All About The Chinese Space Programme

Go Taikonauts!

龙腾太空

Issue 3 January 2012

MISSION DOCKING
Behind the Scenes

All about the Chinese Space Programme

Go Taikonauts!

Editor's Note

The year 2011 may become a key turning point in the Chinese space programme. In this year, China surpassed the United States in annual space launch rate , started initial Beidou positioning service, revived commercial launch ... page 2

Quarterly Report

July - September 2011

Launch Events

As in previous years, Chinese launch activities accelerated in the second half of the year. There were nine space launches in the third quarter of 2011, eight of which were successful, which established a string of records in the history of the Chinese space programme ... page 3

Analysis

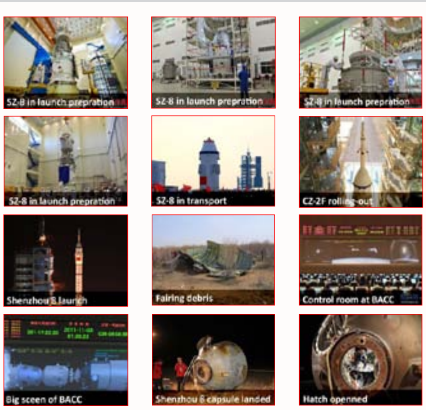
When Two Became One

As media both inside and outside China have reported, the Shenzhou 8 docking mission with Tiangong 1 towards the end of 2011 was a full success. What does success mean in this context? What are the direct consequences for China's ambitions in space? And could this have any implications for international cooperation/ collaboration in the future? ... page 14

Gallery

Shenzhou 8 Mission

page 38



Mission Docking: Behind the Scene

The Shenzhou 8 and the Tiangong 1 rendezvous and docking mission was undoubtedly one of the most important space events in 2011. It becomes especially dramatic now that the US has retired its shuttle fleet and lost its capability to send humans into space, and Russia has recently encountered a string of disappointing launch failures and the loss of the high-profile Phobos-Grunt probe ... page 6

International Cooperation

Harmonious Interference Dissolves Galileo "Misunderstandings"

People often like to talk about the "new space race to the Moon". But in the background, almost un-noticed by the public, another more tangible race is taking place. It is a highly strategic race - to establish a globally dominating satellite ... page 21

International Cooperation

The Glow of the Firefly Shines into the Future

Yinghuo 1 - a Martian Space Environment Exploration Orbiter

It could have been the cherry on the cake, the peak of a highly successful space year for China. The teeny-weeny Mars probe Yinghuo 1 is the first Chinese spacecraft for Mars exploration. The micro-satellite ... page 26

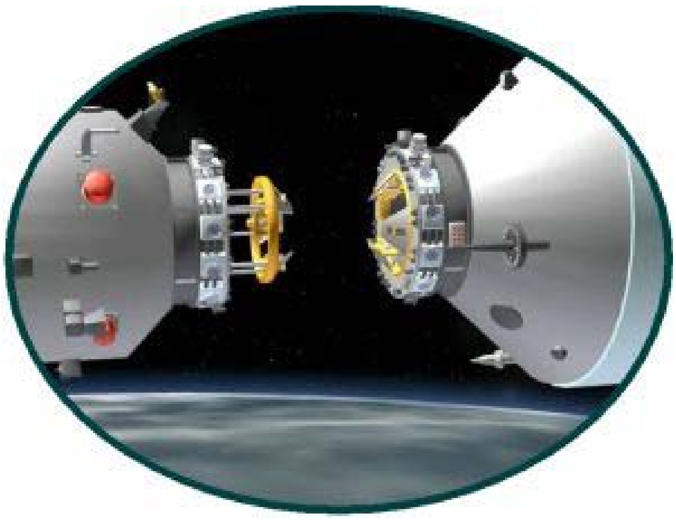
Database

Chinese Space Launch History - Part 3

The most detailed Chinese launch record ... page 35

Chinese Launch Sites - Part 3

China has three launch sites in use and one site under construction ... page 37



Editor's Note

The year 2011 may become a key turning point in the Chinese space programme. In this year, China surpassed the United States in annual space launch rate, started initial Beidou positioning service, revived commercial launch activity, launched the first space station module and successfully tested rendezvous and docking in space. All of these events representing the emergence of a major player in almost all important space areas including human space flight. Undoubtedly, the most eye-catching event in 2011 was the Shenzhou 8 rendezvous and docking mission. Many people say that the Chinese space programme is still very secretive and mysterious. But unlike the time of the Soviet Union, the Chinese are in fact much more open concerning their human space programme. There was live TV coverage of every major event. Multiple onboard cameras captured spectacular live video from different angles during the docking, which makes it as good as watching a Hollywood film. However what's on TV is just the tip of the iceberg. The cover story of this issue has more details from behind the scenes.

The successful Shenzhou 8 docking raised an interesting question. Is the Chinese docking system compatible with that of the ISS and is China ready for international cooperation on human space flight? China has claimed that its docking mechanism is compatible with the international standard. But other than this statement and appearance shown in photos of the docking mechanism, there is not yet any conclusive technical confirmation. The article "When Two Became One" in this issue gives a technical review and analysis on the Chinese system and the international docking standard. The conclusion of the article is that the Chinese system is almost certainly compatible with the IDSS - the International Docking System Standard. Sounds good and promising.

A compatible docking system paves the way for a joint manned mission in the future. However, cooperation is not always smooth and easy. There are also difficulties and setbacks. China's participation in the European Galileo navigation system encountered a lot of problems or even conflicts and at one time stalled before being reviewed again in November this year. And just days after the successful Shenzhou 8 mission, China lost its first Mars probe, the Yinghuo 1, when its mother ship, the Russian Phobos-Grunt Mars moon orbiter, failed to leave low Earth orbit. We have two articles in this issue discussing these two cooperation projects. We hope that the price paid for the Galileo cooperation will lead to a better understanding and communication in future cooperation. And for the Yinghuo 1 mission, no one is to be blamed. The article is just in commemoration of the perished pioneer of future Chinese Mars probes.

If 2011 is a turning point, then there is strong enough reason to expect 2012 to be a year with even more excitement. Yes, the manned Shenzhou 9 and 10 missions could be such an excitement. Will there be something surprising? Maybe. The Chinese often do things in this way.

(Chen Lan)

Imprint

Go Taikonauts! e-Magazine

Go Taikonauts! e-Magazine on iTunes:
http://itunes.apple.com/de/app/go-taikonauts!/id454679742?mt=8

The Go Taikonauts! Team
William Carey - Dave Chen Qing - Chen Lan - Jacqueline Myrrhe

Contact us at: info@go-taikonauts.com
Web site: www.go-taikonauts.com

Chinese Space Quarterly Report

July - September 2011

Launch Event

As in previous years, Chinese launch activities accelerated in the second half of the year. There were nine space launches in the third quarter of 2011, eight of which were successful, which established a string of records in the history of the Chinese space programme:

- Most frequent launches in one calendar month (4 times in July) and most frequent launches in one quarter (9 times).
- Shortest interval between two successive launches (2 days 9 hours and 58 minutes between the Beidou IGSO-4 and the SJ-11-03 launches).
- Shortest interval between two successive launches from the same launch site (15 days 6 hours and 3 minutes between the TL-1-02 and the Beidou IGSO-4 launches).
- Shortest interval between two successive launches from the same launch pad (20 days 1 hour and 46 minutes between the SJ-11-02 and SJ-11-04 launches from Pad 603, JSLC).
- Fastest "return to flight" from a total launch failure (31 days 6 hours and 5 minutes from the SJ-11-04 failure to the ZX-1A launch).

The nine launches were:

- At 12:28:03 on 6 July, a CZ-2C from JSLC sent the SJ-11-03 satellite into orbit.
- At 23:41:04 on 11 July, a CZ-3C from XSLC sent the Tianlian-1-02 tracking and data relay satellite into GTO and finally stationed it at 176.8°E on 18 July.
- At 5:44:28 on 27 July, amid heavy rain, thunder and lightning, a CZ-3A blasted off from XSLC, putting the Beidou IGSO-4 navigation satellite into an inclined geo-synchronous orbit. It was the 9th satellite in the Beidou 2 constellation.
- At 15:42 on 29 July, a CZ-2C from JSLC sent the SJ-11-02 satellite into orbit.
- At 0:15:04 on 12 August, a CZ-3B from XSLC launched the Paksat-1R communication satellite into GTO that positioned it at 37.8°E on 11 September.
- At 6:57:19 on 16 August, a CZ-4B (Y14) from TSLC launched the HY-2 oceanic satellite into SSO.
- At 17:28 on 18 August, a CZ-2C from JSLC launched carrying the SJ-11-04 satellite, but failed to reach orbit. This was the first total failure since 15 February 1996. The result of the investigation into the failure was announced on 6 August. The investigation concluded that a structural failure of the servomechanism for the second stage vernier engine, caused a loss of attitude which finally lead to destruction of the rocket.
- At 0:33:04 on 19 September, a CZ-3B (Y16) from XSLC sent the Chinasat 1A (ZX-1A) communication satellite into GTO. It was stationed at 129.8°E on 26 September.
- At 21:16:03 on 29 September, a CZ-2F/T1 from JSLC launched the Tiangong 1 space laboratory into space, to await the arrival of Shenzhou 8 for the historic rendezvous and docking mission.

Launch Vehicle

The Long March 5 development continued to make steady progress. In early September, the first of four large static load test facilities for the new generation launch vehicle was completed in the Tianjin New Generation Launch Vehicle Industrial Base. This facility is able to support a 2,000-tonne class static load test on the core stage. According to the plan, static load tests of the inter-stage segment of the core module and the equipment bay will be completed by the end of 2011.

Engine

There was a breakthrough in development of large solid motors. On 27 July, China's first 2 m diameter, 3-segment solid motor demonstrator, made its first successful test-firing. This followed a previous milestone where the 1 m, 2-segment solid motor was successfully test-fired in April 2010. The demonstrator was developed by the Academy of Aerospace Solid Propulsion Technology, or the 4th Academy of CASC. This new success paves the way for a solid-fuelled booster that will be used on the future heavy launch vehicle.

Earlier, the 4th Academy made another successful solid motor test. In the test, a solid motor was dropped vertically from a height of 30 m. There was no explosion or burning, and the motor structure remained intact. The dropping test proved the safety margin of the motor, and was the first time China has made such a kind of testing.

In the field of liquid-fuelled engines, on 8 July, the 6th Academy of CASC, or Academy of Aerospace Propulsion Technology (AAPT) completed the main steel structure of the test stand for the new generation propulsion system, paving the way for equipment installation in the next step.

Satellites

The Haiyang 2 (HY-2) is China's new generation oceanic satellite. It is equipped with passive and active microwave sensors. It is also the first Chinese satellite with centimetre-class high-precision orbital control, and carries a ground-space free space laser communication payload for the first time in China. However, after the successful launch on 14 August, the satellite was rumoured to have failed to establish the correct attitude. On 29 August, there was an official announcement that the satellite established an Earth-facing attitude, which indirectly confirmed the earlier attitude problem. On 1 September, the onboard Doppler orbital determination system and the GPS payload were switched on and data communication was established. The radar altimeter and the calibration microware radiometer were then powered on. Up to the end of September, the satellite was still in in-orbit testing and it appeared to be working well.

On 11 July, the engineering model of the wind scatterometer (SCAT) for the Chinese-French Oceanic Satellite 1 (CFOSAT-1) completed testing on the electrical satellite model. SCAT is one of two major payloads on the CFOSAT-1, and is developed by the Key Laboratory of Microwave Remote Sensing (Mirslab), CAS (China Academy of Sciences). Another payload, a wave-scatterometer spectrometer SWIM (Surface Waves Investigation and Monitoring) is supplied by CNES, the French Space Agency.

Besides CFOSAT-1, the Mirslab made another breakthrough in July. The GEO Millimetre Wave Atmosphere Temperature Sensor successfully completed a series of ground field tests. It was reportedly the world's first full-sized prototype able to obtain temperature data with a ground resolution of 50 m from geostationary orbit.

On 18 July, the Ministry of Environment Protection of China held a discussion panel on the plan of the HJ (Environment) satellite. The Ministry of Environment officials believe that it is necessary to establish its own satellite system. Experts urged planning of the future HJ satellite as soon as possible, as the HJ-1A/B satellites are near end of their 3-year working lifetime. On 19-30 July, the Resource Satellite Application Centre of China completed calibration testing for the HJ-1A CCD camera and the hyper-spectrum camera. The testing was done in Dali Lake, Inner Mongolia.

On 22 September, China's first pico-satellite, the 3.5 kg Zheda-Pixing 1A, developed by Zhejiang University, has operated successfully for a full year in-orbit. It has completed all onboard experiments, including a tracking and communication test, 3-axis attitude control test, MEMS sensor testing, panorama camera imaging testing, as well as testing of subsystems of the satellite.

Zhejiang University is not the only educational organisation in China involved in small satellite development. On 27-28 July, a delegation from North-western Polytechnic University (NPU) participated in the second QB50 workshop held at the von Karman Institute for Fluid Dynamics (VKI) in Belgium. The QB50 is an international network of 50 CubeSats for multi-point, in-situ measurements in the lower thermosphere and re-entry research. NPU is the coordinator for eight Chinese universities participating in QB50. It will also develop a CubeSat and will build a mission control centre, one of three such centres in QB50.

Manned Space Flight

The third quarter of 2011 had been expected to be the most important moment since the Shenzhou 7 EVA mission in 2008 - the long anticipated Tiangong 1/Shenzhou 8 rendezvous and docking mission. The Tiangong 1 spacecraft had been in JSLC for testing since late June, and the CZ-2F/T1 rocket arrived in JSLC on 23 July. However, the 18 August CZ-2C/SJ-11-04 launch failure interrupted preparations for the mission. At that time, the Tiangong 1 had already been fuelled. Fortunately, the launch failure investigation progressed very quickly, and in early September, the cause of failure was clarified as not being related to the new CZ-2F/T1 vehicle. On 26 August, the ground team made the last rehearsal of the launch. On the same day, another CZ-2F for the Shenzhou 8 arrived in JSLC. On 29 September, the Tiangong 1 space lab was finally launched into space successfully, starting the countdown for the rendezvous and docking mission about one month later.

In late July, China Academy of Space Technology (CAST) completed the review on the space robotic arm design. The robotic arm was planned for the future space station, with the study being started in 2007. In collaboration with leading Chinese robot research organisations, CAST completed a proof-of-principal prototype, and then started the detailed design and development of key components, such as the large integrated joint. The review paved the way for the next stage engineering development.

On 29 September, the day of the Tiangong 1 launch, Zhang Shancong, a scientist involved in the application sub-system of the manned programme, revealed that China will open the future space station for scientific experiments from organisations and personnel in China. China Manned Space Engineering Office (CMSEO) will soon release an official guide for applications to fly experiments on the manned space station. It has planned eight research areas on the space station. They are "space Earth science and applications", "space life and biological science and applications", "space material science", "microgravity fundamental physics", "microgravity fluid physics and combustion science", "space physics and space environment", "space astronomy", and "new technologies for space applications". It did not specifically mention whether it would be open to international partners or not.

On 8 July, CMSEO announced the first result of the naming competition for the Chinese manned space station programme. Only 10 names for the planned cargo vehicle were selected from 9,640 proposals. They are Tiansuo (space shuttle), Kunpeng (a kind of large bird), Tianzhou (space vessel), Shenlong (divine dragon), Longzhou (dragon vessel), Shenji (divine base), Tianma (space horse), Yunti (ladder in cloud), Shenju (divine resident), and Xingzhe (traveller). The competition was carried out from April to May 2011. The official name will eventually be selected from one of the above 10 candidates.

Lunar and Deep Space Exploration

China's second lunar probe Chang'e 2 arrived at a Halo orbit around the Earth-Moon's second Lagrange Point (L2) at 23:27 on 25 August, 2011. The transit from the lunar orbit to the L2 point took Chang'e 2 77 days. On 21 September, it sent back its first batch of data while orbiting the L2 point (about 1.7 million kilometres away from Earth). From 19:25 on 23 September, Chang'e 2 started sending back data of solar wind, high-energy particles and gamma rays, at a rate of 750 kbps. The probe was in good status. Up to 20 September, it still had 115 kg of fuel remaining. Chinese scientists suggested in the media that Chang'e 2 may perform a further extended mission, flying to the Sun-Earth L1 point or an asteroid, or a comet.

Late August, the Lunar Surface Rover, to be launched with China's first lunar lander Chang'e 3, started intensive in-door field-testing. The test field in CAST was covered with dust finer than flour, to simulate the lunar surface. The Chang'e 3 rover has to withstand those conditions during operations on the lunar surface. This test was also an opportunity to check procedures, management and the performance of the several test teams involved. Meanwhile, the Chang'e 3 lander underwent stability testing in Institute 508 of CAST in August.

