



All About The Chinese Space Programme

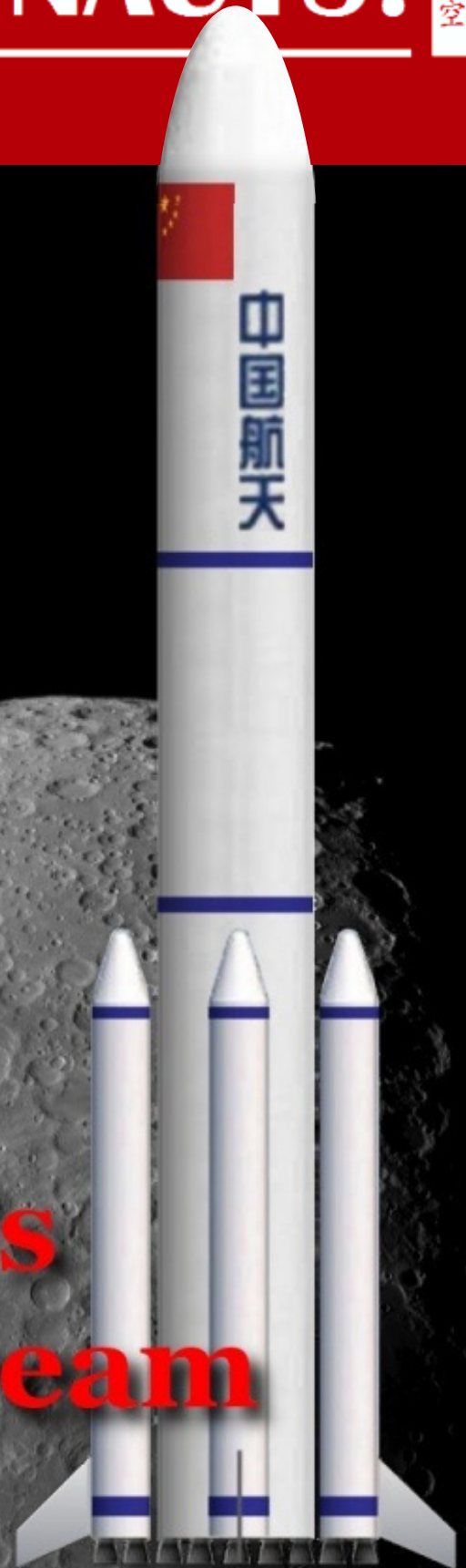
Go TAIKONAUTS!

龙腾太空

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Revised Version

May 2014



China's Apollo Dream



Editor's Note

We have covered the Chang'e 3 robotic lunar landing mission in our previous issue. It was a great achievement for China that in the past only the U.S. and the former Soviet Union have completed. However, ... page 2

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January - March 2014



Launch Events

The only Chinese space launch in this quarter was on the last day of the quarter. At 10:58, 31 March, the SJ-11-06 was successfully launched by a CZ-2C vehicle from JSLC. The satellite is supposed to be the replacement of ... page 3

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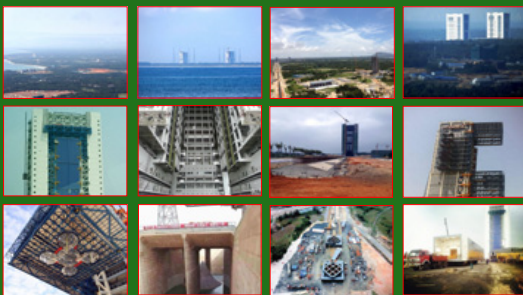
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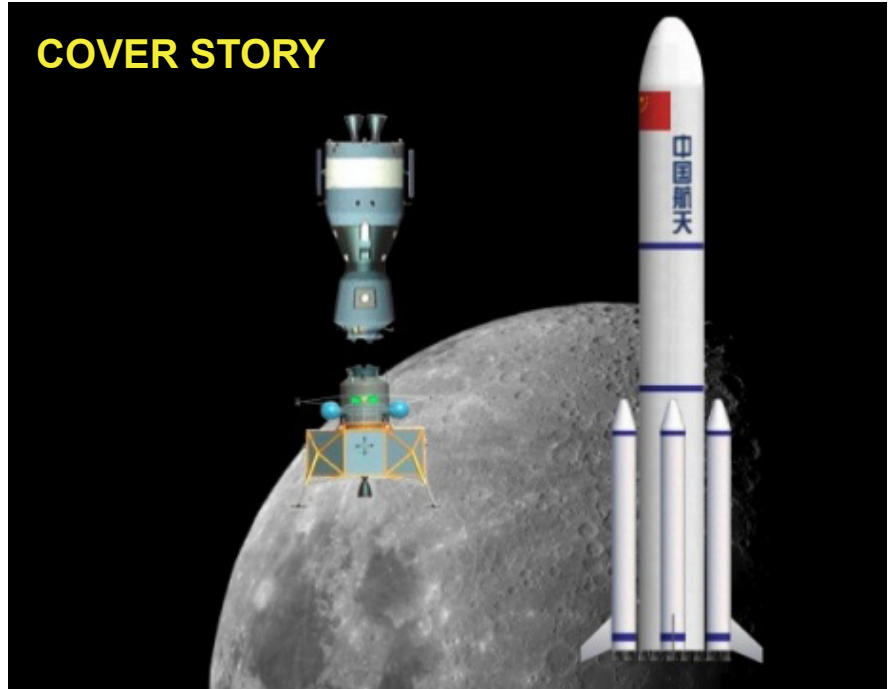
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COVER STORY



