build the hardware. It is possible to perform the demonstration flight within 2-3 years, and the system could be ready once Tiangong 3 is in orbit around the middle of this decade. China will continue the station operation with its own 60-tonne class modular space station after 2020. If the ISS is to be further extended beyond 2020 which is quite likely to happen, the mutual rescue mechanism could service both stations for 10 years or more. Considering the minimum investment and great benefit such a mechanism would bring, it would be very worthwhile to do.

(Chen Lan)

Learning Rendezvous and Docking

How difficult is international space cooperation with China?

Finally it happened! Tiangong 1 is in orbit and the next milestone, the technical demonstration of rendezvous and docking, only a few days away from now. But rendezvous manoeuvres on the space policy level between China and the rest of the space community remain difficult, not even to think about a docking phase. The thunder and vibration of the Tiangong 1 launch on 29 September was not really felt in the European media reflections but with or without noticing, it left the space world changed.

As little as three or four years ago, even experts in space agencies around the world were smiling if the discussion came to China in space. This has gradually changed since the launch of Chang'e 1 and Chang'e 2 but more significantly since the 29 September 2011. Comments and analyses published now, after the launch of the Tiangong docking target, are different from comments and opinions a little while ago. The international space community is about to take China seriously. It took a while, it was a long march on a long way, but this must be considered the biggest strength of China: it is always working with the time as a beneficial factor.

Until today, critics of the Chinese space programme are pointing out that the launch frequency within the Chinese human space flight programme is too slow. But this is only a problem if the space programme would not be designed for a long-term goal. Also, when critics are taking the position of a too-slow-space-programme, they have in mind the way how human space capabilities were developed in the past. China is different and China is doing things differently.

Zhou Jianping, the Chief Designer of China's Manned Space Engineering Project within the China Manned Space Engineering Office (CMSEO) stated before the launch of Tiangong 1 on 29 September, in front of the media that compared with the Soviet Union and the United States, the Tiangong 1 mission has certain advantages. "Russia and the US launched pairs of spaceships to experiment with rendezvous and docking. China, however, has designed a two-year target spacecraft for docking experiments with three spaceships. The costs for Tiangong 1 are similar to that of a Shenzhou spaceship. By doing it the way we now are doing, we only need four launches and can experiment with rendezvous and docking three times. The Soviet Union and the US, in the early stages of their space race, would have needed six launches to carry out three experiments, entailing greater costs." Zhou said. He also added that Tiangong 1 can stay in orbit for two years, much longer than a spaceship could. This will provide a crucial platform to conduct experiments and verify key technologies for building a future space station.

Coming a long way does not necessarily mean to have reached the destination. Nothing is truer for China's ambitions in space exploration.

"Overall, China is behind the US in technology and in actual presence in space - the US operates dozens of satellites, the Chinese only a few." James Lewis, Director for Technology and Politics of the Washington-based Centre for Strategic and International Studies, commented last year after it became evident that US-President Obama had dropped the Constellation Programme. "The real concern is the trend: China's capacities are increasing while the US, despite spending billions of dollars, appears to be stuck in a rut." With a view on the cancellation of Constellation and the steady orientation by China on lunar exploration Lewis added: "I see it as a confirmation of America's decline."

Gregory Kulacki, China Project Manager for the Union of Concerned Scientists, in an article for Nature in June this year raised the following thought: "China has shown that it has the talent and resources to go it alone. The sanctions have only severed links between the countries and made a new generation of Chinese intellectuals resentful and suspicious of the United States."

These reservations among young Chinese are not coming out of the blue but are based on a long history of blockades from the West. In 1955 Qian Xuesen, one of the founders of the Jet Propulsion Laboratory, left the United States for China. Qian was born in China and studied in Shanghai before he joined MIT at the age of 24 and later Caltec. Although he was involved in top-secret Pentagon programmes, he was accused of communist sympathies in 1950 and kept under house arrest until he could leave the USA five years later. Ironically, in his new-old home country, Qian Xuesen became the "Chinese father of Astronautics".