In late July, CAST also completed a review of key technology developments being prepared for China's future exploration of Mars. These technologies cover Mars orbit design and control, overall design of the Mars probe, deep-space tracking and communication, ground simulation and test systems, etc.

Miscellaneous

On 1 July, China's first space movie, Feitian (flying to space, or flying in space), was on show nationwide. Casting for the movie was supported by various official Chinese space organisations and its shooting locations included the Beijing Aerospace Control Centre (BACC), Astronaut Centre of China (ACC), Jiuquan Satellite Launch Centre (JSLC), and even Moscow and Star City in Russia. The fictional movie story is about a Chinese space station that is hit by space debris, and a new manned spacecraft launched to rescue the station and its crew. The film has 600 special effects, a new record for a Chinese movie. Its production cost is reportedly more than RMB 100 million (more than USD 10 million).

On 7 July, the National Space Science Centre (NSSC) was officially inaugurated. The newly established centre is built on the basis of the Centre for Space Science and Applied Research (CSSAR), Chinese Academy of Sciences. It will support national space science programmes which have never been at the national level. Its budget will come directly from the central government. Its current projects include the development of five space science satellites, selecting and supporting several new mission studies before the engineering phase, supporting a number of long-term enabling technology studies for future missions, and strategic study for space science in China.

In mid July, China delivered the GVU-600 space environment simulator to Russia. GVU-600 is a horizontal thermal vacuum chamber with diameter of 8 m and length of 10 m. It will be used to test the new generation of Glonass satellites. CAST was contracted by the Russian company Reshetnev to build the simulator, which was completed in 21 months.

China and Belarus signed a contract on 18 September in Minsk for China to build and launch a communication satellite for Belarus. The satellite will use the DFH-4 satellite platform with 40 onboard transponders, and has a design lifespan of 15 years. It will be launched from the Xichang Satellite Launch Centre two and a half years after the contract start date. China will also build a ground station in Minsk for Belarus to monitor the satellite, and provide training to Belarusian technicians.

(Chen Lan)

The Static Load Test Facility in Tianjin. credit: internet photo

Image sent back to Earth from Zheda-Pixing 1A. credit: Xinhua

Haiyang 2 in thermal vacuum test. credit: SCA

Checking of the failed second stage engine on CZ-2C. credit: internet photo

Mission Docking: Behind the Scenes

The Shenzhou 8 and the Tiangong 1 rendezvous and docking mission was undoubtedly one of the most important space events in 2011. It becomes especially dramatic now that the US has retired its shuttle fleet and lost its capability to send humans into space, and Russia has recently encountered a string of disappointing launch failures and the loss of the high-profile Phobos-Grunt probe.

However, China's steady progress in space in 2011, including the launch of the two man-rated spacecraft and two times successful rendezvous and docking demonstrated by Shenzhou 8, was not accomplished in one day. It was the result of a long-term investment and uninterrupted research and development. The story started almost 20 years ago, involving innumerable people and effort, as well as difficulties and setbacks. Thanks to modern communication technologies, especially the internet, the Shenzhou 8 docking was reported worldwide. There are impressive launch and docking videos posted everywhere on the internet. But what happened behind the scenes? What's the new technological development involved in this mission? How did the Chinese master the rendezvous and docking technologies? What did the Chinese space planner decide for the docking standard and why? Was there help from the outside world in developing these technologies? How will this docking mission influence the future Chinese manned programme? This article will try to reveal some of the answers, if not all.

Shenzhou as a Ferry Spacecraft

Shenzhou 8 has a length of 9 m and a weight of 8,082 kg, and looks almost identical to previous Shenzhou spacecraft. However, it will inevitably become a milestone in the Shenzhou programme. Shenzhou 8 is the first designed as a transportation vehicle, i.e. a "ferry" between the ground and the space laboratory or the future space station. China has announced that it will launch about 20 manned spacecraft by 2020, and will start small-scale serial production of Shenzhou spacecraft soon.

As a ferry spaceship, all unnecessary functions were removed from Shenzhou 8 and it was enhanced with the rendezvous and docking objective in mind. Among approximately 600 pieces of equipment, 40 % has been improved and 15 % are totally newly developed. Major changes include:

- An APAS-type docking system on top of the orbital module.
- Installation of a microwave radar, laser radar, and CCD sensors and lighting device used for the docking with Tiangong 1.
- Removal of the solar panels and other equipment designed for independent flight from the orbital module.
- Compared to Shenzhou 7, removal of the airlock function from the orbital module, including the EVA hatch, EVA suit, and other facilities used to support EVA.
- Addition of the spacecraft-space station interface and modification of the control system to enable unified control by the station (Tiangong 1).
- More onboard live-transmission video cameras to help monitor the unmanned docking and other in-space operations. Two of them are at the side of the orbital module to capture solar panel deployment, and another one is within the docking ring to closely observe the docking.
- A domestically developed gamma ray altimeter used to trigger the landing rocket ignition when the capsule is one meter above the ground. It was reportedly the last component "Made in China" on Shenzhou, which implies previous capsules use an imported altimeter, most likely made in Russia.
- Payload capability increased to 300 kg.

Similar to Soyuz and Progress, the Shenzhou ferry is designed to be able to remain attached to a space station for 180 days as a rescue vehicle. It is interesting to note that not only are the Chinese seemingly learning from Russia at every opportunity, but also that Shenzhou could be a good replacement for the Soyuz on ISS.

The development of the Shenzhou 8 ferry spacecraft started even before the Shenzhou 7 mission in 2008. Its assembly was completed in late 2010 and the thermal vacuum testing was conducted in early May 2011. The SJ-11-04 CZ-2C failure on 18 August made the schedule uncertain, but it did not stop the preparation. On 24 September, the Shenzhou 8 was transported to the Jiuquan Satellite Launch Centre.

After the launch failure investigation was released and the Tiangong 1 successfully launched, the Shenzhou 8 mission was back on track. However, on 22 October, just three days before the planned roll-out, the launch schedule became uncertain again. At 16:00 that day in Beijing, during a thermal testing of the next space craft, Shenzhou 9, its CTU (the onboard central computer) lost a telemetry signal, which means loss of contact from the ground. If the Shenzhou 8 spacecraft was to be dissembled to verify its CTU problem, the launch windows on 1 November, 3 November and 5 November would be missed and the launch would have to be delayed until the end of December. Fortunately, the analysis on the Shenzhou 9 CTU was concluded by late night on 25 October. It turned out that the problem happened only in ground testing, which paved the way for an on-time launch in early November.

Sixteen Years

China started the developing of the rendezvous and docking system in 1994. From the first day, China decided to go with the APAS (Androgynous Peripheral Assembly System) -type docking system. The reason is not only that it has more advantages and is more technologically advanced, but the space experts at that time already had the next generation docking system in mind. The APAS was planned for the Soviet Shuttle Buran, the Mir (Kristall Module) and the ISS. This confirmed that China's willingness to participate in international cooperation on human spaceflight existed from a very early stage.

Also by that time, there was a report about the fact that when the Chinese were considering purchasing Russian technology, Russia had quoted a USD 100 million price tag for the technology transfer and license. This "high cost" resulted in China deciding to develop its own technology. The Shanghai Academy of Spaceflight Technology (SAST) was given the role for pre-studies in 1994. Rendezvous and docking principle research was initiated in 1995 by a small team of 6 people, while today they have nearly 250 people involved in the project. The team listed 4 key technologies for the system, namely system integration technology, dynamic simulation technology, key standalone technologies and ground test technology. Lead by Institute 805 of SAST, many research organisations and manufacturers in the Chinese space industry were involved in the 16-year long work.

SAST completed a proof-of-concept docking demonstrator in 1999. In early 2004, it was reported that SAST had made a "breakthrough" in docking mechanism develop-

left: Initial ascent.
credit: CCTV

right: 2nd-stage ascent.
credit: CCTV

left: Shenzhou 8 separation.
credit: CCTV

right: Solar panel deployment.
credit: CCTV

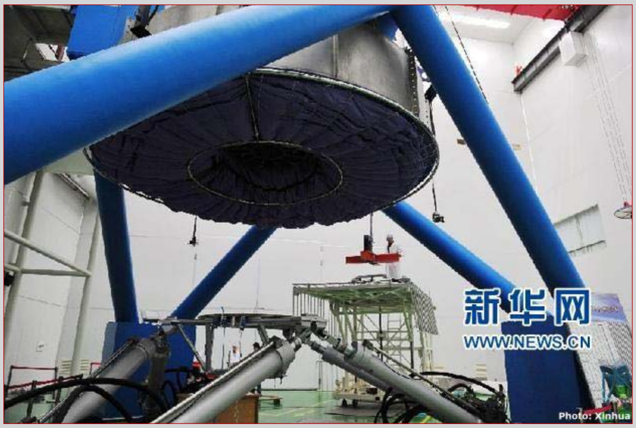
Timeline: Launch
(Beijing Time)

- **24 September:** Shenzhou 8 spacecraft arrived in JSLC (Jiuquan Satellite Launch Centre).
- **26 October:** Shenzhou 8, at top of the CZ-2F was rolled-out to the launch pad.
- **31 October:** The fuelling was done in about 10 hours.
- **5:58:10, 1 November:** Lift-off.
- **6:00, 1 November (T+120):** Separation and jettison of the escape tower.
- **6:01, 1 November (T+140):** Strap-on boosters and the first-stage separation.
- **6:02, 1 November (T+212):** Shroud separation.
- **6:07, 1 November (T+583):** Spacecraft separation. Shenzhou 8 entered an orbit of 200 x 329 km with an inclination of 42.78 degrees.
- **6:10, 1 November (T+720):** Solar panel deployment.
- **6:11, 1 November (T+846):** Deployment of the tracking and data relay antenna.
- **7:06, 1 November:** The TL tracking satellite captured signals from Shenzhou 8.
- **12:51, 1 November:** Shenzhou 8 completed its first manoeuvre, raised its perigee for about 60 km, and entered an orbit of 261 x 318 km.
- **0:10, 2 November:** Shenzhou 8 completed its second manoeuvre, and adjusted its orbital plane to be precisely aligned with Tiangong 1.
- **4:38, 2 November:** Shenzhou 8 completed its third manoeuvre, and raised its apogee to 330 km.
- **9:55, 2 November:** Shenzhou 8 completed its fourth manoeuvre, raised its perigee to about 330 km, and entered a near-circular orbit.
- **17:05, 2 November:** Shenzhou 8 completed its fifth manoeuvre, the final pre-docking correction, and was ready for the upcoming docking.

ment. Around the same year, the Space Laboratory project (later named Tiangong) was formally approved and entered full-scale development. The docking mechanism development was then sped up. The first prototype of the docking mechanism was completed in 2006, but subsequent testing revealed that both contact force and separation angular velocity exceeded their tolerances. The team took nearly one year to overcome these problems. During the development, SAST applied for 45 patents related to space rendezvous and docking technologies, of which over 15 have been approved and granted. Before the launch of SZ-8 and TG-1, they completed manufacture of 9 sets of the docking mechanism including backups, some of which are to be used by flight models after Shenzhou 8.

The Chinese APAS was claimed to be compatible with the ISS docking port, but it may need minor modifications before any actual ISS docking. Similar to the APAS-89/95 system used on the ISS, it has a tunnel with diameter of 0.8 m, three inward alignment petals at the docking collar and 12 latches for air-tight sealing and 4 springs for separation.

left: The Space Docking Characteristics Test-Bed. credit: Xinhua
right: The Space Docking Thermal Vacuum Test-Bed. credit: Xinhua



left: The Space Docking Buffer Test-Bed. credit: Xinhua

right: The Space Docking General Test-Bed. credit: Xinhua

Each latch is able to provide a tightening force of 3 tonnes and each spring has pushing force of hundreds of Newtons. Five controllers, 18 electrical or electromagnetic actuators, 118 sensors, 291 gears, 759 bearings, 11,000 fasteners and nearly 10,000 other components work together to complete a docking operation.

Chinese media have highlighted the ground docking simulation system as the key to the success of SZ-8 and TG-1 mission. Institute 805, together with its sub-contractors, developed 4 large simulation test beds, the Space Docking Buffer Test Bed, the Space Docking General Test Bed, the Space Docking Characteristics Test Bed, and the Space Docking Thermal Vacuum Test Bed. This makes China the owner of a set of world-class space docking simulation facilities. Institute 509 and Factory 149 of SAST are the main contractors of the simulation system, which is able to simulate the complete process of docking and undocking on the ground. 1,101 docking tests and 647 undocking tests have been carried out before the actual docking took place in space on 3 November. According to Tao Jianzhong, previously in charge of the simulation system, the 3 November docking was so accurate that the planned force calibration was not performed. As compared to simulation results on the ground, the mutual capture process of the two spacecraft took 1.045 second, just 0.003 second longer than the simulated result. The complete docking process took 7 m 29 s while it lasted 7 m 28 s in the simulation, only 1 second of difference!

Eyes in Space

Besides the docking mechanism, another key technology is the measurement and navigation system used during approach and docking. The Shenzhou 8 utilises three types of measurement system to provide range measurement at different distances. The microwave radar operates 150 km distance from the docking target. The laser radar was used from a distance of 20 km. And the CCD sensors operate during the final phase of approach (within 100 m). The Chinese system incorporated similar technologies of the Russian Soyuz/Progress (microwave radar) and the European ATV (laser range finder) but is reportedly having higher precision than the Russian system.

The Institute 25 of CASIC (China Aerospace Science & Industry Corp.) is in charge of developing the microwave radar, which could detect the target spacecraft in a range from 150 km distance up to 20 metres with help of the transponder installed on the target spacecraft. The radar weighs less than 12 kg and has very low power consumption and no moving parts. It uses high-speed pseudo-code ranging, two-way coherent Doppler velocity measurement and interferometer based angle measurement. The Chief Designer has mentioned in an interview in the Chinese media that future versions will be half the size, weight and power consumption, while maintaining the same performance.

Timeline: Docking
(Beijing Time)

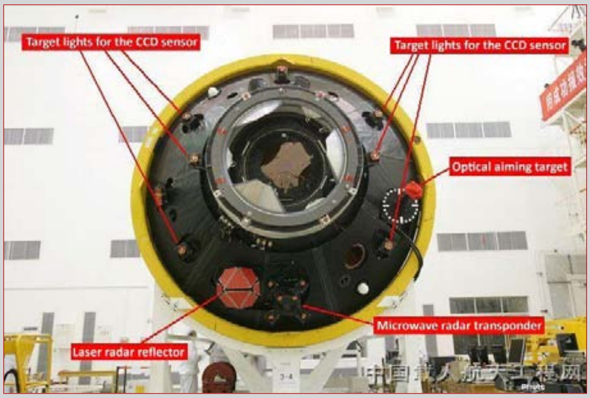
- **19:34, 30 October:** The Tiangong 1 space lab made a 180 degree U-turn, directing its docking port backward and waited for the Shenzhou 8 unmanned spacecraft for the first Chinese docking in space.
- **20:58, 2 November:** The microwave radar on the Shenzhou 8 was powered on. It was designed to capture targets within 150 km but it captured the Tiangong 1 immediately at a distance of 217 km.
- **23:08, 2 November:** At an altitude of 343 km, Shenzhou 8 reached a "parking point" 52 km behind the Tiangong 1 and started target-seeking and rendezvous sequence with the Tiangong 1.
- **0:16, 3 November:** After 4 manoeuvres, Shenzhou 8 arrived at the 5 km parking point.
- **0:34, 3 November:** Shenzhou 8 started approaching the Tiangong 1 from the 5 km mark to the 400 m parking point.
- **1:03, 3 November:** Deployment of the docking ring at the Shenzhou spacecraft.
- **1:05, 3 November:** Shenzhou 8 arrived at the 400 m parking point while flying over the Malindi tracking station in Kenya and TL-1 coverage.
- **1:06, 3 November:** After confirmation by ground control, Shenzhou 8 continued approaching the docking target.
- **1:16, 3 November:** Shenzhou 8 arrived at the 140 m parking point.
- **1:19, 3 November:** Activation of the laser radar navigation.
- **1:20, 3 November:** CCD camera navigation activated.
- **1:20, 3 November:** Shenzhou resumed approaching from the 140 m parking point, at a speed of 0.5m/s.
- **1:23, 3 November:** The spacecraft arrived at the 30 m parking point.
- **1:27, 3 November:** Shenzhou started the final approach.
- **1:29, 3 November:** Docking ring contact at speed of 0.2m/s.
- **1:29:06, 3 November:** 4 engines ignited to give the spacecraft a slight pushing force in support of the docking.
- **1:29, 3 November:** Docking mechanism capture.
- **1:30, 3 November:** Completion of capture and engine shutdown.
- **1:30, 3 November:** Buffering and calibration done, locking started.
- **1:34, 3 November:** Sealing completion, rigid connection established.
- **1:36, 3 November:** Completion of locking.
- **1:37, 3 November:** Tiangong 1 took control of the complex.
- **1:42, 3 November:** The complex completed the attitude correction. Docking done successfully. It then turned 180 degree back to "normal flight altitude" a few hours later.

left: TG-1 seen from SZ-8.
credit: CCTV

right: Final approach.
credit: CCTV

left: Final approach seen from TG-1.
credit: CCTV

right: Contact.
credit: CCTV



Docking equipment at Tiangong 1.
credit: CMSEO

above: The laser radar.
credit: internet photo

right: Corner reflector for the laser radar.
credit: internet photo

Shenzhou 8 capsule air-dropping test in January 2011.
credit: CMSEO

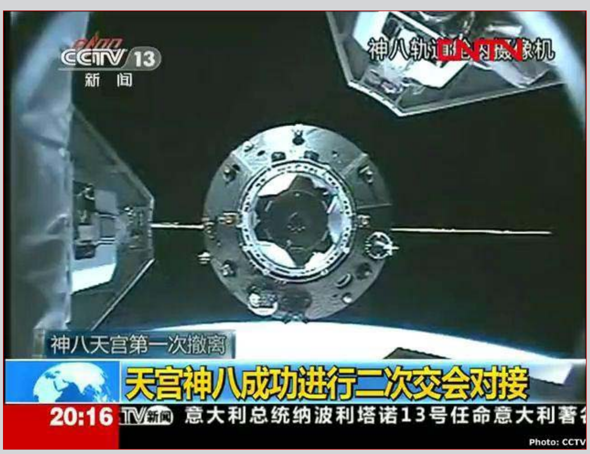
The Institute 25 started developing the microwave radar in 1999. The initial proposal for rendezvous and docking detection and tracking was not microwave radar. To avoid sunlight interference, a microwave radar proposal was adopted in early 2007. The operation in the two docking/undocking tests during SZ-8/TG-1 mission was perfect, e.g. the actual detection distance of the target spacecraft was at 217 km instead of expected 150 km.