China's Apollo Dream

Early Light

On 20 July 1969, three Americans made history by setting foot on the Moon, the closest celestial body to the Earth. The Apollo 11 manned lunar landing was one of the most significant events in the 20th century that turned a new page of human history. However, at that moment, on the other side of the Earth, one billion Chinese people were trapped in the chaos of the Cultural Revolution. Only a very few of them were aware ... page 8

Analysis

What if...?

Searching for Evidence - An Attempt to Analyse the "Space Science & Technology in China: A Roadmap to 2050"

China's space programme has been accused of many opaque objectives, including numerous negative associations, such as military goals, space dominance, space super-power ambitions and similar. Searching for evidence, it may be possible to support one or the other above postulates. There was the 2007 ASAT test, and there are programmes about which very little is known, e.g. the 13 May 2013 launch from the Xichang ... page 31

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"Exploration of space becomes a global effort in the real sense of the word."

Interview with Dutch-born NASA astronaut Lodewijk van den Berg

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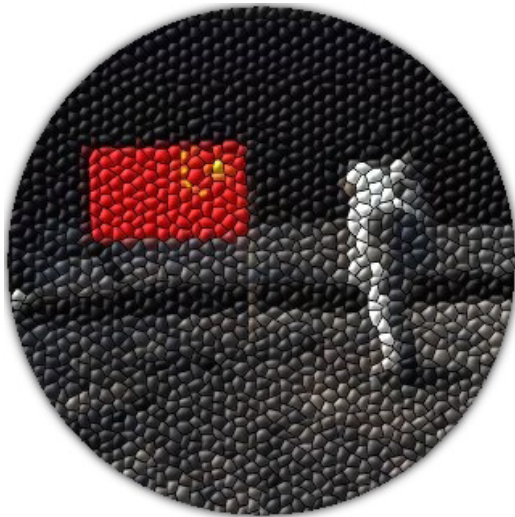
Movie Review

Fei Tian - Flying Apsaras

The film opens with Chinese taikonaut Zhang Tiancong (actor: Liu Zhibing) together with his two crew members, Li Dawei and Zhou Guanxiang ... page 39



Editor's Note



We have covered the Chang'e 3 robotic lunar landing mission in our previous issue. It was a great achievement for China that in the past only the U.S. and the former Soviet Union have completed. However, many people are more interested in a much more ambitious mission - sending a taikonaut to the Moon and bringing him or her back safely - a feat that even the Soviet Union failed to do more than 40 years ago. In fact, a Chinese version of the Apollo mission has been rumoured for years. It was not groundless. China has carried out studies and research on it since almost the same time as the rumour began. The cover story of this issue has a comprehensive review on related work that Chinese scientists and engineers have done since the beginning of this century. Although the work is mostly on paper, and the mission will still be a dream for many years, this dream, China's Apollo dream, will definitely be realised one day. The next human on the Moon could be a Chinese! This comment was given by Eugene A. Cernan, pilot of the trans-lunar Apollo 10 mission and Commander of the Apollo 17 lunar landing mission, and as a consequence, the last person to leave the Moon in 1972. The cover story also includes Cernan's talk with Hartmut Saenger, our cooperating author from Germany.

The mystique of China's Moon plan attracted many people into a guessing game. On the other side however, China's space programme has been accused of aiming for too many opaque objectives, among them numerous objectives with negative connotations, such as military goals, space dominance, space super-power ambitions and similar. Searching for evidence, it might be possible to support the one or the other postulates. Go Taikonauts! tries to shed some light on the Chinese intentions in space. With the help of the document: "Space Science & Technology in China: A Roadmap to 2050", we want to prove that more information is out there than most people are aware of.

In the past, there have been no U.S.-American contributions to our content. This was a small pity. This has now changed, almost overnight. Based on his detailed research and review of original Chinese documents, Jordan J. Foley gives an overview on the technology and political potential of the Chinese Space Station (CSS), and puts those considerations into the wider political context. He stresses that the CSS is suitable for international cooperation, if certain conditions can be fulfilled. Jordan not only offers some interesting ideas, but he has also used his talent for cartoon drawing to illustrate his article with two intriguing graphics. While another U.S. Author, Andrew Johnson, draws a sharp analysis of the current status-quo in the space cooperation between the U.S. and China.

In reality, China and the U.S. have many links, and space is no exception. It is a not very well known fact that there has been a Chinese-born astronaut flying already on one of the early Space Shuttle missions. Fate led to the interesting configuration of having the first Dutch-born and the first Chinese-born space traveler flying together on the same mission back in 1985. Lodewijk van den Berg and Taylor Wang were the science team (payload specialists) for STS-51B. We had the pleasant opportunity to ask Lodewijk van den Berg about his memories on the cooperation with Taylor Wang. The interview is presented in this issue as well.