Not that long ago, in 2003, Europe and China decided to cooperate for the European Satellite Navigation System Galileo. Galileo was, and is, intended to make Europe independent from the US-American GPS. From the beginning, Washington had objections against the plans in Brussels for becoming autonomous. However, the political pressure from the US increased when the European Commission decided to bring China on board. China was ready to invest 230 Million Euros in the Galileo satellite tracking system, roughly a fifth of the total cost estimated by that time. The EU Transport Commissioner Loyola de Palaci was over the Moon when the agreement was signed: "China will help Galileo to become the major world infrastructure for the growing market for location services." The European Union struggled enormously to finance the satellite system, even more after the concept of a public-private-partnership with the European industry did not work out. China's financial contribution was welcomed and the prospects of entering the navigation market in the Middle Kingdom were more than promising. The European Space Agency, the management arm of the European Union Galileo project, and the Chinese Ministry of Science and Technology even inaugurated a joint training centre for satellite navigation at Beijing University in September 2003. All these efforts were null and void when after continued protests from Washington, Europe cancelled all cooperation with China on Galileo. Since then, China has given national priority to the development of its own operational satellite navigation system, Beidou.

Another unfortunate case was the refusal to help China with the United States' deep space communications network on the Chang'e lunar mission. This time the European Space Agency stepped in and offered its deep-space network to China. In return the Chinese Space Agency shared the data obtained with ESA.

left: ESA Kourou station (photo: ESA)

right: AMS-2 on ISS (photo: NASA)

During the last few years, China had stressed several times, that it would be interested in a participation in the International Space Station. Conservative forces in the US, especially the Republican Member of the US House of Representatives, Frank Wolf, knew how to prevent this. Wolf, as the Chairman for the United States House Sub-Committee on Appropriations for Commerce, Justice, Science, and Related Agencies, is overseeing the NASA budget. In April 2011 Wolf introduced a clause into the budget planning which prohibits any scientific activity or spending on cooperation between China and the White House Science and Technology Office or NASA. As a consequence, Chinese journalists were denied access to the Space Shuttle STS-134 launch on 16 May this year. Space Shuttle Endeavour had the Alpha Magnetic Spectrometer (AMS) on board. Its supra-conductive magnets were built in China. Therefore, the launch of Endeavour has been a big event in China, but with the refused access to the launch site and press conference for the Chinese reporters, the Chinese media had no live coverage of the launch.

In the meantime, the Obama Administration found ways to circumnavigate the "Wolf Clause". Barack Obama declared all scientific activities with China as being part of his Foreign Policy. The former NASA astronaut and current NASA Administrator, Charles Bolden is using the same pragmatic approach. He has been for a visit to his Chinese colleagues in October 2010, and he returned noticeable impressed: "I recently came back from a trip to China. I spent a whole week over there with Bill Gerstenmeyer and Peggy Whitson, the Chief of the Astronaut Office. We got an opportunity to see everything. Everything that we asked for plus some more."

Regarding the human space flight programme he said: "So it's a different environment than what we're accustomed to. The People's Army runs everything. That's just the way it is." Bolden said, he explained to his Chinese counterparts, that a possible cooperation needed to be linked to certain principles and would have to be carried out for mutual benefit. Bolden concluded with an interesting anecdote: "My final night there, I met with the big head of their human space flight program who ironically is also head of their anti-satellite program. An odd mix of responsibility. He is a Three-Star, a Lieutenant General in the People's Liberation Army, Air Force or something. And he started out the conversation. He introduced the conversation and he said they're going to be very candid. We don't need you. We don't need the United States, and you don't need us. But the potential, if we choose to work together, is incredible. I thought that spoke volumes."

Jean Michel Contant, Secretary General of the International Academy of Astronautics (IAA) has a similar look at the potential of China which he stated in an interview with Space News just one year ago: "I'm not innocent. There are a lot of challenges. But the key is that those problems can be solved and be worked. … What I'm saying is if we clearly develop what we would like to do, there will be a strong impact in the relations between, for instance, the United States and China. First in space, but on the other hand in other areas because those are places where the country's leadership wants to put their image at the highest values. Their leaders care about space. ... When you prevent people from doing cooperation it usually creates more problems or simply new competition. ... But ultimately it is very important to continue to work to bring those two countries to the International

Space Station. I strongly encourage and invite space station agencies to put that on the table. That would be an excellent revitalisation of cooperation, and it would continue to bring experience for the future." And, like Bolden, he stresses: "… if you take the best technology of many nations then you can build something that never existed."