The laser radar was developed by the Institute 27 of the China Electronics Technology Group Corporation (CETC). With a reflector installed on the docking target, the radar is able to detect and measure distance between two spacecraft at a distance of 20 km. The CCD Sensor system is used during final approach, and was developed by the Xi'an Institute of Optics and Precision Mechanics of CAS (Chinese Academy of Sciences). The system has a high precision with a relative optical distortion of under 0.018 %.

The docking radars and sensors were tested on various ground test-beds. The Chinese reconfigured two Y-8 transportation planes into the long and medium distance rangefinding test-bed. They used ground vehicles to simulate medium and short distance approach and used a high precision nine-degree-of-freedom platform to perform the final stage docking measurement testing.

Timeline: Re-docking
(Beijing Time)

- **22:37, 13 November:** The combined spacecraft configuration of the Shenzhou 8 and the Tiangong 1 turned through 180 degrees, and established the same attitude as in the first docking.
- **19:24, 14 November:** The separation command was sent.
- **19:27, 14 November:** Separation.
- **19:34, 14 November:** Shenzhou 8 arrived at the 140 m parking point.
- **19:41, 14 November:** Shenzhou 8 started approaching Tiangong 1.
- **19:48, 14 November:** Shenzhou 8 arrived at the 30 m parking point.
- **19:49, 14 November:** Sunset.
- **19:50, 14 November:** Shenzhou 8 started approaching Tiangong 1 again.
- **19:53:36, 14 November:** Contact.
- **19:53, 14 November:** Capture.
- **19:59, 14 November:** Locking completion.



left: Undocking seen from SZ-8.
credit: CCTV

right: Undocking seen from TG-1.
credit: CCTV

left: At the 140 m parking point.
credit: CCTV

right: Re-docking.
credit: CCTV

Inside the Shenzhou 8

Shenzhou 8 was the first unmanned spacecraft to be launched after the Shenzhou 4 launch in December, 2002. It was interesting to see the dummy taikonaut back at work after nearly eight years. This time, there were two 75 kg dummies in the Shenzhou 8 capsule. The purpose of the dummies is to make the conditions of the spacecraft as realistic as possible during the docking mission, and it was also an opportunity to test and accumulate working time for all related equipment, including the spacesuit, in space.

The Sino-German joint SIMBOX project was also a focus during this mission. The SIMBOX is a general biological incubator developed by EADS Astrium in Friedrichshafen, under contract to the German space agency DLR that carried 17 experiments among which 10 were from China, 6 from Germany, and one was a joint experiment. SIMBOX was the first payload off-loaded from the Shenzhou 8 capsule at the landing site and sent to the laboratory in Beijing within a few hours.

Besides the dummies and the SIMBOX, there were also many other payloads and piggyback materials inside the Shenzhou 8, some of which are very interesting and some of which have very Chinese characteristics. These materials consisted of 123 items in 8 categories, including:

- The Dream Chip, a flash memory chip containing 42,891 statements collected from the Chinese public.
- A tomato growth experiment. It was successful with a flower blossoming in space.
- An embroidered portrait and a paint work of Qian Xuesen, the father of the Chinese space programme who died in 2009.
- Other artistic works, including drawings done by children and a 2 m long embroidered scenic landscape of Hunan province.
- Philatelic covers, a Chinese space tradition on recoverable satellites and Shenzhou.
- Signed flags of Chinese universities.
- 300 grams of plant seeds, another Chinese space tradition.

The Shenzhou 8 orbital module has no capability for independent flight, as it was not equipped with solar panels and other necessary facilities. The orbital module will re-enter the atmosphere soon in a natural decay. Chinese media did not report any specific payloads in the orbital module unrelated to the docking system.

A Turning Point

The successful rendezvous and docking paves the way for the planned manned docking in 2012. According to the original plan, Shenzhou 10 will be manned and the result of the Shenzhou 8 mission will decide whether the Shenzhou 9 carries a crew. Many recent reports on Chinese media indicate that the Shenzhou 9, to be launched in the first half of 2011, has been already decided to be manned. And the Shenzhou 10 in later 2011 will carry a female taikonaut. It will be the first time China launches two manned mission within one year. Considering the plan which recently revealed that China will perform 20 manned space missions by 2020, it is likely that an averagely twice-a-year launch rate could be achieved in the coming years of this decade. Undoubtedly, 2012 will be a turning point for the Chinese manned space programme marking the end of the slow-paced activities in the last two decades and the start of a new era focused on space laboratory and space stations on a scale comparable to the Russian manned space programme.

Being manned, the Shenzhou 9 and 10 missions are expected to perform more tasks than the unmanned Shenzhou 8. The taikonauts on Shenzhou 9 and 10 will open the hatch and enter Tiangong 1 and will start their space station experience, making history. It is expected to extend the duration of the

Timeline: Landing
(Beijing Time)

- **16:59, 15 Novermber:** The Tiangong 1 – Shenzhou 8 complex turned through 180 degrees, established the "normal flight attitude" and was ready for Shenzhou 8's final undocking and return to the Earth.
- **18:30, 16 November:** Shenzhou 8 undocked from the Tiangong 1.
- **18:44, 17 November:** First attitude adjustment, turning the spacecraft through 90 degrees.
- **18:45, 17 November:** Orbital module separation.
- **18:45, 17 November:** Second attitude adjustment, turning the spacecraft through another 90 degrees.
- **18:46, 17 November:** Beginning of retrofire sequence.
- **18:49, 17 November:** End of retrofire.
- **19:07, 17 November:** Propulsion module separation.
- **19:12, 17 November:** Shenzhou 8 entered the blackout zone.
- **19:17, 17 November:** Re-established radio contact after the blackout zone.
- **19:19, 17 November:** Jettison of the cover of the parachute compartment followed by deployment of the pilot chute, the drogue chute, the extraction chute, and finally the main chute.
- **19:22, 17 November:** Jettison of the heat shield.
- **19:32:30, 17 November:** Landing at 111.298°E, 42.239°N. Then the hatch was opened and the SIMBOX payload was taken out.

docked configuration mission by mission. It is also reasonable to speculate that manual docking will be tested, though unlikely for the first manned docking. There are reports that the crew selected for the upcoming manned docking mission are under training with a focus on manual docking. For those watching the Chinese space programme since a long time, another exiting moment is definitely coming soon!

(Chen Lan, Dave Chen)

Please, go to the Gallery for more photos.

left: Orbital module separation.
credit: CCTV

right: Propulsion module separation.
credit: CCTV

left: Re-entry seen from ground.
credit: CCTV

right: Main parachute deployed.
credit: CCTV

When Two Became One

As media both inside and outside China have reported, the Shenzhou 8 docking mission with Tiangong 1 towards the end of 2011 was a full success[1]. What does success mean in this context? What are the direct consequences for China's ambitions in space? And could this have any implications for international cooperation/collaboration in the future?

A Tricky Process

It was American astronauts Neil Armstrong and Dave Scott that performed the first rendezvous and docking (RVD) between two spacecraft on 16 March 1966. The RVD was carried out manually with Armstrong and Scott in a Gemini spacecraft (as the chaser vehicle), and an unmanned Agena as the target vehicle. About 17 months later, on 30 October 1967, the first automatic RVD took place between two Soviet vehicles, Cosmos 186 and Cosmos 188.

The Rendezvous & Docking/Berthing process is one of the most difficult challenges in space flight, whether it is performed in a manned or an unmanned mission. It consists of a series of orbital manoeuvres and controlled trajectories to bring an active spacecraft, termed the "chaser" vehicle in close proximity to a passive, or "target" vehicle. In the first Chinese RVD scenario of November 2011, Tiangong 1 was the target vehicle for the unmanned Shenzhou 8 chaser vehicle.

The primary objective of the rendezvous part of the process is to ensure that the parameters of position, velocity, attitude and angular rates are within certain specified limits so that the docking (RVD) or berthing (RVB) - i.e. the mating of the two spacecraft - may be accomplished.

Definitions of docking and berthing[2]:

- **Docking (RVD):** In this case it is the Guidance, Navigation and Control (GNC) system of the chaser spacecraft that controls the vehicle state parameters required for entry into the docking interfaces of the target vehicle and for capture.
- **Berthing (RVB):** In this case the GNC system of the chaser spacecraft delivers the vehicle (nominally at zero relative velocity and angular rate change) to a location quite close to the target vehicle. A manipulator (i.e. robotic arm) normally located on the target vehicle then grapples the chaser vehicle, and transfers it to the required berthing port on the target vehicle.

The Shenzhou 8/Tiangong 1 scenario was an RVD in which the GNC system of the Shenzhou 8 chaser vehicle controlled the complete process through to capture and structural connection. Following confirmation of the successful docking, the GNC system of Tiangong 1 then took over control of the combined configuration, and remained in control until the repeat of the RVD procedure 12 days later, but on the second occasion under sunlight conditions while the first RVD occurred in darkness. As both RVD procedures appeared to achieve full success, it may well be that the next two RVD missions, Shenzhou 9 and Shenzhou 10, both scheduled for this year will be manned missions.

RVD/B on the ISS

One example of RVD in relation to the International Space Station (ISS) would be the automated docking of the European Space Agency's Automated Transfer Vehicle (ATV) "Jules Verne" to the ISS on 3 April 2008 [Figure 1]. Note that in the case of the ATV however, the docking mechanism employed, is the Russian "probe and drogue" type, as all ATV missions dock to the rear of the Zvezda module on the Russian Orbital Segment of the ISS.

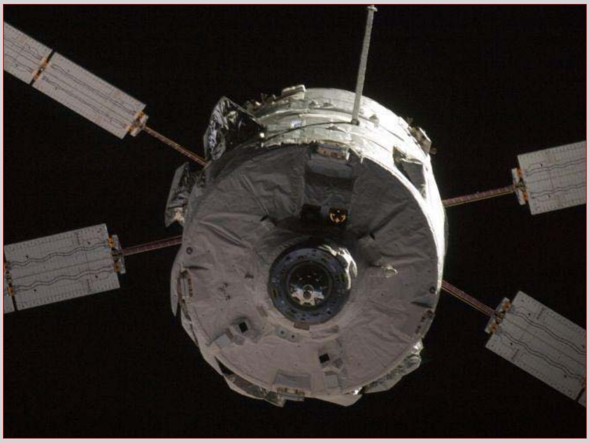
Another RVD example would be the docking of the Space Shuttle to the ISS. The active part of an APAS-95(89) docking mechanism is on the Shuttle, and the passive part on the ISS (on the Pressurised Mating Adapter – PMA).

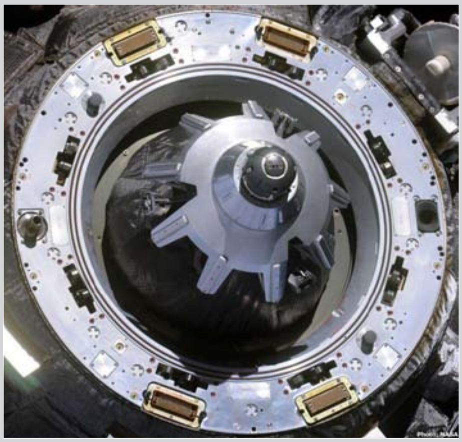
An example of an RVB mission would be the delivery of the unmanned Japanese H-II Transfer Vehicle (HTV) to the ISS [Figure 6].

Generic Rendezvous Mission Phases

The RVD/B process may be divided into several individual phases[2], i.e.:

1. **Launch and Orbit Insertion:** This phase is aimed at delivering the chaser spacecraft into a stable orbit in the orbital plane of the target spacecraft.
2. **Chasing:** Usually at the start of this phase, the chaser spacecraft is in a lower orbit, and at an arbitrary phase angle behind the target spacecraft. The objective of this phase is thus to reduce the phase angle between the chaser and target vehicles, and to acquire an "aim point" (close to or on the orbit of the target vehicle); from where the far range rendezvous operations may be initiated.
3. **Far Range Rendezvous:** Sometimes referred to as "homing", the intention in this phase is to reduce any residual trajectory dispersions, i.e. the achievement of position, velocity and angular rate conditions necessary for the initiation of the close range rendezvous phase.
4. **Close Range Rendezvous:** Normally divided into a preparatory closing phase and a final approach phase, aimed at achieving the required mating conditions.
5. **Mating – Docking (or Berthing):** This phase is initiated





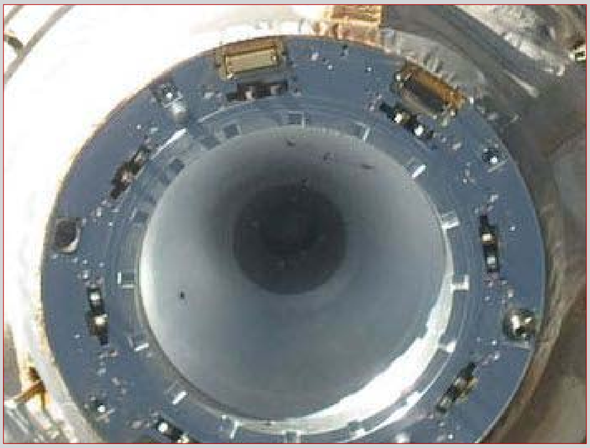


Figure 1 (top left):
ATV Jules Verne approaching the ISS.
credit: NASA

Figure 2 (top right): Close-up of the Russian probe-and-drogue active docking system. credit: NASA

Figure 3 (left): Close-up of the Russian probe-and-drogue passive docking system. credit: NASA

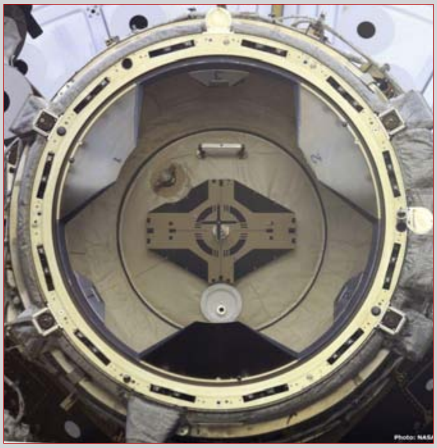


Figure 4 (top left): Close-up of the Russian APAS-95 (89) active docking system. credit: NASA
Figure 5 (top right): Close-up of the Russian APAS-95 (89) passive docking system. credit: NASA
Figure 6 (right): Berthing H-II Transfer Vehicle (HTV) to the ISS. credit: NASA

once the chaser spacecraft has delivered the capture interfaces of the chaser into the reception range of those of the target vehicle within the constraints of:

a. Approach velocity, lateral alignment, angular alignment and lateral and angular rates for RVD.

b. Position and attitude accuracy, residual linear and angular rates for RVB.

So Why Bother?

If RVD or RVB is such a difficult thing to do, why bother at all?

Since 1998 until today RVD/B has proven to be a key operational technology in the day-to-day operations of the ISS, and will continue to be so throughout the now extended ISS lifetime up to 2020 and maybe even beyond. Both manned (i.e. Space Shuttle, Soyuz) and unmanned (i.e. Progress, Automated Transfer Vehicle - ATV, H-II Transfer Vehicle - HTV) vehicles have been involved in RVD/B operations.

Prior to the ISS, the success of both Russian (i.e. Salyut space laboratories and Mir station) and US American (i.e. Apollo, Skylab) space activities involved considerable use of RVD technologies and techniques. Russia and the US have additionally also carried out joint RVD/B activities in 1975 with the Apollo Soyuz Test Project (ASTP), and again in the 1990s with the docking of the Space Shuttle with the Mir orbital complex.

RVD/B technologies and techniques are thus critical ones to master in order to implement space missions that involve establishing some kind of "assembly" in outer space, no matter whether it occurs in Low Earth Orbit (LEO) or beyond. This "assembly" can be as straightforward as two spacecraft coming together for a short period of time, as in the case of the Apollo Soyuz Test Project, or as complex as the assembly of the complete configuration of the ISS.

With a mastery of RVD/B technology China can implement the building of its own "large" space station, as it has stated its intention to do so by the year 2020. In addition, it could in principle, also implement its own human mission to the Moon or Mars, as most of the Design Reference Missions - DRMs, addressing such type of missions produced by space agencies around the world involve the in-space assembly of elements required for the mission. As China itself admits though, demonstration of a capability and full mastery are two completely distinct things. However, building on the success of the Shenzhou 8 mission through the two planned missions of Shenzhou 9 and Shenzhou 10 should allow China to move closer to the level of "mastery" required to implement its own large space station towards the end of this decade as planned. Shenzhou 8 demonstrated unmanned RVD, and it is highly likely that either or both Shenzhou 9 and Shenzhou 10 will demonstrate manual RVD following the nominal performance of Shenzhou 8.

Shenzhou 8/Tiangong 1 Docking Summary

Observing the live transmission of the final stages of the docking[3], it was noted that there were a number of what were termed "Parking Points - PPs" involved in the mission. As the name suggests, these were points on the approach trajectories at which the chaser vehicle Shenzhou 8 paused for a period of time to verify that it was safe to proceed with the next step in the process. It appeared from the transmission that there were at least five of these PPs, at distances of 52 km, 5 km, 400 m, 140 m and 30 m respectively from the Tiangong 1 target vehicle.

The time taken to go from the 400 m PP to the 140 m PP was approximately 11 minutes. The next PP was at 30 m, and Shenzhou 8 stopped here again for a few minutes to verify that the docking parameters were within the allowed limits. On certain occasions, the animation visible on the large screen of the mission control centre in Beijing showed the firings of the thrusters on Shenzhou 8 in real time, to bring the vehicle back onto the correct approach path to Tiangong 1. It then took about 3 minutes to go from the 30 m PP to capture. Concerning the mating phase itself, there were four procedures involved, i.e.:

1. Capture.
2. Absorption of impact energy of the active vehicle by the docking mechanism.
3. Forced alignment of the two vehicles.
4. A pull-back of the docking ring to achieve an airtight connection between the two vehicles. This "pull-back" is achieved through a series of twelve hooks, which are present on both vehicles, i.e. system level redundancy. The time to achieve an airtight connection was stated to be 260 seconds. Each of the twelve hooks has a pulling capability of 3 tonnes, so 36 tonnes in all to tighten the rubber ring seal of the docking mechanism.

On this occasion, the hatch between the two vehicles was not opened as there were no crew present on either vehicle, but this will occur on the next crewed mission to Tiangong 1. The first docking was performed in darkness (within the umbra of the Earth's shadow) to avoid any possible perturbations due to sunlight interfering with the automated docking process. The two vehicles became one for a period of 12 days, at which time they separated again for a second docking attempt, this time in sunlight. Here Shenzhou 8 moved away to the 140 m PP location, moved to the 30 m location and then docked again. The distance between the two vehicles was measured using a microwave radar and a laser radar, and they started measuring their relative distance when they were 52 km apart.

International Docking Standard

It was announced[4] in October 2010 that the Partners of the ISS Programme (through the Multilateral Coordination Board) had agreed upon a new standard for docking systems – an International Docking System Standard (IDSS)[5].

So an interesting question to now ask is if the Chinese docking mechanism is compatible with this newly defined international standard? Indeed the question was already raised by James Oberg as early as 2004 in a statement to the US Senate[6], where he notes "Although China is primarily interested in docking its spacecraft with its own small space stations, the decision to employ the APAS-89 mechanism would allow Shenzhou to link with both the space shuttles and the ISS".

Almost 40 years earlier to the day, in October 1970, the minutes-of-meeting[7] or "protocol" in Russian, of one of the first meetings between the Russian and US teams cooperating on the ASTP stated that a major goal of the ASTP was to design mechanisms that would serve as a basis for the future spacecraft and orbital stations of different space-faring nations – in short, to develop an international standard. During this meeting it was concluded that all existing docking mechanisms had two major disadvantages, i.e.:

1. A probe mechanism can only dock with a drogue mechanism.
2. Probe and drogue docking mechanism designs "blocked" the transfer tunnel between the two spacecraft, and so needed to be removed to allow crew access.

The APAS approach, using identical mechanisms (androgynous) on both vehicles, but with one active and one passive, and moving the docking mechanism to the perimeter (peripheral) thus became the preferred solution for the ASTP.

The abbreviation APAS stands for "Androgynous Peripheral Assembly System". There are several variations of what APAS means, but this is the original Russian definition[7] generated by Lev B. Vilnitskiy, who worked with the key designer of all Russian APAS systems, Vladimir Syromiatnikov.

The first APAS was developed jointly by Russia and the US for the Apollo-Soyuz Test Project, and was termed APAS-75. The number 75 is derived from the year of the ASTP mission, 1975. In his book[7], Syromiatnikov writes that he was often asked whose idea was taken as the basis for the APAS-75, and notes: "There is no simple answer to this question.", as although the overall Russian APAS concept was indeed initially taken, the US also contributed significantly to the final design. So APAS-75 became a joint Russian-US product. However, Syromiatnikov also notes that for various other reasons, he always felt that it was more "ours" than "theirs", i.e. more Russian than US.

The APAS-75 design was subsequently significantly updated by the Russians (reduction of outside diameter from 2,030 mm to 1,550 mm, and alignment petals facing inward rather than outward) to a so-called APAS-89 which was originally intended for the docking of the Russian Buran vehicle to the Mir space station, but was used on the Kristall module on Mir and on the Mir Docking Module – an element located between Mir and a visiting Space Shuttle. The number 89 again refers to the year it was introduced.

The APAS-95 is essentially the same as APAS-89, only slightly modified for use on the ISS for docking of the Space Shuttle.

The new International Docking Standard builds upon the successful APAS-75, -89 and -95 genealogy in that the proposed standard is fully androgynous.

IDSS Interface Requirements Document

The Interface Requirements Document (IRD) for the International Docking System Standard, downloadable from its website, states its primary purpose as being "to provide basic common design parameters to allow developers to independently design compatible docking systems". The IRD requirement definitions allow support of the following missions:

1. Visits to the ISS.
2. Exploration of the Moon.
3. Crew rescue.
4. Various international cooperative missions.

The IRD states that some docking features (e.g. sensors, separation system) are not standardised, and as such may be independently designed. It is also noted that resource umbilicals (e.g. power, data, water) have not yet been standardised.

The standard may be used by vehicles in the mass range of 5 - 8 tonnes and 8 - 25 tonnes, and allow the docking of these vehicles with large space complexes in the mass range 100 - 375 tonnes; and to Earth departure stages in the mass range 33 - 170 tonnes.

Key aspects of the International Standard:

- The IDSS interface is fully androgynous about one axis.
- During docking one interface must be active and one passive.
- Docking occurs in two stages, the first performed by a Soft Capture System (SCS), and the second by a Hard Capture System (HCS).
- The active part of the docking mechanism stabilises the joined spacecraft during capture and pulls the two spacecraft together.
- A Hard Capture System (HCS) then completes structural latching and sealing, and creates the pressurised tunnel to allow crew transfer between the vehicles.

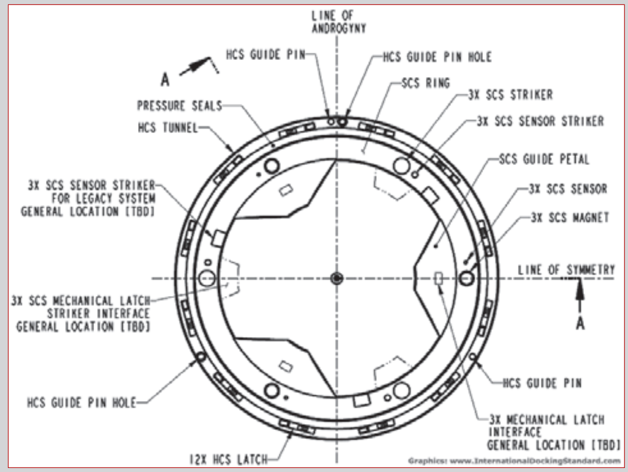
- The active interface controls the soft capture function and all sequences of docking up until hard capture.
- The SCS should provide an 800 mm transfer tunnel in its mated configuration.
- The definition of the mating interfaces are summarised in Figures 7 through 9.

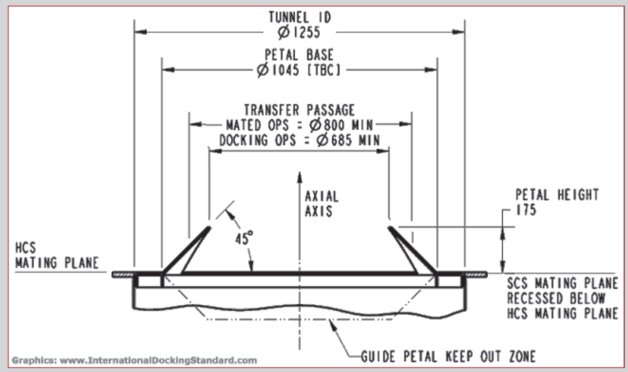
From the images shown in figures 10 and 11 which were the "best" images we could locate to date, it would appear that the docking mechanism used in the Shenzhou 8/Tiangong 1 docking is indeed very similar to the APAS-89. However, clearer images that would allow a graphical overlay of the IDS standard to confirm that at least from a mechanical viewpoint, the Chinese system would be IDSS compatible are needed. But at first sight, compatibility cannot be excluded.

The IRD also recommends a set of initial contact conditions:

Initial Condition	Limiting Value
Closing (axial) rate	0.05 to 0.10 m/sec
Lateral (radial) rate	0.04 m/sec
Pitch/Yaw rate	0.15 deg/sec (vector sum of pitch/yaw rate)
Roll rate	0.40 deg/sec
Lateral (radial) misalignment	0.11 m
Pitch/Yaw misalignment	5.0 deg (vector sum of pitch/yaw)
Notes: 1. Values are 3σ maxima and shall apply simultaneously in a statistically appropriate manner, provided that the reach capability of the internal petals is not exceeded. 2. Closing (axial) rate may be increased to achieve necessary capture performance. 3. Post contact thrust may be used to achieve necessary capture performance. 4. Lateral (radial) rate limit includes combined lateral and rotational rates of both vehicles. 5. Lateral misalignment is defined as the minimum distance between the center of the active soft capture ring and the longitudinal axis of the passive soft capture ring at the moment of first contact between the guide petals.	

Table 1: Initial contact conditions.





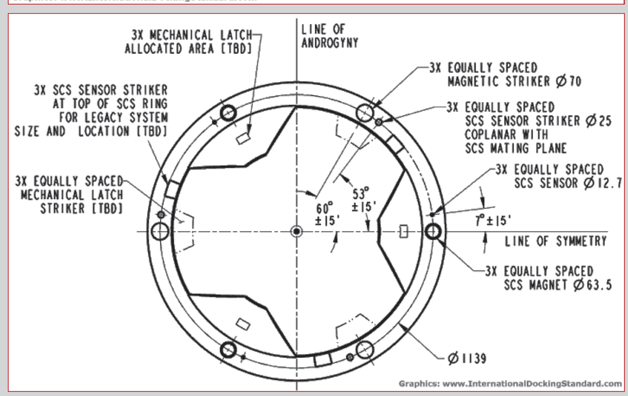


Figure 7 (top): Androgynous docking interface – axial view. credit: www.InternationalDockingStandard.com

Figure 8 (middle): Androgynous docking interface – cross section (though mid-plane of two petals). credit: www.InternationalDockingStandard.com

Figure 9 (bottom): SCS interface – capture system. credit: www.InternationalDockingStandard.com

Key Parameters of the Shenzhou 8/Tiangong 1 Docking

For Shenzhou 8 to achieve successful capture by Tiangong 1, three key requirements are known, i.e.:

1. The relative velocity needs to be in the range 5 cm/s to 35 cm/s, and in fact was noted to be nominally 20 cm/s.
2. The lateral deviation, that is essentially the distance between the centre of the circular docking mechanism on Shenzhou 8 as compared to the centre of the circular docking mechanism on Tiangong 1 should be no more than 18 cm, as the two vehicles come into contact.
3. The angular error in pitch and yaw should be no more than 4 degrees.

Based on the three key requirements for the Shenzhou 8/Tiangong 1 docking, the Chinese docking system would appear to be compliant at least with respect to relative velocity, lateral alignment and pitch/yaw alignment.

Conclusions

Concerning future human spaceflight, China has successfully accomplished their first space rendezvous and docking test. The demonstration of this particularly complex space technology augurs well for the future Shenzhou 9 and Shenzhou 10 missions, either or both of which could involve a demonstration of manual docking. Video animation[8] of the planned 2020 space station by China available on the web, also shows that two of the modules of this station will be delivered using rendezvous and berthing (RVB). A robotic arm on the core module of the station will move the modules to their final location, in similarity to the delivery of the HTV to the ISS.

Even though significant progress has been made by China up to and including this docking demonstration, it also acknowledges that its overall level of scientific technologies (especially indigenous innovation capabilities) still lag far behind world-leading levels[9]. So success is acknowledged, but so is the full extent of the road ahead, but with such an attitude, it is difficult to imagine that China will not successfully conclude its three-step manned space programme.

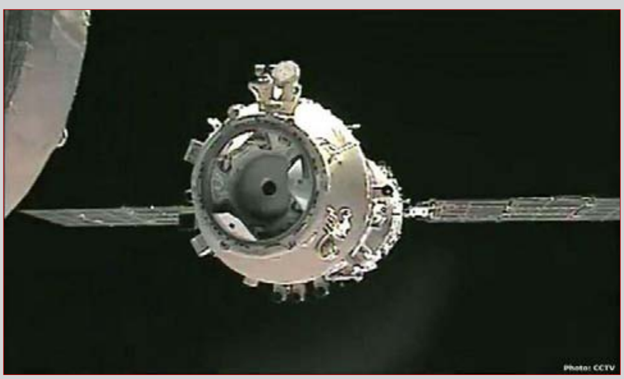


Figure 10 (top): Chinese docking mechanism – active segment. credit: CCTV
Figure 11 (bottom): Chinese docking mechanism – passive segment. credit: CMSEO

In a recent article[10], Mr. Zhu Zhisong, the head of SAST, in an interview with our colleague Chen Lan, stated that "The Chinese docking mechanism used by Tiangong 1 and Shenzhou 8/9/10 docking is fully compatible with the international standard.", although he did not reveal whether the mechanism was of the Russian APAS-89 design or not.

From the brief review made in this article, and taking the comment by Mr. Zhu Zhisong at face value, it would appear that the docking mechanism developed by China could indeed be "fully compatible" with the emerging international standard, thus opening the door for future cooperative missions with other space-faring nations. A possibility often discussed is the inclusion of China as a partner in the ISS, but there are also possibilities for cooperation on lunar exploration and in the future, on Mars exploration.

On 21 December 2011, ESA published a document[11] by the ESA Director General Mr. Jean-Jacques Dordain. The document contains an analysis by Mr. Dordain of ESA's position as it is today, how it plans to meet the challenges of the future, and the importance of the organisation in shaping Europe's future.

This document specifically mentions that ESA could play a unique role in extending the ISS partnership "to other space powers willing to join and to bring their own capabilities and their own culture.", as it represents a successful model of cooperation among 19 countries currently, on an optional basis. It goes on to suggest that such an extension could be organised in steps aimed at building up the partnership without necessarily involving all of the current International Partners of the ISS Programme. Further, in a section related to the development of enabling technologies, it is stated that some key technologies should be developed and associated to demonstration missions, and one example given is the "... docking a European vehicle to the Chinese space station…".

During a visit to China in October 2010, Charles Bolden NASA Administrator, met with the Head of the Chinese Human Spaceflight Programme. Bolden reported briefly on this meeting in a speech[12] at NASA Marshall in November 2010. Part of the statement made by the Chinese Three-Star General went as follows, "… we don't need the United States, and you don't need us. But the potential, if we choose to work together, is incredible". Mr. Bolden considered this "spoke volumes". It is certainly true that China can indeed go it alone, but it has also clearly stated that it is open to international cooperation in general, and specifically in relation to its future 2020 space station. Clearly there is a will, it only remains to find a way - and the potential could indeed be incredible!