Jeffrey Manber, who was Chief Executive of MirCorp, a private company which leased the Russian space station Mir on a commercial basis, already in 2008 advocated stronger US-cooperation with China: "The United States has reason to mistrust Chinese intentions in outer space. The successful demonstration of a satellite-killer missile a year ago created a debris field of more than 40,000 pieces that will orbit Earth for years. This abuse of the precious resource of near-Earth space demonstrated the belligerence of China's high-frontier military planners. But there is still plenty of room for cooperation, and the Space Station is one such area. The United States, which is committed to the troubled station and scrambling to prepare for a post-shuttle future, must not miss this opportunity. This is a mistake we fortunately avoided in the 1990s, during the debate about allowing Russia access to what was then called Space Station Freedom. Opponents spoke of technology-transfer concerns, unsure political motives and the supposed cost of including Russia in the Space Station program. The same issues are now being raised regarding China. ... Including China in the largest cooperative technical program on - or off - the planet is not just a political gimmick. It could solve substantial issues in space operations."

Looking back at 2011, a certain dynamic in the positioning towards China's space efforts is recognisable. Chinese Delegations visited the German Aerospace Agency and the European Space Agency several times. For the launch of Shenzhou 8 many VIPs from Europe are expected. One who in particular will be looking forward to this launch is the Head of German Aerospace Agency, Prof. Dr. Johann-Dietrich Woerner. The German-built space incubator SIMBOX housing German and Chinese biological experiments will be on board of the historical Shenzhou 8 spacecraft, which will dock with the Tiangong 1 space module two days after its launch, currently planned for 1 November 2011. SIMBOX is the first non-Chinese experiment on a Shenzhou mission and also within the Chinese human space flight programme. In an interview which Woerner gave to the German daily newspaper "Stuttgarter Zeitung" immediately after the launch of Tiangong 1, he found clear words: "In space exploration one is only accepted as an adequate partner if you can prove your competence. It is not so much about vanity, but about the strategic positioning of China. We in Germany are doing it in the same way, for example in the area of satellites for Earth observation or with the space transporter ATV." Woerner continues by saying, that China has not only proven its reliability with the launch of Tiangong 1 but already years ago, when it launched the first Long March rocket carrier. "Already by that time it was obvious that China was on the way to becoming a space nation. Now, the ISS partners, also the European Space Agency, should take the initiative to engage in a dialogue with China. I would not wait for much longer."

Next to Prof. Dr. Woerner, another German will be watching the launch of Shenzhou 8 with great interest. His fellow countryman and former colleague, Prof. Dr. Berndt Feuerbacher, is President of the International Astronautical Federation (IAF) since 2008. Feuerbacher considers the organisation he is responsible for as a bridge builder: "The IAF is an independent, politically neutral, international organisation which considers itself as a mediator between space nations. Of course, we would like to see, that China's space endeavours get connected with the Western efforts in this area. The campaign with the IAF flags is therefore part of a bigger strategy. We have already organised last year a lunar conference in China, and the annual conference of the IAF in 2013 will also take place in China." Prof. Feuerbacher is proud of the exceptional idea with the IAF flags. He explains: "At the end of June we have handed over a small parcel with 300 IAF flags to our partners of the Chinese Association for Astronautics. These flags have already flown on board of the Russian Soyuz spacecraft to the International Space Station. They came back from the Station to Earth with the US-American Space Shuttle Endeavour. Now they are about to take-

left: Prof. Dr. Berndt Feuerbacher and Zhai Zhigang (photo: IAF)

right: German SIMBOX experiment (photo: DLR) off with Shenzhou 8 which will dock with the Chinese space laboratory. This means, the flags will have been flown on all currently existing space flight systems. After return to Earth, the flags will be framed, packed and distributed as a birthday present to more than 200 members of the IAF which is celebrating its 60th anniversary this year."

On 21 July 2011, the day the last Space Shuttle mission landed back on Earth, the Russian Space Agency Roscosmos published a statement which declared: "From today, the era of the Soyuz has started in manned space flight, the era of reliability." Only one month later, on the 24 August, the unmanned version of the Soyuz carrier failed just over five minutes after launch. This malfunction of the rocket added a lot of stress to the ISS programme, demanding a re-planning of the manning of the station, and caused concerns about its future.

Should China's next space missions work out flawlessly, the announced "era of the Soyuz" may turn out to be the era of the Shenzhou.

For a long time China asked for docking opportunities on the political level. This is about to change now. It seems that the international community might have to learn how rendezvous and docking is spelt in Chinese.