(William Carey)

References

1. China announces first space docking mission a full success:
http://news.xinhuanet.com/english2010/china/201111/17/c_131253680.htm.

2. Automated Rendezvous and Docking of Spacecraft. Wigbert Fehse. Cambridge University Press, 2003.

3. Live coverage of Shenzhou 8 and Tiangong 1 docking. Eagle 3x8. http://vimeo.com/31514848.

4. New international standard for spacecraft docking:
http://www.esa.int/esaCP/SEMODMYOBFG_index_0.html.

5. International Docking Standard website:
http://internationaldockingstandard.com/index.html.

6. Testimony of James Oberg: Senate Science, Technology, and Space Hearing: International Space Exploration Program. 27 April 2004.

7. 100 Stories About Docking and other adventures in space. Volume 1 - Twenty Years Back. Vladimir Syromiatnikov. Moscow. Universitetskaya kniga, 2005.

8. Video animation of future Chinese space station:
http://www.youtube.com/watch?v=1GICFt6Phs&feature=related.

9. China celebrates success of space docking mission:
http://news.xinhuanet.com/english/china/2011-12/16/c_131309987.htm.

10. Touch the Chinese Space Programme in Three Days. Chen Lan. Go Taikonauts!, Issue 2, October 2011.

11. Agenda 2015: A Document by the ESA Director General. ESA BR-303. 21 December 2011.

12. Speech by Charles Bolden at NASA MSFC on 16 November 2010.

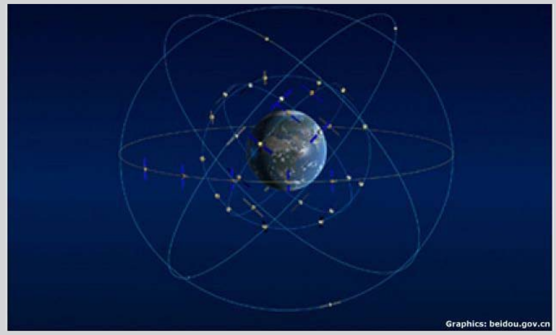
Harmonious Interference Dissolves Galileo "Misunderstandings"

People often like to talk about the "new space race to the Moon". But in the background, almost un-noticed by the public, another more tangible race is taking place. It is a highly strategic race - to establish a globally dominating satellite navigation system.

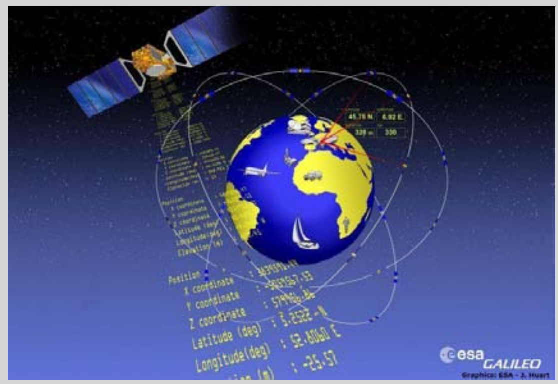
Once again, Europe is dreaming big dreams. Europe wants to become emancipated; it would like to prevent being "a technological vassal of the USA", as French President Jacques Chirac is quoted as saying. This time it is about satellite navigation. The starting point of this development goes back to the end of the nineties. The US-American military Global Positioning System - GPS has always been available for civilian users. This has made it the only operational civil service worldwide. However, until April 2000 the signal for the civil service was artificially jammed, called "selective availability – SA", to prevent a too-high accuracy for non-military use. As a consequence, the Commissioners of the European Commission began dreaming of an independent European civilian system with unprecedented accuracy which could serve countless business models and could gain users from around the world. They did not even try to challenge the military GPS, anticipating that this would never work out for Europe as a member of NATO, the trans-Atlantic military alliance, inseparably connected with GPS. Based on these considerations, a civilian concept counter to the military GPS began to take shape.

The European Galileo navigation system was initially planned to be more precise, faster and commercially more versatile. The US did not like it and said so. Why would Europe need a satellite navigation system of its own? GPS is for free and available to everyone. The world does not need duplication in this field. Next to commercial concerns, the US was not pleased about sharing certain frequencies of their own system with the new Galileo system. The Spanish Commissioner for Transport and Energy, confirmed after requests by the European media whether there was pressure from the US: "There was a letter and there was pressure from the side of the United States. The American pressure against the Galileo project has increased since the 11 September." Media revealed that the letter, the Commissioner was referring to, was sent on 1 December 2001 by US Vice Secretary of State, Paul Wolfowitz to his European counterparts within NATO.

Additionally, initial financing problems threatened the project even before it would come to life, but eventually in May 2003, the European Galileo satellite navigation system project was agreed. Two-thirds of the by that time estimated total cost of 3.6 Billion Euro would be financed with the help of Public Private Partnerships between the European Commission and European industry. But European industry did not believe in the over-optimistic business models drafted by the European administrators. In parallel, the European



Beidou-2/Compass constellation. credit: Beidou.gov.cn



Developed by ESA in collaboration with the European Union, Galileo is a complete civil system, designed to provide the world in general and Europeans in particular with an accurate, secure and certified satellite positioning system. credit: ESA

Soyuz VS01, the first Soyuz flight from Europe's Spaceport in French Guiana, lifted-off on 21 October 2011. The rocket carried the first two satellites of Europe's Galileo navigation system into orbit. credit: ESA/Corvaja

On 10 October 2011, the combined Galileo IOV satellites plus their supporting dispenser were mated to the Fregat-MT upper stage that will transport them into their final 23,222 km orbit. credit: ESA/CNES/Arianespace

Commission had to face a national tug-of-war by several Member States of the European Union, as to who would get the biggest chunk out of the orders for building the satellites, building the ground infrastructure and the locations for the control centres.

From the beginning, the Commissioners in Brussels liked the idea of getting China on board. Although, at this time, the Middle Kingdom had already put into action the setting-up of its own satellite navigation test system, both sides still decided to go for cooperation in that field.

Formal negotiations between China and Europe started on 28 March 2003. After two rounds of talks the two partners finalised a draft agreement on 18 September 2003 that paved the way for China's active participation in the Galileo programme. This agreement was signed at the 6th EU-China Summit on 30 October 2003 in Beijing.

On 19 September 2003, the China-Europe Global Navigation Satellite System Technical Training and Co-operation Centre - CENC was inaugurated on the estate of Beijing's Zhongguancun Hi-Tech Zone. The centre serves as a focal point for all activities on Galileo in China and is promoting industrial cooperation. The training centre is the result of joint efforts by the Chinese Ministry of Science and Technology, the Chinese Remote Sensing Centre, the European Commission and the European Space Agency. With the beginning of 2006, the European Space Agency supported the work of the centre also with permanent staff. Although this centre saw its ups-and-downs in its work, the institute still survives until today.

By the end of 2003 and early 2004 experts from Europe and China worked together on joint satellite navigation demonstrations. Chinese and European engineers used a temporary regional ground network of European Geostationary Navigation Overlay Service - EGNOS stations what allowed dynamic tests on the Yangtze river. The tests showed very good availability and accuracy of the EGNOS test-bed signals and that satellite navigation could improve safety for waterway navigation in China. The tests also showed the truly global nature of Galileo.

In April 2004, preparation works for the participation in the bidding process for The Galileo Search and Rescue Transponder - SART project started in the Institute 504 of the Chinese Academy of Space Technology - CAST. The search and rescue transponders and satellite laser retro-reflectors finally became a Chinese contribution to the Galileo In-Orbit Validation (IOV) satellites.

Officially, China joined the Galileo project after signing an agreement document with the European Union on 9 October 2004 in Beijing, and pledged 200 Million Euros for the project out of which 70 Million Euros were invested in technological research of the Galileo System, and the remaining 130 Million Euros were planned for space and ground facilities. "The partnership with China is good news and paves the way for future other bilateral and regional agreements which are of mutual benefit.", said Loyola de Palacio, by then European Commission Vice-President in charge of Transport and Energy. "The EU-China agreement will do more than secure a promising future for Galileo and European business interests: it opens the way for China's participation in the Galileo Joint Undertaking and a substantial financial stake-holding of some 200 million Euro.", she explained and added: "China will help Galileo to become the major world infrastructure for the growing market for location services."

Clearly, Europe had the conquest of the Chinese market and the limitation of US-American dominance in this field in mind. China wanted to take the opportunity to learn from European technology and system management.

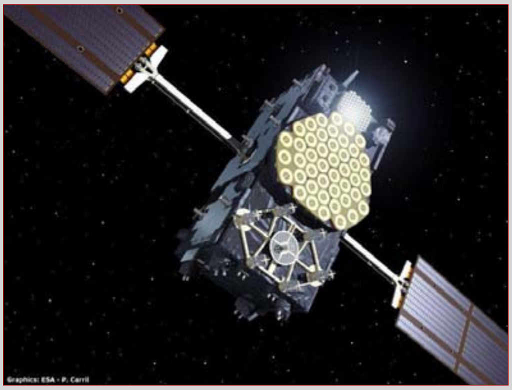
Back in 2004, the European Commission predicted that by 2020 the Galileo system will have generated an income of more than 10 Billion Euros (12.2 Billion US-Dollar), creating thousands of jobs. Chinese experts expected the project to bring 260 Billion Yuan (32.1 Billion US-Dollar) of economic benefit to China's satellite navigation industry by 2020.

This all sounded pretty attractive, but unfortunately Galileo faced another crisis when the political pressure from Washington increased again.

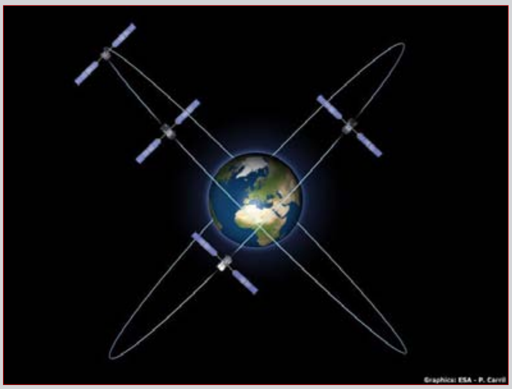
In October 2004, just after China had officially joined the Galileo programme, a report in the British media revealed that during a conference in London, the European delegation did not agree to a demand by the US delegation that Europe should jam or switch-off the Galileo signal in case it would be used against the US. A US delegate "made it clear that they would attempt what they called reversible action, but, if necessary, they would use irreversible action." Some media translated this to mean: if China is using your Galileo service during an attack on the US we will shoot down your European satellite.

In the meantime, the Chinese side made further progress in building its administrative infrastructure for its Galileo cooperation with Europe. In December 2004, China Galileo Industries Ltd. (CGI), a state company owned by China Aerospace Science and Technology Corporation, China Electronics Technology Group Corporation, China Satcom and China Academy of Space Technology, was formed to execute China's participation in the Galileo project. Shanghai Galileo Navigation Co., Ltd became the new shareholder in August 2005, which was the company expected to develop the chip for the Galileo terminals.

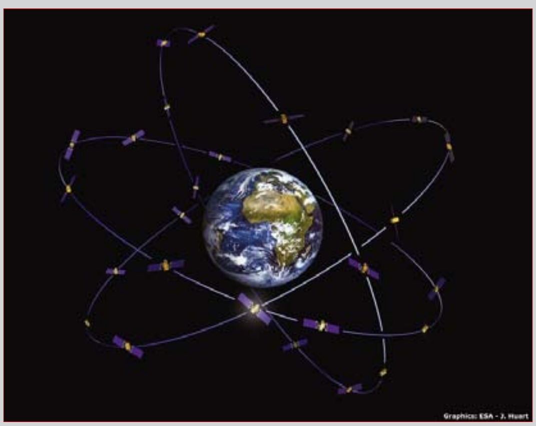
On 28 July 2005, a Chinese general contractor obtained three application projects for Galileo. The Galileo Joint Undertaking (GJU) endorsed China Galileo Industries (CGI) to develop the fishery application system, the location-based services and special ionospheric studies for the Galileo re-



left: Artist's impression of the Galileo IOV satellite. credit: ESA/Carril



right: The four Galileo In-Orbit Validation - IOV satellites in their orbits. credit: ESA/Carril



left: The Galileo constellation. Galileo is intended to enable Europe to become a major partner in the setting up of a civilian satellite service. This service will meet worldwide the multimodal navigation requirements and can operate either autonomously or together with other systems. Aeronautical, maritime and land mobile users will greatly benefit from the service. credit: ESA/Huart

right: European Commission Vice President Antonio Tajani (left) during the interview on 1 December 2011 together with translator Frau Christine Weise (middle) and the Editor in Chief of Raumfahrt Concret, Herr Uwe Schmaling (right). credit: RC/Sänger

gional augmentation services.

The first "China-Europe Galileo Cooperation Conference" took place on 1 and 2 June 2006 in Beijing.

Meanwhile, the European Commission was struggling to find sufficient budget for the financial outfitting of the programme. European industry still resisted in entering into a Public Private Partnership with the European Commission. Finally the EC had to act. By the end of 2007 almost overnight, funding of nearly 4 Billion Euro was found by diverting money from the competition budget and from funds for agriculture. This action paved the financial way for Galileo. However, the international squabbling had not yet finished. In the end, Europe's bold declarations about not becoming a vassal of the US did not really work out. It had to give in to the overriding US security concerns and put the cooperation with China on the Galileo project on ice.

Since then, China has given the assembly of its own operational system for satellite navigation national priority. And has done so with success. Since 2 December 2011, the 10th of its indigenous global navigation and positioning network of the second generation Beidou 2-Compass is in orbit.

Moreover, on 27 December 2011 Beidou 2-Compass started providing initial positioning, navigation and timing operational services to China and its surrounding areas. By the end of next year Beidou should cover most parts of the Asia Pacific territory and should be in a position to provide a global service by 2020 - something Europe is still dreaming of. Ran Chengqi, the Director of China Satellite Navigation System Office, said: "Test results show that Beidou has met the required technical standards, we have completed the migration from an experimental system to an operational one. This signals an official beginning of the application of Beidou system."

The accuracy of the Chinese second generation satellite navigation system will be 10 m what surprised the outsiders. This is exactly the same accuracy of the current GPS system, but would be superseded by the Galileo system with a 4 m resolution in the free accessible service and later on also by GPS, after up-graded satellites would be added to its fleet.

Originally, the full fleet of 30 Galileo satellites were planned to circle around Earth in 2013. As of today, there are two test satellites and two In-Orbit Validation IOV satellites in operation. The two IOV satellites launched 21 October 2011. Two more IOV satellites will be launched this year. It is hard to get an estimate when Galileo will provide service to the users and taxpayers in Europe. Only incorrigible optimists believe in 2020 for the full constellation, as stated by the European Commission.

Something else is also making Europeans unhappy: Unlike GPS and Galileo, the Chinese constellation of satellites is also relying on satellites in geostationary orbit. Such a formation requires higher signal strength. On top of that, the International Telecommunications Union ITU has given overlapping frequencies to China and Europe in the military spectrum. Maybe the ITU did not expect Europe to use Galileo for military service since the European Commission places emphasis on the civilian use of the system? To resolve the issue of overlapping signals, the common procedure in such a case would be to negotiate the actual implementation. However, unfortunately for Europe, China has its navigation system already in place, and can thus negotiate from a stronger position than the newcomer Galileo. Another "little" detail which may have backed China into a corner was that during the Munich Satellite Navigation Summit in March 2010, it became obvious, that the European Commission wanted to order the builder of the initial four IOV satellites to remove the already integrated Search and Rescue transponders provided by China. Jonathan Amos from the BBC reported after the October 2011 launch that the transponders were replaced with dummy payloads.

Understandable then that China would not be interested in showing much flexibility towards Europe in the overlay issue. Until recently, it looked as if China would not move an inch. Europe did not know if it should be more annoyed about the Chinese or about the US which refused to put political pressure on China. Maybe the US recalled the same situation with Europe a few years ago, or maybe was simply too busy with its own problems. Whatever it was, an unexpected turn came in November 2011.

In an interview with the German space magazine "Raumfahrt Concret", European Commission Vice President Antonio Tajani announced: "During the 3rd International Exploration Conference on 9 and 10 November in Lucca, Italy, we as the European Commission have signed an agreement with China which settled the controversy on the frequency overlap between our Galileo and the Chinese Compass system. With the signature from my side and the Chinese Minister we have revived the cooperation with China for the Galileo project. The document paves the way for a closer cooperation with China in the Galileo programme. In the run-up to the agreement, I have been in China, I have been meeting with the Chinese Minister in Rome and my Directorate General has been working hard, to clear up misunderstandings. I think, we are taking now the road leading into the future."

The term Beidou is a synonym for the Chinese name of the star formation called the Big Dipper in Europe (in the constellation of Ursa Major). This star formation has always been the signpost for finding the Pole Star. Within living memory, the Pole Star has been the star which has helped sailors to navigate the world's oceans. Compass, an invention by the Chinese, and the Pole Star are representative of navigation since antiquity. It is more than a metaphor to call the navigation system of today Beidou-Compass. It seems as if China is – step-by-step - in the middle of re-inventing itself. No matter with or without Galileo.

(Jacqueline Myrrhe)

See next page for the full text version of the EU-China agreement on Galileo, signed in November 2011 in Lucca.

EC-CHINA COOPERATION ON SPACE

ELEMENTS OF CONSENSUS

Following the Cooperation Agreement on Civil Global Navigation Satellite System (GNSS)-Galieo signed in 2003 and in view of the achievements of EU-China GNSS cooperation, further to the impulse given by Vice President Antonio Tajani and Minister Wan Gang, the Ministry of Science and Technology of China (MOST) and the European Commission (EC) have a common willingness to enhance cooperation in the field of Space and between their respective GNSS programmes and to work on a roadmap for follow-up cooperation. Both sides have reached the following consensus:

1. The EC, European Space Agency (ESA) and MOST have started discussions on a Space Dialogue. This will provide for an occasion to review annually issues of cooperation on Space science and technologies. An event to witness those progresses is regularly envisaged.

2. The EC and MOST agree to confirm the roadmap and sign a Memorandum of Understanding (MOU) on GNSS to promote the agreement signed in 2003. Both sides ensure that joint Galileo projects in IOV phase will be handled smoothly and bring mutual benefit for both sides. Both sides have resumed planning for GNSS-related projects. The progress of the cooperation will be annually monitored at a High-level Steering Committee meeting. Both sides will also encourage R&D activities integrating GNSS technologies with other Space- or ICT- science and technologies.

3. The EC and MOST will explore the possibility to strengthen cooperation under the theme "Space" of the 7th European Framework Program for research and development (R&D). EC will encourage Chinese enterprises to join FP7 with European corporations in the Space and GNSS field.

4. The EC and the COMPASS administration have proposed to each others solutions that are constructive for improvement of the compatibility of the two systems. The EC and China appreciated the work implemented by the Technical Working Group (TWG), which promoted the understanding of their respective system. Building on past successes in the framework of the International Telecommunication Union and the TWG, both sides agree to continue cooperation and mutual support in radio-spectrum issues, and work towards compatibility and interoperability of the two systems to provide better service for users of the world, especially the People's Republic of China and the European Union.

5. The China-Europe GNSS technology training and cooperation centre (CENC), which has been co-funded by both sides, has played an important role in the Galileo cooperation since 2003. The EC and MOST agree to resume supporting the activities of CENC and the implementation plan for 2012-2013 will be decided by the end of this year.

Initialed in Lucca, Italy, on 10th November, 2011.

Deputy DG ENTR **Paul Weissenberg** European Commission	Vice Minister **Cao Jianlin** Ministry of Science and Technology of China

The Glow of the Firefly Shines into the Future

Yinghuo 1 - a Martian Space Environment Exploration Orbiter

It could have been the cherry on the cake, the peak of a highly successful space year for China. The teeny-weeny Mars probe Yinghuo 1 is the first Chinese spacecraft for Mars exploration. The micro-satellite journeyed into space on 9 November 2011, only a few days after the launch of the unmanned Shenzhou 8 spacecraft heading for its docking mission with the earlier positioned Tiangong 1 docking target. In 2011, China also accumulated a record number of 19 (one of which failed) rocket launches, bypassing for the first time the US (18 launches - one failed) and ranking China as second to Russia with respect to annual space launches. And if this would not be good enough, right after Christmas, China started positioning service provision via its initial configuration of Beidou-Compass navigation satellites, and on the almost last day of the year China's State Council Information Office released the White Paper on China's space strategy for the next five years. 2011, the year when China celebrated the 100th birthday of Qian Xuesen, was the best year ever for China in space.

Launching a Huge Ambition

On 9 November 2011, at 00:16:03 Moscow Time, 04:16 Beijing time, 20:16 GMT, and 15:16 EST, the latter both times are corresponding with 8 November, a Zenit-2SB41.1 took-off from the Baikonur cosmodrome in Kazakhstan. The Ukraine-Russian two-stage rocket carrier had two passengers on board. The primary payload was the Russian Phobos-Grunt mission, an ambitious sample return mission from the Mars moon Phobos. The Russian space agency Roscosmos tried something that nobody has attempted before: landing on Mars moon Phobos, collecting within 17 minutes a soil sample of 200 grams and bringing it back to Earth until 2014. Russia's space community sincerely hoped to put themselves back into the supreme club of deep-space explorers. Along with Phobos-Grunt, the Chinese Yinghuo 1 hitch-hiked an interplanetary trip towards Mars. Compared with the ambitions of the main mission the major objective of the dwarf Yinghuo 1 was very modest: just the investigation of the space environment around the Red Planet and the interaction of the solar wind with that Martian space environment.

11 minutes after lift-off from Launch Pad 45 in Baikonur, the spacecraft separated from the second stage of the rocket. Phobos-Grunt reached its initial parking orbit with an apogee of 347 km and a perigee of 207 km. Shortly before completing the second orbit around Earth the main thrusters of the Fregat upper-stage should have been automatically fired twice for the insertion into a Mars-bound trajectory. This did not take place. Phobos-Grunt got stranded in low Earth orbit and at the same time Russian ground controllers failed to receive radio signals from their spacecraft. While Chinese officials declared their part of the mission lost on 17 November, the Russian space experts started a desperate day-and-night rescue campaign which they had to give up after a week-long search for any radio signals from the Mars exploration spacecraft.

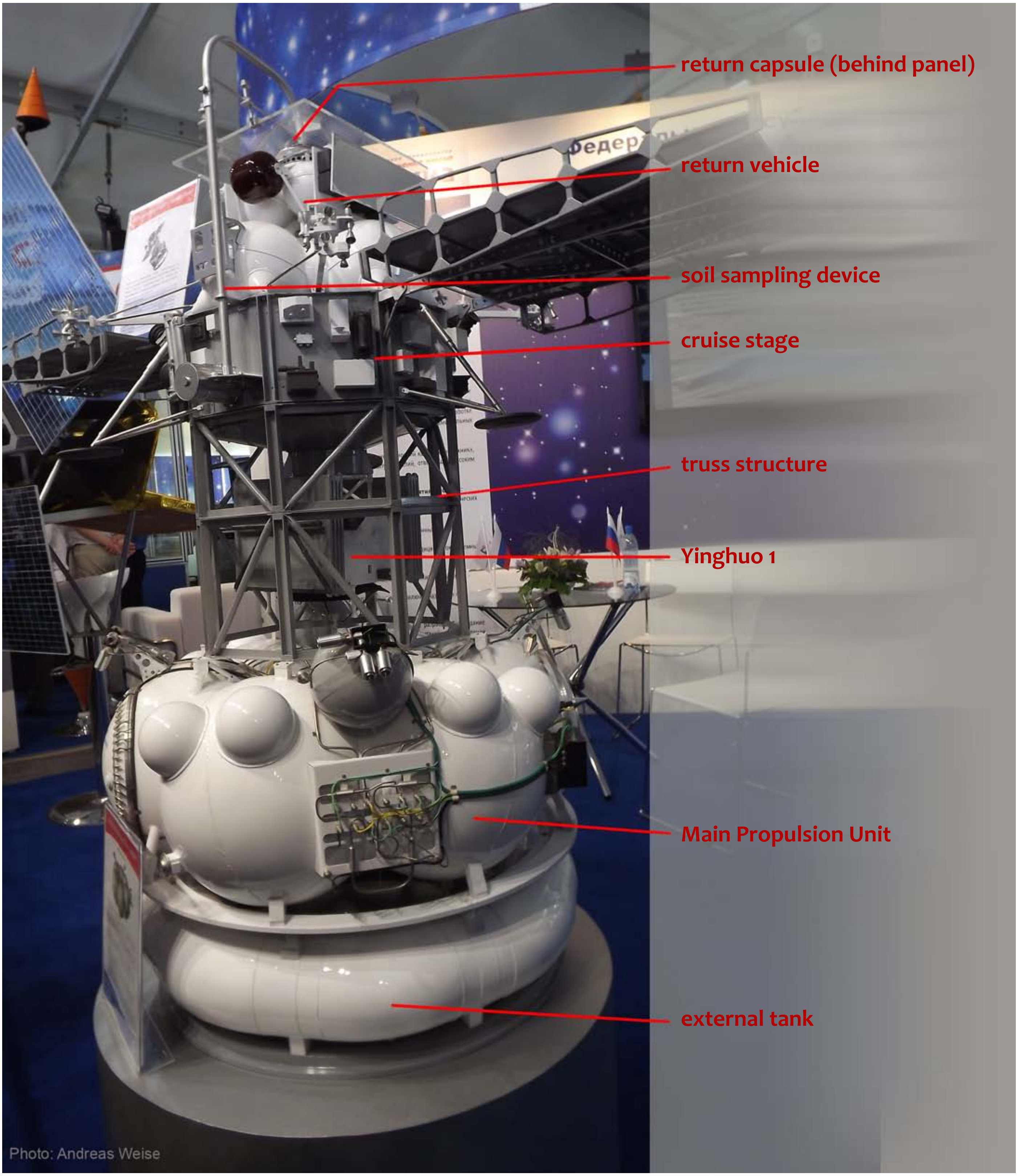
The First Mission Milestone

Yet, in the beginning, it all began with such promise. The Centre for Space Science and Applied Research (CSSAR, now NSSC) of the Chinese Academy of Sciences (CAS) first proposed a joint programme for the exploration of Mars to Russia. A high-level Sino-Russian handshake marked the starting point of China's first international cooperation for exploration.

On 26 March 2007, the Director of the China National Space Administration, Sun Laiyan, and the then Head of the Russian Space Agency, Anatoly Perminov, signed the 'Cooperative Agreement between the China National Space Administration and the Russian Space Agency on joint Chinese-Russian exploration of Mars.' The signature ceremony was witnessed by Chinese President Hu Jin-

The launch of the ambitious Phobos-Grunt mission with the Yinghuo 1 Mars satellite on board a Zenit rocket. credit: IKI

Graphic of the Phobos-Grunt spacecraft design. The Yinghuo 1 satellite is visible in the middle part of the Phobos-Grunt truss structure. credit: Lavochkin



A model of the Phobos-Grunt interplanetary spacecraft on display during the Moscow Airshow MAKS 2011. Yinghuo is nicely visible in the middle of the photo, integrated into the truss structure of Phobos-Grunt. credit: Andreas Weise tao and Russian President Vladimir Putin.

The participation in the Russian Phobos-Grunt project enabled China to design and construct its first Mars exploration mission at low cost. The cooperation with the Russians was intended to boost the Middle Kingdom's ability in deep space exploration, to raise the level of spacecraft design and development, and to promote the developments of planetary exploration as well as fundamental research in physics. On the other side of the equation was China which had maintained a strong momentum in its economic development over the past years. China would be in the position to support Russia economically while at the same time taking advantage of Russia's experience and cutting-edge technology for deep space exploration.

According to the agreement, China had to develop a sub-satellite, to be launched with the main probe Phobos-Grunt initially planned for 2009 and to be released into the Martian orbit 300 days into flight. The spacecraft construction on the Chinese side was the responsibility of the China Great Wall Industry Corporation - CGWIC, a subsidiary of China Aerospace Science & Technology Corporation - CASC. The Chinese part of the programme is administered by China National Space Administration, managed by CASC and executed by the Shanghai Satellite Engineering Institute (509th Institute) of the Shanghai Academy of Spaceflight Technology - SAST, also a subsidiary of CASC. Phobos-Grunt was built by the Russian space company Lavochkin Research and Production Association.

Part of the agreement was also the provision of a "Soil Preparation System" for the main Phobos-Grunt probe, built by the Hong Kong Polytechnic University – PolyU.

The 230-gram 'Soil Preparation System' is capable of grinding and sifting Phobos rock to the size of less than 1 millimetre for in-situ analysis by the Phobos-Grunt lander. The tool would be mounted at the end of the remote-controlled manipulator, together with a miniature spectrometer and a camera. The Hong Kong team has a far-reaching experience in space engineering. They developed the rock corer and grinder at the end of the robotics arm for the ill-fated British Beagle 2 Mars lander mission, launched with ESA's Mars Express in June 2003. Professor K.L. Yung of the Department of Industrial and Systems Engineering has been working closely with CAST not only on the Soil Preparation System but also on the development of the 'Camera Pointing System' for lunar exploration.

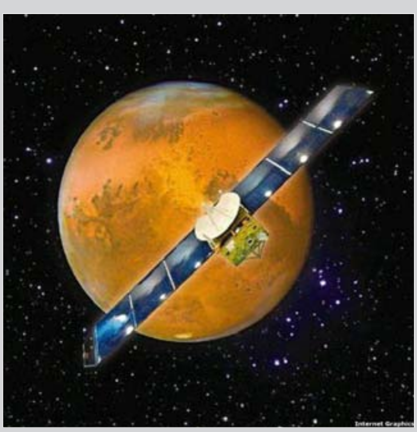
A Micro-Satellite for the first Chinese Rendezvous with the Red Planet

The sub-satellite's name was chosen as Yinghuo 1 – YH-1. The meaning of the name translates to "firefly" after the bugs, capable of shining in the dark after sunset. Some explanations of the name also refer to "yinghuo" as the ancient Chinese name for the planet Mars.

YH-1 is 3-axis stabilised, has a body 0.75 m by 0.75 m by 0.6 m in size and a pair of solar panels spanning 7.85 m. The overall weight of the mini space probe was 115 kg, although earlier reports mention a weight of 110 kg. Yinghuo was supposed to work at a 72.8 hours highly-elliptical orbit with an apogee of 74,000 to 80,000 km, a perigee of 400 to 800 km, and with an inclination of 5 degrees. It has no orbital transfer capability and would have been released from the Phobos-Grunt main probe immediately after the Mars orbit insertion, which would have taken place after 11 months into flight. Yinghuo is equipped with a one-meter high-gain X-band antenna which allows direct Earth-Mars communication for telemetry and data downlink through Russian ground stations. The spacecraft also comprised a low-gain antenna and receiver. Additionally, on Yinghuo a VLBI beacon was installed. Very Long Baseline Interferometry - VLBI, a proven technology used for the Chang'e 1 mission, was intended to be used for YH-1 tracking involving Chinese facilities. The probe's designed working life was two years, consisting of one year in cruise phase and one year at Martian orbit.

The Quartet of Scientific Instruments

As small as the Chinese Mars-bound space probe might be, there was still space enough for a set of four scientific in-



Artist's impression of the Yinghuo 1 probe.
credit: internet

A Yinghuo 1 mockup in display.
credit: internet

vestigation devices comprising the primary payload on YH-1:

- Plasma package, consisting of an electron analyser, ion analyser and a mass spectrometer,
- Sat-sat radio occultation sounder,
- Flux-gate magnetometer, and
- Two optical CCD cameras with a 200 m-resolution

YH-1's scientific objectives include the detection and description of a plasma field around Mars, imaging the Martian surface including sandstorms, and determining the Martian gravity field. During the mission, YH-1 and the main probe Phobos-Grunt would have been aligned for a two-point measurement configuration in the Martian space environment. Therefore the two spacecraft are equipped with similar plasma and magnetic field detecting instruments which enable a Martian occultation observation while the two probes are at opposite sides of Mars. It would have been reportedly the first time in Mars exploration history. Especially the long wave (800/400MHz) occultation between the two spacecraft would investigate regions within the Martian ionosphere, such as sub-solar and midnight regions, which were neglected by previous Mars missions. Furthermore, the mission aimed at answering questions like: What caused the planet to lose its water? How does the space environment of Earth-like planets evolve? How is the Martian space environment structured and the plasma around it distributed? What are the possible mechanisms of the Martian ion-escape processes? How is the interaction between the solar wind and the planets atmosphere and how can the energy deposition processes being explained?

For the mission, Chinese space experts and engineers have developed some key technologies such as: ultra-long-range communication technology, deep space exploration attitude determination and control technology, and thermal control technology.

Ready for Lift-off

The development and testing of Yinghuo 1 was completed within 23 months as originally scheduled. The full range of standard spacecraft testing was conducted on the Mars probe, among others were vibration tests, vacuum-thermal tests, detailed power checks, tests in the acoustic chamber, test of the solar panel deployment, and leak detection examination. Special care was taken for the test of the solar panel deployment which would happen during the mission only after the insertion into the Martian orbit, after a period of 8 hours in the shadow of the Red Planet with temperatures around -150°C, and after an 11-month cruise. The Chinese engineers tried beforehand to minimise the risk of failure when it would come to this crucial moment of the mission.