(Jacqueline Myrrhe)

The magnet of AMS-02 during assembly at CERN.
(photo: CERN)

Chinese Space Launch History (Part 2: 1990 – 1999)

#1	#2	Date	Time (UTC)	ID	Model	LV S/N	Launch Site	Lch Pad	Payload		Orbit				Remark
									Name	Weight	Type	Peri.	Apo.	Incl.	
29	21	02/04/1990	12:27	90011	CZ-3	Y6	Xichang	3	DFH-2-5 (ZX-3)	1024	GTO	200	36171	31.1	
30	22	04/07/1990	13:30	90030	CZ-3	Y7	Xichang	3	Asiasat-1	1247	GTO	200	36140	31.1	First commercial launch
31	23	07/16/1990	0:40	90059	CZ-2E/ SpaB-140A	Y1	Xichang	2	Optus Model Badr-A	7338 70	GTO	200	1000	28.5	
32	24	09/03/1990	0:57	90081	CZ-4A	Y2	Taiyuan	old	FY-1B, DQ-1A, DQ-1B	881	LEO/SSO	900.6	905.7	98.9	
33	25	10/05/1990	6:14	90089	CZ-2C	Y9	Jiuquan	138	FSW-12	2080	LEO	211	311	56.98	
34	26	12/28/1991	12:00	91088	CZ-3	Y9	Xichang	3	DFH-2-6						3rd stage early shutdown
35	27	08/09/1992	8:00	92051	CZ-2D	Y1	Jiuquan	138	FSW-13	2592	LEO	176	351	63.02	return to Earth after 3 days
36	28	08/13/1992	23:00	92054	CZ-2E/ Star-63	Y3	Xichang	2	Optus-B1	7597	GTO	200	1050	28	
37	29	10/06/1992	6:20	92064	CZ-2C	Y10	Jiuquan	138	FSW-14 Freja	2080 259	LEO	210	329	63	
38	30	12/21/1992	11:21	92090	CZ-2E/ Star-63F	Y4	Xichang	2	Optus-B2	7615					Y3 was abandoned after launch aborted on 3/22/1992
39	31	10/08/1993	8:00	93063	CZ-2C	Y11	Jiuquan	138	FSW-15	2099	LEO	209	300	56.95	
40	32	02/08/1994	8:30	94010	CZ-3A	Y1	Xichang	2	KF-1 SJ-4	1342 396	GTO GTO	200	36194	28.5	KF-1 is the mock-up of DFH-3
41	33	07/03/1994	8:00	94037	CZ-2D	Y2	Jiuquan	138	FSW-16	2755	LEO	176	359	63.98	launch failure, 2nd stage vernier thruster failure
42	34	07/21/1994	10:31	94043	CZ-3	Y8	Xichang	3	Apstar-1	1385	GTO	200	42386	27	
43	35	08/27/1994	23:10	94055	CZ-2E/ Star-63F	Y5	Xichang	2	Optus-B3	7669	GTO	185	1105	27.86	

#1	#2	Date	Time (UTC)	ID	Model	LV S/N	Launch Site	Lch Pad	Payload		Orbit				Remark
									Name	Weight	Type	Peri.	Apo.	Incl.	
44	36	11/29/1994	17:02	94080	CZ-3A	Y2	Xichang	2	DFH-3-1	2232	GTO	200	36197	285	
45	37	01/25/1995	22:40	95F01	CZ-2E/ Star-63F	Y6	Xichang	2	Apstar-2						destroyed due to wind shear
46	38	11/28/1995	11:30	95064	CZ-2E/ EPKM	Y7	Xichang	2	Asiastar-2	3500	GTO	185	309		
47	39	12/28/1995	11:50	95073	CZ-2E/ EPKM	Y8	Xichang	2	Echostar-1	3288	GTO	185.34	306.71	28	
48	40	02/14/1996	19:01	96F01	CZ-3B	Y1	Xichang	2	Intelsat-708	4180					exploded shortly after leaving launch pad
49	41	07/03/1996	10:47	96039	CZ-3	Y10A	Xichang	3	Apstar-1A	1400	GTO	222	41838	27	
50	42	08/18/1996	10:27	96048	CZ-3	Y14	Xichang	3	Chinasat-7						3rd stage early shutdown
51	43	10/20/1996	7:20	96059	CZ-2D	Y3	Jiuquan	138	FSW-17	2970	LEO	176	354	63	
52	44	05/11/1997	16:17	97021	CZ-3A	Y3	Xichang	3	DFH-3-2	2200	GTO	207	36194	28.4	
53	45	06/10/1997	12:01	97029	CZ-3	Y11	Xichang	3	FY-2A 02	1369	GTO	200	36000		
54	46	08/19/1997	17:50	97042	CZ-3B	Y2	Xichang	2	ABS-5	3775	GTO	205	44771	24.6	payload original name Agila-2 and Mabuhay
55	47	09/01/1997	14:00	97048	CZ-2C/SD	Y1	Taiyuan	Old	Iridium MFS-1 MFS-2	667	LEO	626	638	86.4	
56	48	10/16/1997	19:13	97062	CZ-3B	Y3	Xichang	2	Apstar-2R	3700	GTO	201	47922	24.4	
57	49	12/08/1997	7:16	97077	CZ-2C/SD	Y2	Taiyuan	Old	Iridium-42 Iridium-44	667	LEO	622	628	86.3	
58	50	03/25/1998	17:01	98018	CZ-2C/SD	Y3	Taiyuan	Old	Iridium-51 Iridium-61	667	LEO	622	628	86.4	
59	51	05/01/1998	21:16	98026	CZ-2C/SD	Y4	Taiyuan	Old	Iridium-69 Iridium-71	667	LEO	632.5	635	86.35	
60	52	05/30/1998	10:00	98033	CZ-3B	Y5	Xichang	2	ChinaStar-1	2917	GTO	201	85732	24.5	
61	53	07/18/1998	9:20	98044	CZ-3B	Y4	Xichang	2	Sinosat-1	2832	GTO	600	35786	19	
62	54	08/19/1998	23:01	98048	CZ-2C/SD	Y5	Taiyuan	old	Iridium-3 Iridium-76	667	LEO	612	635.5	86.4	
63	55	12/19/1998	11:30	98074	CZ-2C/SD	Y6	Taiyuan	old	Iridium-11A Iridium-22A	667	LEO	630	647	86.35	

#1	#2	Date	Time (UTC)	ID	Model	LV S/N	Launch Site	Lch Pad	Payload		Orbit				Remark
									Name	Weight	Type	Peri.	Apo.	Incl.	
64	56	05/10/1999	1:33	99025	CZ-4B	Y2	Taiyuan	old	FY-1C SJ-5	958 298	LEO LEO				
65	57	06/11/1999	17:15	99032	CZ-2C/SD	Y7	Taiyuan	old	Iridium-14A Iridium-21A	667	LEO	630		86.4	
66	58	10/14/1999	3:16	99057	CZ-4B	Y1	Taiyuan	old	ZY-1A SACI-1	1540 60	LEO LEO				
67	59	11/19/1999	22:30	99061	CZ-2F	Y1	Jiuquan	921	Shenzhou		LEO				

Note:

1. #1 and #2 are flight numbers of all launches and launches per vehicle respectively.

Sources:

1. CGWIC website: http://cn.cgwic.com/LaunchServices/LaunchRecord/LongMarch.html
2. Chinese Internet forum: http://www.9ifly.cn/thread-407-1-1.html (author: heito, darklighter, liss, zhaoyublg)
3. Jonathan McDowell, History of Space Flight, http://www.planet4589.org/space/book/index.html
4. Wikipedia, http://zh.wikipedia.org/wiki/中国运载火箭发射列表

Chinese Launch Sites

(Part 2 - Taiyuan Satellite Launch Center)

Brief History

The construction of the Taiyuan Satellite Launch Centre started in 1967 as a missile base. The existence of the launch site was highly confidential at the time and was only known to the public as a satellite launch centre in 1988 when China's first weather satellite FY-1 was successfully launched from there. TSLC is about 284 km North West of Taiyuan, the capital of Shanxi province. TSLC has been mainly used for LEO and SSO missions.

Facilities

Launch Pad "Old":

- First completed in 1979.
- Capable of launching CZ-2 and CZ-4 vehicles.
- Refurbished and upgraded in 2008/2009 and re-inaugurated in April 2009.

Launch Pad "New":

- Build and in use since September 2008.
- "Fully digitised launch mode".
- Capable of 3 launches per month.