SAST finalised the construction of Yinghuo in the first half of 2009 and delivered the satellite in June of the same year to Lavochkin for final integration into the Phobos-Grunt truss structure. However, in September 2009, the Head of the Russian Space Agency Roscosmos, Anatoly Perminov, informed the international partner and the public that the Phobos-Grunt mission is postponed until October 2011, to allow time for improving the spacecraft. As a consequence, Yinghuo was transferred back to China. In the following 16 months, Yinghuo 1 was kept in China, with some of its components needing replacement. In January 2011 the Chinese probe was back again in the clean rooms of Lavochkin for integration into the truss structure of the Russian spacecraft and to prepare for their joint launch in November. On 17 October 2011, Yinghuo 1 was finally delivered to the cosmodrome in Baikonur along with Phobos-Grunt.

Though a series of technical challenges have delayed the mission for about 2 years, these issues could be finally settled.

During the two years of launch delay there were unconfirmed reports that China would launch the YH-1 independently in

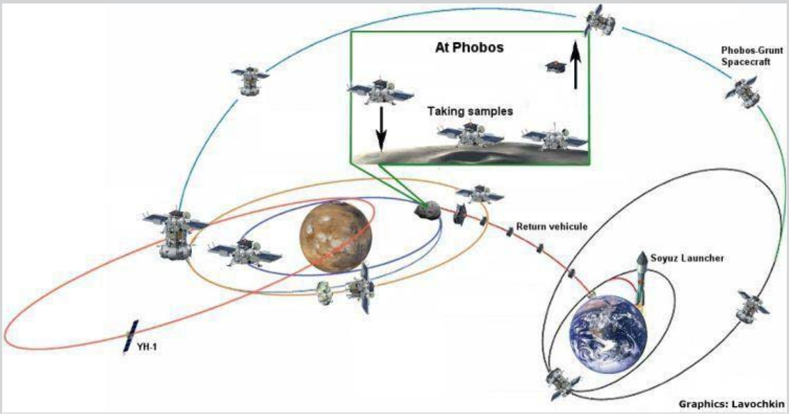
Launch configuration of Yinghuo 1.
credit: internet

Yinghuo 1 in testing before being transported to Russia.
credit: internet

2011 in case the Phobos-Grunt mission would face cancellation. It was said that China has started preparation for this mission, including development of a new 4th stage on top of the existing Long March launchers. In parallel there have been on several occasions unofficial reports on the internet that China is interested in a Mars mission on its own.

The Power of International Cooperation

After Russian ground controllers lost contact with the Mars mission, they activated all resources and initiated all possible measurements to receive a radio signal. These efforts were hindered by poor preconditions: Russia had only the

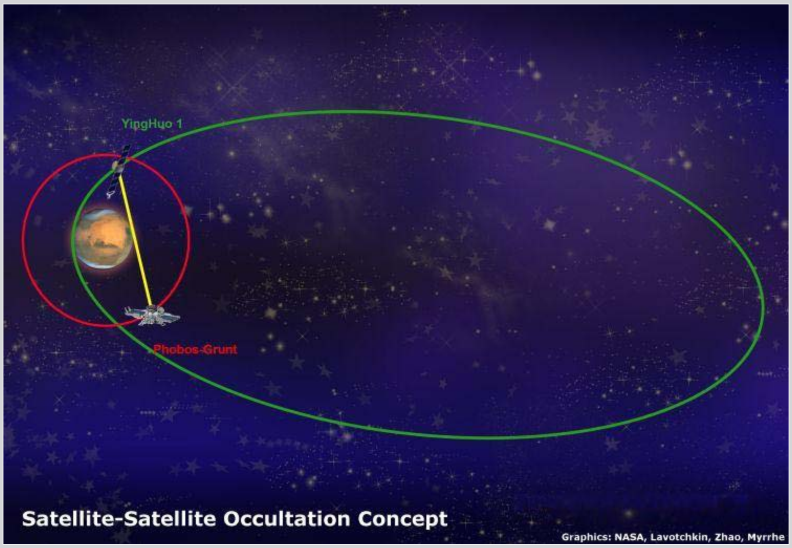


top left: The Phobos-Grunt (top) and Yinghuo 1 (middle) spacecraft are pictured in the cleanroom of Lavochkin in October 2009. The two spacecraft are mounted on the main engine (the four large spheres). After the delay of the mission was officially confirmed the Yinghuo space craft was transported back to China and came back to Russia in January 2011. credit: Lavochkin

above right: Phobos-Grunt mission profile. credit: Lavochkin

bottom-left: Phobos-Grunt and Yinghuo 1 spacecraft. The Yinghuo 1 interplanetary probe is visible in the middle part of the Phobos-Grunt truss structure. credit: Lavochkin

below: The graphic shows the concept of the satellite-to-satellite occultation experiment, using the instruments on both spacecraft. A receiver on Yinghuo is equipped to receive the signal sent by the Phobos-Grunt probe at a frequency of 400 MHz and 800 MHz. The phase shift and bending of the wave can be measured on Yinghuo and the observed changes used to prepare maps of electron density profiles in the Martian ionosphere. credit: NASA/Lavochkin/Zhao/Myrrhe



Baikonur ground station ready for communicating with the spacecraft. This ground station would have been suitable for deep-space operations but not for the short fly-overs with approximately 300 seconds of visibility while in LEO. Also, the Russian engineers were staff-wise not prepared for such a contingency situation but made all efforts to cope with it. Admirable and remarkable was the optimism spread since the beginning of the emergency operations to save the mission in any possible way. From the first second it was a race against time, because the launch window for a trajectory to Mars would be closed within two weeks time.

Also, immediately after the word about the situation of the mission became public, an incredible scope of world-wide rescue initiatives, official and unofficial, rode around the world. On 8 December 2011 Academician Lev Zelenyi, Director of the Russian Space Research Institute IKI, which had the science lead for the mission, sent a letter to all international partners of the Phobos-Grunt project. In this letter Zelenyi recalls these days: "Several foreign organisations, in particular, ESOC-ESA, DSN-JPL-NASA, NORAD-STRATCOM, numerous amateur observers tracked the spacecraft to establish communication and determine parameters of the orbit, its orientation and attitude."

Finally on 22 November 2011, the first flicker of hope arose when ESA's 15 m antenna at its ground station in Perth, Australia established contact with Phobos-Grunt. ESA responded to a request from Roscosmos, channelled to ESA through NPO Lavochkin, the designer and operator of the spacecraft. Starting with 9 November 2011, ESA made daily contact attempts using numerous configuration and modes. Only after the installation of an additional 'feed horn' antenna at the side of the 15 m main dish, could the European ground controllers observe the very low-power signals and make several two-way communication sessions with the interplanetary spacecraft. ESA's Service Manager for Phobos-Grunt, Wolfgang Hell, located at the European Space Operations Centre in Darmstadt/Germany and his team were delighted by this success. Since Russia is not any more capable of deep-space communication, it had a cooperation agreement with ESA for the support of the mission during its cruise phase. The European ESTRACK network of global ground stations is famous for its reliability and its support for international space missions of a wide range of mission profiles. Although ESA was prepared for the support of the mission in a later phase, it was pleasant to see that international cooperation is not an empty word but standard practice when it comes to space exploration.

Anatoliy Zak, the owner of www.russianspaceweb.com reported that "according to industry sources, the European assistance to Russia in tracking Phobos-Grunt was provided free of charge, partly in the hope that Russian space agency would reciprocate with providing a costly Proton launch vehicle for the financially troubled ExoMars project."

During the days after 22 November, space engineers in ESA

right: ESA's Perth station is located 20 kilometres north of Perth (Australia) on the campus of the Perth International Telecommunications Centre (PITC), which is owned by Telstra, and operated by Stratos. credit: ESA

left: View of ESA's 15 m antenna in Perth/Australia. The black arrow is pointing to the low-power feed horn antenna additionally mounted near the small, 1.3 m search antenna, both mounted at the side of the main dish. The mini-antenna was used to send wide angle telecommands to Russia's Phobos-Grunt mission in Earth orbit on 22 November 2011. credit: ESA


Photo: ESA

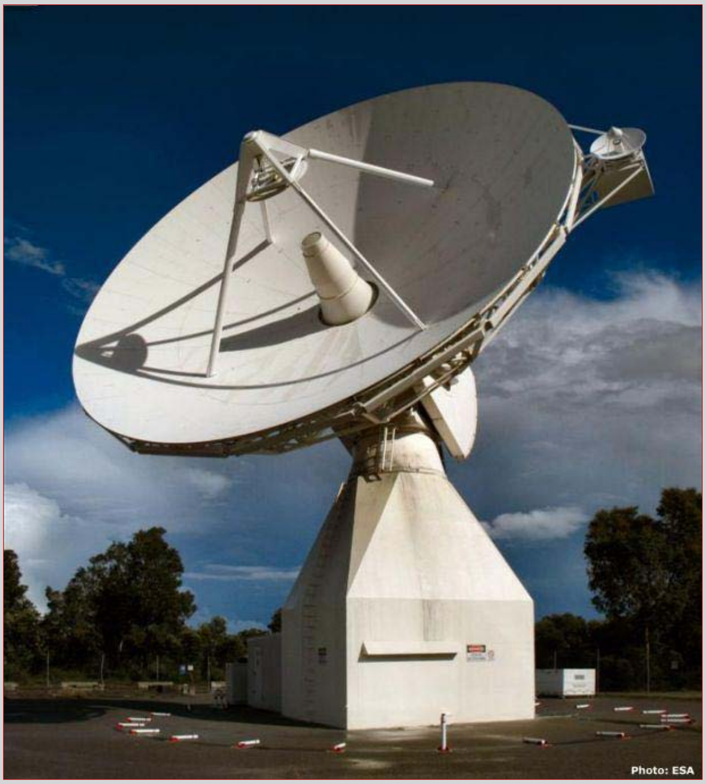
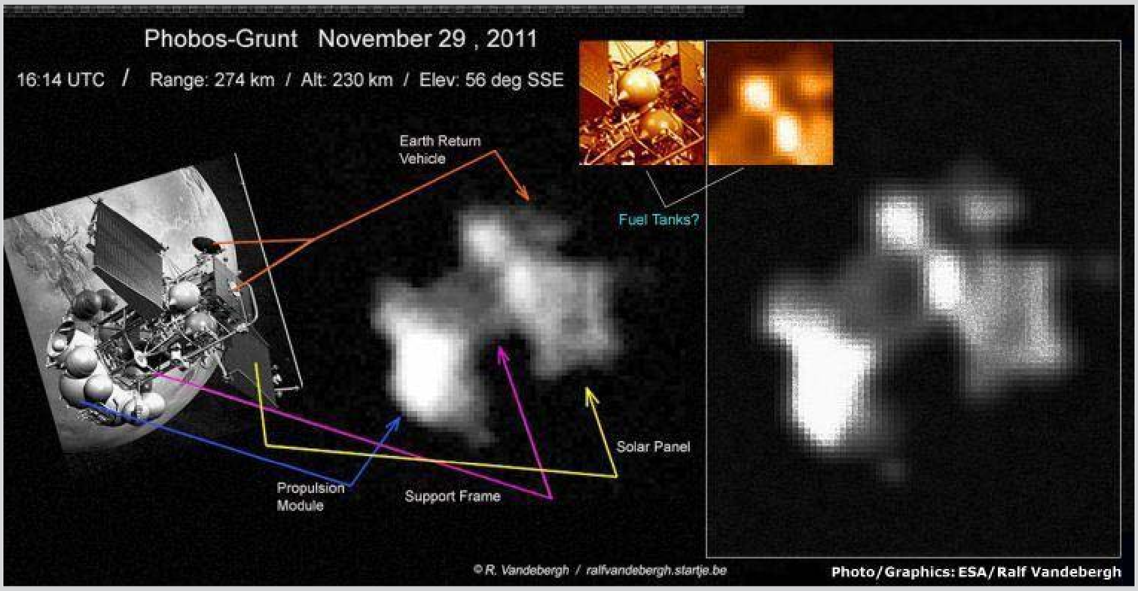


Photo: ESA

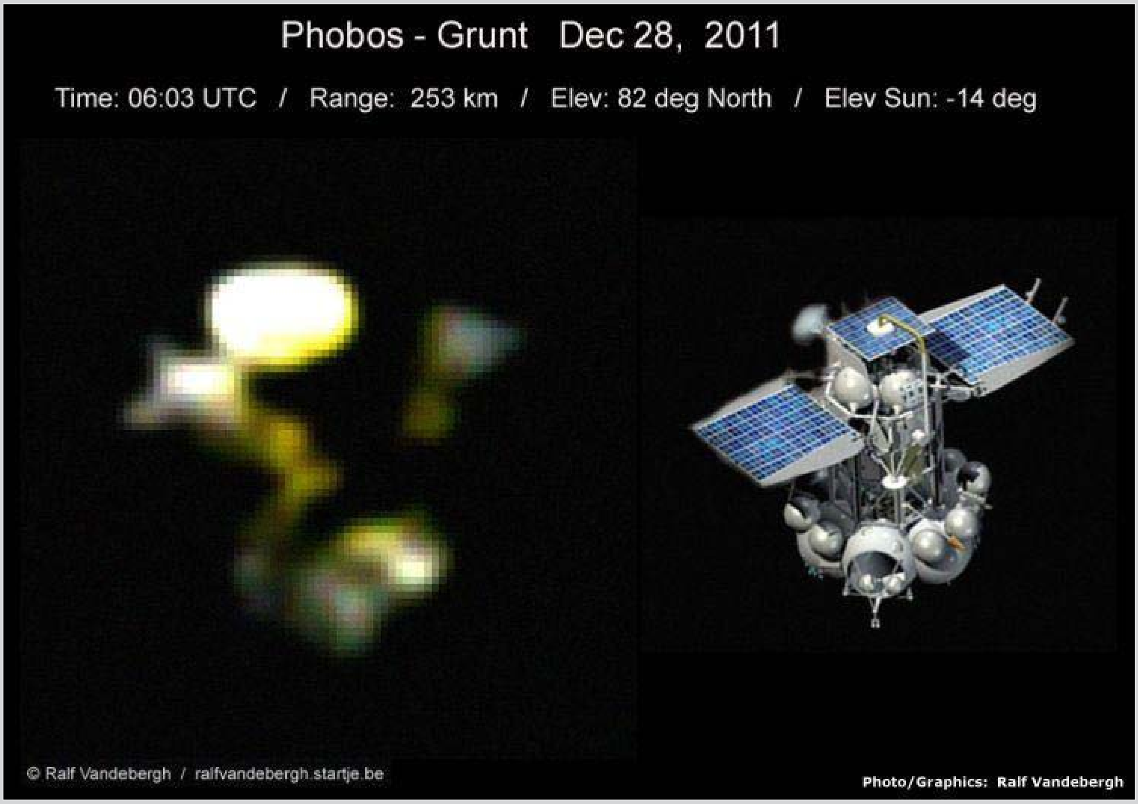
and Russia became very enthusiastic in thinking of preliminary scenarios to dedicate the mission to a new target. Although just thoughts, this approach gave a positive response to a difficult situation: combining the best talents of the international space community could make impossible things possible.

Also, worth mentioning is the fact that there was no room for gloating in the web forums discussing the mishap of the project. The international space community was certainly disappointed but also showed fairness in the evaluation of the circumstances. No finger pointing, everybody was aware of the importance of the mission and the difficulties and challenges involved. Moreover, one could feel that everybody wished the space mission might somehow succeed, no matter how.

Unfortunately, all high motivation and creativity is not needed anymore for Phobos-Grunt and Yinghuo. After several subsequent failures to contact Phobos-Grunt, ESA suspended its efforts for tracking the mission on 2 December. On 8 December Lev Zelenyi sent his letter in which he states furthermore: "However, despite people being at work 24/7 since the launch, all these attempts have not yield any sat-



Phobos-Grunt image taken from ground, 29 November, by amateur astronomer Ralf Vandebergh, in The Netherlands.
credit: Ralf Vandebergh



Phobos-Grunt image taken from ground, 28 December, by amateur astronomer Ralf Vandebergh, in The Netherlands.
credit: Ralf Vandebergh

isfactory results. We are grateful to our foreign colleagues, who provided us with every list of information about the spacecraft which was crucial at the time. [...] At present, the next steps of the Russian space science program on the Solar system exploration are being discussed. In accordance with the current plans, the next missions are Luna-Glob and Luna-Resource. As another possible additional step, at the moment ROSCOSMOS, ESA and NASA are discussing the collaboration on the ExoMars and Russian Mars-NET missions. Moreover, the Russian Academy of Sciences would like to prepare a new mission to Phobos. However, no decision has been taken yet.

We would like to express our deep gratitude to [...] all the scientists and specialists for collaboration on the Phobos-Soil Mission, preparation of scientific instruments and provision of ground support. We are deeply sorry about the failure of the Phobos-Soil Mission. We hope in future to continue our collaboration on space science projects."

The Phobos-Grunt mission was not only a Sino-Russian exploration project. The launcher was a Ukrainian Zenit rocket, equipped with a Russian Fregat upper stage. Onboard the Russian spacecraft has also been a US-American experiment: LIFE - Living Interplanetary Flight Experiment, an astrobiological project by the US-American Planetary Society. (see text in box). This makes Phobos-Grunt a three-continent cooperation. Certainly, this might be the way to go in the future.

Vladimir Popovkin, the new Head of the Russian Space Agency Roscosmos, confirmed during his speech at the 62nd International Astronautical Congress in October last year in Cape Town that he cannot think of deep-space exploration without broader international cooperation.

This was underlined by the President of the Chinese Academy of Science, Bai Chunli, when he confirmed in his speech during the inauguration of the National Space Science Centre - NSSC in Beijing last summer, that one of the tasks of the newly set-up institute will be the promotion of international cooperation.

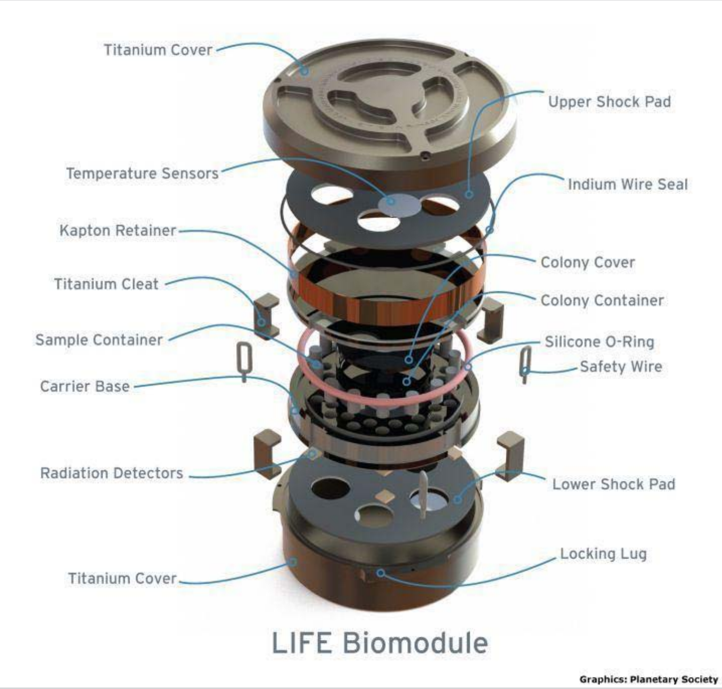
This statement is in accordance with the just-published White Paper on Chinese space activities for the next five years. Under the title "China's space activities in 2011" the document is dedicating a full chapter, Chapter V, to international cooperation. The paper also places a strong emphasis on further efforts for deep-space. It reads: "China carries out deep-space exploration in stages, with limited goals.", and a few lines later: "China will conduct special project demonstration in deep-space exploration, and push forward its exploration of planets, asteroids and the sun of the solar system."

The Light of Firefly Shines into the Future

Shortly after China officially announced the loss of Yinghuo 1, several observers of the Chinese space programme re-

LIFE - Another hitchhiker on Phobos-Grunt

The LIFE (Living Interplanetary Flight Experiment) experiment is a astrobiological project by the US-American Planetary Society. The 88 gramme LIFE bio-module is a flat disk 56 mm in diameter and with a maximum thickness of 18 mm. The small module contains 10 types of organisms including bacteria, eukaryota and archaea. Each of the 10 samples is provided in triplicate and placed in 30 self-contained capsules within the sample return box, but kept separated from the canister which would have contained the Phobos samples. The Planetary Society wanted to test whether life can survive a three years-long interplanetary journey, something what was never tried before. By the time of the project planning, the Phobos-Sample Return mission has been the only scheduled mission that would return to Earth from deep space and therefore the Planetary Society considered the mission a unique opportunity for the conduction of the LIFE experiment. Some of the experts, involved in the project believe that the experiment could survive the fiery re-entry and in case of landing on land, might even be retrievable.



Exploded view of the Planetary Society's LIFE experiment hardware. credit: Planetary Society fused to talk about a failed mission and gave reasons why the project was partly accomplished. One of those articles is "Yinghuo was worth it" by Australian space analyst Morris Jones published on 17 November on www.spacedaily.com.

Rightly, Morris Jones states that: "Like the tip of an iceberg, the small Yinghuo spacecraft is just one part of a larger program, with infrastructure, personnel, and knowledge. The rest of this program is on the ground, and it remains intact." He also emphasises that Yinghuo was a "low-key way for China to begin its planetary exploration program." compared with the 13.5 tonne Russian Phobos-Grunt mission which cost app. 5 billion Roubles (163 Mio. US-Dollar or 119 Mio. Euros)

Another article entitled: "China Forges Ahead in Space Despite Yinghuo-1 Setback" was written by David Cyranoski and published on 15 November 2011 in Nature magazine. Cyranoski anticipated already prior to the Morris article, that the loss of Yinghuo 1 is "a relatively small setback for a nation that has notched up a string of high-profile space successes in recent years". The experience gained during the preparation of this mission is the actual value of it, as both authors note. Cyranoski also points out that the inauguration of the National Space Science Centre – NSSC in July 2011 in Beijing will enable the centralised planning of future Chinese space science efforts, something what was not done in the past, although this seems hard to believe in a strongly centralised administration like China. The new institute of the Chinese Academy of Sciences will make it possible to "manage space science missions as a series" and with a broad international participation. Missions to Mars will certainly not be the last in the queue.

Firefly Will Live up to its Name

According to Roscosmos, the space probe re-entered Earth's atmosphere on 15 January, late afternoon Greenwich Mean Time. Russian space controllers confirmed that most of Phobos-Grunt burned up during its re-entry and that only fragments have hit the Earth's surface over the Pacific Ocean. This was of particular interest since the miniaturised version of a Mössbauer spectrometer, MIMOS II, provided by the German University of Mainz for Phobos-Grunt was working with an insignificant amount of radioactive Cobalt-57 possessing a half-life of 271.79 days. It is not because of the radioactive element on board, but because of the failure of the mission, that "Firefly 1" eventually lived up to the meaning of its name: it was glowing during the destructive re-entry and might just have reminded the international community that it should combine its efforts for the future of space exploration.

(Jacqueline Myrrhe, Chen Lan)

References

1. Zhao Hua. Yinghuo-1- Martian space environment exploration orbiter. Chin. J. Space Sci., 2008, 28(5): 395-401.
2. Wu Ji, Zhu Guangwu, Zhao Hua, Wang Chi, Li Lei, Sun Yueqiang, Guo Wei, Huang Chengli. Overview of scientific objectives of China-Russia Joint Mars exploration program YH-1. Chin. J. Space Sci., 2009, 29(5): 449-455.
3. Chen Changya, Hou Jianwen, Zhu Guangwu. YH-1 Mars probe's key technology and its design feature. Chin. J. Space Sci., 2009, 29(5): 456-461.
4. LIFE (Living Interplanetary Flight Experiment) http://www.planetary.org/programs/projects/innovative_technologies/life/facts.html#experiment.
5. http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=49100&farchive_objecttypeid=18&farchive_objectid=30912
6. http://www.esa.int/SPECIALS/Operations/SEM4NEZW5VG_1.html
7. http://freeimagehosting.nl/pics/a1a21f-081f6a52b6ef827eb867842c5b.jpg

Chinese Space Launch History (Part III: 2000 – 2006)

#1	#2	Date	Time (UTC)	ID	Model	LV S/N	Launch Site	Launch Pad	Payload		Orbit				Remark
									Name	Weight	Type	Perigee	Apogee	Inclina-tion	
68	60	1/25/2000	16:45	00003	CZ-3A	Y4	Xichang	2	ZX-22	2300	GTO	210	41974		
69	61	6/25/2000	16:45	00032	CZ-3	Y12	Xichang	3	FY-2B	1372	GTO	204	36041	27.3	
70	62	9/1/2000	3:25	00050	CZ-4B	Y3	Taiyuan	old	ZY-2 01		LEO				
71	63	10/30/2000	16:02	00069	CZ-3A	Y5	Xichang	2	BD-1 01		GTO	200	41991		
72	64	12/20/2000	16:20	00082	CZ-3A	Y6	Xichang	2	BD-1 02		GTO	212	41986	25	
73	65	1/9/2001	17:00	01001	CZ-2F	Y2	Jiuquan	921	Shenzhou 2		LEO				
74	66	3/25/2002	14:15	02014	CZ-2F	Y3	Jiuquan	921	Shenzhou 3		LEO				
75	67	5/15/2002	1:50	02024	CZ-4B	Y5	Taiyuan	old	FY-1D	950	LEO/SSO				
									HY-1A	368	LEO				
76	1	9/15/2002		02F01	KT-1		Taiyuan		HTSTL-1/PS-1						launch failure
77	68	10/27/2002	3:17	02049	CZ-4B	Y6	Taiyuan	old	ZY-2 02						
78	69	12/29/2002	16:40	02061	CZ-2F	Y4	Jiuquan	921	Shenzhou 4		LEO				
79	70	5/24/2003	16:34	03021	CZ-3A	Y7	Xichang	2	BD-1 03		GTO				
80	2	9/16/2003		03F01	KT-1		Taiyuan		PS-2						launch failure
81	71	10/15/2003	1:00	03045	CZ-2F	Y5	Jiuquan	921	Shenzhou 5		LEO				
82	72	10/21/2003	3:16	03049	CZ-4B	Y4	Taiyuan	old	ZY-1A 02	1540	LEO				
									CX-1	88	LEO				
83	73	11/3/2003	7:20	03051	CZ-2D/2	Y4	Jiuquan	603	FSW-18	3800	LEO	191	339	63	
84	74	11/14/2003	16:01	03052	CZ-3A	Y8	Xichang	2	ZX-20	2300	GTO	212	41981		
85	75	12/29/2003	19:06	03061	CZ-2C/SM	Y1	Xichang	3	TC-1/DS-E	335		555	78051	28.5	
86	76	4/18/2004	15:59	04012	CZ-2C/2	Y14	Xichang	3	SY-1	204	SSO				
									NX-1	25	SSO				
87	77	7/25/2004	7:05	03061	CZ-2C/SM	Y2	Taiyuan	old	TC-2/DS-P	343		681	38278	90	

#1	#2	Date	Time (UTC)	ID	Model	LV S/N	Launch Site	Launch Pad	Payload		Orbit				Remark
									Name	Weight	Type	Perigee	Apogee	Inclina-tion	
88	78	8/29/2004	7:50	04033	CZ-2C/3	Y12	Jiuquan	603	FSW-19	3900	LEO	168	553	63	
89	79	9/8/2004	23:14	04035	CZ-4B	Y7	Taiyuan	old	SJ-6 01A		LEO				
									SJ-6 01B		LEO				
90	80	9/27/2004	8:00	04039	CZ-2D/2	Y5	Jiuquan	603	FSW-20	3800	LEO	205	297	63	
91	81	10/19/2004	1:20	04042	CZ-3A	Y9	Xichang	2	FY-2C	1380	GTO	288	36048		
92	82	11/6/2004	3:10	04044	CZ-4B	Y8	Taiyuan	old	ZY-2 03		SSO				
93	83	11/18/2004	10:45	04046	CZ-2C/2	Y15	Xichang	3	SY-2		LEO				
94	84	4/12/2005	12:00	05012	CZ-3B	Y6	Xichang	2	Apstar-6	4680	GTO	209	49991	26	
95	85	7/5/2005	22:40	05024	CZ-2D/2	Y6	Jiuquan	603	SJ-7		LEO				
96	86	8/2/2005	7:30	05027	CZ-2C/3	Y13	Jiuquan	603	FSW-21	3900	LEO	169	547	63	
97	87	8/29/2005	8:45	05033	CZ-2D/2	Y13	Jiuquan	603	FSW-22	3800	LEO	205	331	63	
98	88	10/12/2005	1:00	05040	CZ-2F	Y6	Jiuquan	921	Shenzhou-6		LEO	201	345	42.4	
99	89	4/26/2006	22:48	06015	CZ-4C	Y1	Taiyuan	old	YG-1	2700	LEO				
100	90	9/9/2006	7:00	06035	CZ-2C/3	Y16	Jiuquan	603	SJ-8	3400	LEO	180	460	63	
101	91	9/12/2006	16:02	06038	CZ-3A	Y10	Xichang	2	ZX-22A	2300	GTO	207	42000	25	
102	92	10/23/2006	23:34	06046	CZ-4B	Y16	Taiyuan	old	SJ-6 02A		LEO				
									SJ-6 02B		LEO				
103	93	10/28/2006	16:20	06048	CZ-3B	Y7	Xichang	2	Sinosat-2	5100	GTO	207	35932	28	
104	94	12/8/2006	0:53	06053	CZ-3A	Y11	Xichang	2	FY-2D	1388	GTO	202	36525		

Note:

1. #1 and #2 are flight numbers of all launches and launches per vehicle respectively.
2. Last digit in CZ-2C/2, CZ-2C/3, CZ-2D/2 designators is unofficial and refers to “block n”.

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 3 - Xichang Satellite Launch Centre - XSLC)

Brief History

XSLC is located at position 28.2°N, 102.0°E in Xichang, Sichuan province. The centre's headquarter is in Xichang City, which is situated at a distance of 65 km from the launch site.

Initially, in 1969, the launch site was planned for launching manned spacecraft. Construction of railways, roads and other infrastructure started in 1970. However, due to financial and other reasons, the manned space program was postponed. XSLC was then re-designed as a China's first low latitude launch site, mainly for launching GEO satellites.

Facilities

Launch Pad 2:

- Initially built for commercial CZ-2E launches in 1990.
- The only pad in XSLC capable of launching the strap-on booster version of the CZ rockets.

Launch Pad 3:

- First launch pad in XSLC, built in 1982.
- Almost completely re-built in 2007.

Other Facilities:

- Technical Centre.
- Communication Centre.
- Command and Control Station.
- 3 Telemetry Stations.
- Xichang Airport, 50 km away from XSLC, with a 3,600 m runway suitable for take-off and landing of large aircraft such as the C-130, An-124 and Boeing 747.

Milestones

08 April 1984: First successful launch of China's first GEO satellite DFH-2.

07 April 1990: Successful launch of China's first commercial GEO satellite Asiasat-1.

24 October 2007: Successful launch of China's first lunar exploration spacecraft CE-1.

Launch Pad Statistics

Launch Zone	#Pad	Construction Date	Service Date	Launch Stats (by LV model)	Launch Stats (by orbit type)	Fuel type	Remarks
	1	1970	Originally planned in 1972				2 km away from Pad 2, originally planned for manned space launches. Not yet built.
	2	May 1989	April 1990	CZ-2E: 7 CZ-3A: 12 CZ-3B: 16 CZ-3C: 8 **Total: 43**	GEO: 42 Others: 1	UDMH /N2O4	The only pad in XSLC capable of launching the strap-on version of the CZ rockets.
	3	1975	1982	CZ-2C: 3 CZ-3: 13 CZ-3 A: 10 **Total: 26**	LEO/SSO: 2 GEO/IGSO: 21 Others: 3	UDMH /N2O4	Re-built in 2007 and moved 2.5 m back from the original position of Pad 3.
				Total: 69			

Sources:
1. 百度百科, http://baike.baidu.com/view/25207.htm
2. CGWIC, http://www.cgwic.com

Gallery

Shenzhou 8 mission

Shenzhou 8 in launch preparation. (Photo: Chinanews)

Shenzhou 8 in launch preparation. The orbital module was on the left. (Photo: Chinanews)

Shenzhou 8 orbital module in launch preparation. (Photo: Chinanews)


Shenzhou 8 in launch preparation. (Photo: Chinamil)


Shenzhou 8 transported to the vertical assembly building, JSLC. (Photo: Xinhua)


CZ-2F roll-out with Shenzhou 8 on top. (Photo: Xinhua)

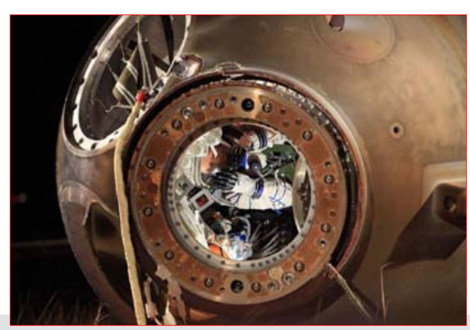

Shenzhou 8 launched on top of the CZ-2F (Y8) from JSLC 5:58, 1 November 2011. (Photo: Xinhua)


Debris of Shenzhou 8 fairing on ground. A high-altitude escape motor can be seen in this picture. (Internet photo)

Beijing Aerospace Control Centre (BACC). This photo was taken when un-docking and re-docking took place on 14 November. (Photo: Xinhua)

Big screen of Beijing Aerospace Control Centre (BACC). This photo was taken during the historic docking on 3 November. (Photo: Xinhua)


Shenzhou 8 re-entry capsule landed in Inner Mongolia 17 November 2011. (Photo: Xinhua)


Shenzhou 8 capsule after landing. A dummy taikonaut can be seen from outside of the hatch. (Photo: Xinhua)