Milestones

18 December 1968: First launch of China's first intermediwwate-range ballistic missile DF-3.

7 September 1988: Launch of China's first weather satellite FY-1A.

18 December 1997: Launch of TSLC's first international payload Motorola Iridium on board of a CZ-2C/SD vehicle.

Launch Pad Statistics

Launch Zone	#Pad	Construction Date	Service Date	Launch Stats (by LV model)	Launch Stats (by orbit type)	Fuel type	Remarks
	Old		1979	CZ-4A: 2 CZ-4B: 10 CZ-4C: 3 CZ-2C/SD: 9 CZ-2C/SM: 1 CZ-2C/SMA: 3 Total: 28	LEO: 23 SSO: 5	UDMH /N2O4	Refurbished and upgraded during 2008-2009 time period.
	New	2006	September 2008	CZ-4B: 4 CZ-4C: 3 Total: 7	LEO: 6 SSO: 1	UDMH /N2O4	
				KT-1: 3	LEO: 3		
				Total : 38			

Note: Launch statistics are up to end of September 2011.

Sources:

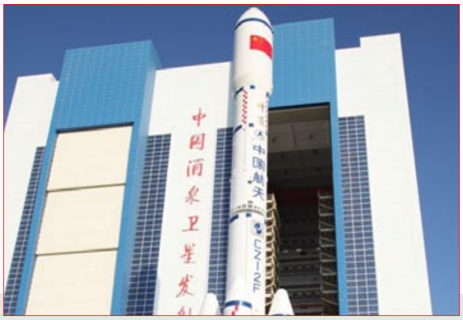
1. 百度百科, http://baike.baidu.com/view/25207.htm
2. 互动百科, http://www.hudong.com/wiki/%E9%85%92%E6%B3%89%E5%8D%AB%E6%98%9F%E5%8F%91%E5%B0%84%E4%B8%AD%E5%BF%83
3. CGWIC, http://www.cgwic.com

Gallery

Tiangong 1 and CZ-2F (T1)

Tiangong 1 was launched at 21:16:03 Beijing Time, 29 September 2011 from Jiuquan Satellite Launch Centre (JSLC). (Photo: Xinhua)

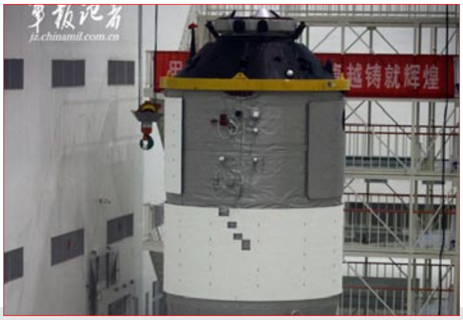
Tiangong 1 inside the vertical assembly building in JSLC before rolling out to the launch pad. (Photo: Xinhua)



Tiangong 1 roll-out to the launch pad on 20 September 2011. (Photo: Xinhua)

Tiangong 1 roll-out to the launch pad on 20 September 2011. (Photo: Chinanews.com)

Tiangong 1 during final test and launch preparation. Two telescope-like cylinders are clearly seen at the side of the TG-1's intersecting segment. (Photo: weibo.com/lifeweek)



Tiangong 1 during final test and launch preparation. The APAS docking mechanism is seen at the top of the spacecraft and the TDRS antenna in red cloth cover is also seen at its lower section (only in iPad version). (Photo: Chinamil.com)

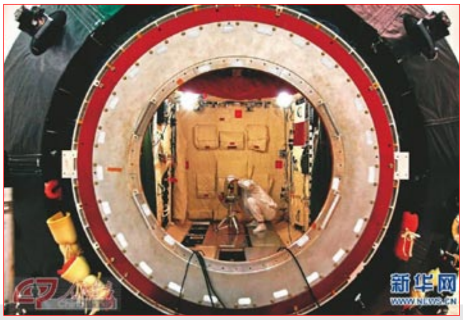
Tiangong 1 during final test and launch preparation. (Photo: Chinamil.com)

Tiangong 1 during final test and launch preparation. (Photo: Chinamil.com)

Tiangong 1 during final test and launch preparation. Note the small porthole on the larger diameter experimental module. (Photo: China.com)

Tiangong 1 during final test and launch preparation. Here the the TDRS antenna in red cloth cover is visible to the right. (Photo: China.com)

Tiangong 1 during final test and launch preparation. Please note that cover on the TDRS antenna and the alleged telescopes were removed. (Photo: Chinanews.com)



Tiangong 1 interior. Note that a protective plate in this photo covered the docking mechanism. (Photo: Xinhua)