At last, for the first time we are presenting a movie review. The Chinese production "Fei Tian" triggered our interest. Although already released in 2011, only now have we taken the initiative to introduce it to our readers. After the sky-rocketing success of "Gravity" we found this film gives a remarkable contrast to Western space movies. We are happy to be able to present three different opinions: Tony Quine from the U.K., Dietmar Roettler from (East) Germany and Go Taikonauts! sharing their impressions with our readers. Have fun with them!

(Chen Lan, Jacqueline Myrrhe)

Imprint

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Chinese Space Quarterly Report

January - March 2014

by Chen Lan

Highlights

- China to launch the first liquid-fuelled general upper stage later this year
- Tianzhou cargo vehicle and Tiangong 2 space lab made ground test
- Yutu rover encountered serious problem
- Chang'e 5 pathfinder to be launched by the end of the year
- China tests largest space camera on ground
- A mystery re-entry vehicle completed approach and landing test last year
- China made progress in hypersonic air breathing engine
- China attended global space forum, NASA shows subtle change on cooperation with China
- Chinese female space expert wins von Kármán Award
- Launch platforms for CZ-5 and CZ-7 assembled in Wenchang, Hainan

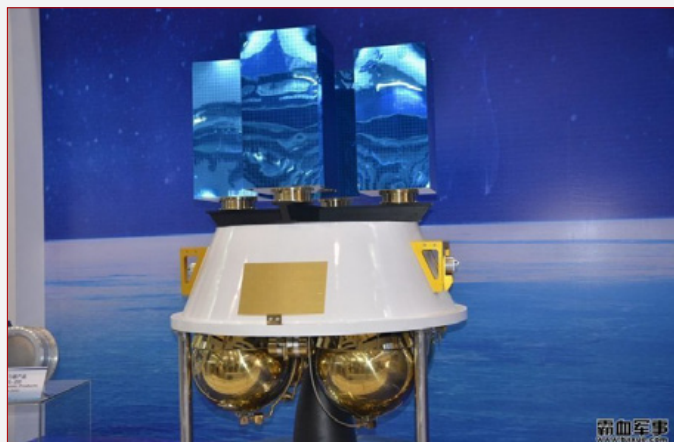
Launch Event

The only Chinese space launch in this quarter was on the last day of the quarter. At 10:58, 31 March, the SJ-11-06 was successfully launched by a CZ-2C vehicle from JSLC. The satellite is supposed to be the replacement of the SJ-11-01 launched on 12 November 2009.

Space Transportation

On 20 January, Liang Xiaohong, a top official of CALT, revealed to Chinese media that they were actively pushing the approval of the super-heavy launcher project that is expected by the end of 2014. Liang expected that the mega launcher with a LEO capability of about 100 tonnes will make its maiden launch in 2028. He also said that China will make 14 space launches in 2014 and 30 in 2015.

In January or early February, the YF-75D expander cycle cryogenic engine, to be used on the second stage of the CZ-5, completed its modal and vibration testing. This shows the further progress of the CZ-5 development following the destructive test of the first-stage oxygen tank completed at the end of 2013. Also, during the annual session of the National People's Congress held in early March, Liang Xiaohong, told reporters that it plans to complete all major ground testing of CZ-5 during



China is developing the first liquid-fuelled general upper stage called Yuanzheng 1 but no picture of it is available. Here is the scale model of the Advanced Upper Stage, the next generation upper stage after Yuanzheng 1 (Expedition 1). (credit: Chinese internet)

2014, including the whole-rocket modal test, hot-firing of the first core stage propulsion system, and the 5.2 meter diameter faring separation test, in order to set a solid basis for its 2015 maiden flight.

CZ-7 development also made solid progress. In February, assembly of the first core stage started. In late March, assembly of another second stage, used for propulsion testing, also began. The first second stage, completed earlier, was stacked with the cargo ship developed for the space station, and started modal and vibration testing in mid-March. CZ-7 is also scheduled to make its maiden flight in 2015.

When development of these new generation launch vehicles entered their final and critical phase, to guarantee the success of all projects, CALT established a joint directorate in March to oversee CZ-5/CZ-5B, CZ-7 and CZ-11 (small solid LV) development.

In addition to the new generation launch vehicles, other news related to China's space transportation system included:

- In early March, China Great Wall issued a statement on the CZ-4B failure that occurred in December 2013. It said that debris coming from the launch vehicle pressurisation feeding system or the assembly process of the third-stage engine, blocked the fuel intake of an upper-stage engine, resulting in a premature shutdown of the second of two third-stage engines. It said that corrective actions including a strengthening quality management and perfecting the foreign object debris-control techniques during assembly, integration and test, would be put into place immediately.
- During the National People's Congress, Liang Xiaohong also revealed that a new upper stage, named Yuanzheng 1 (means Expedition in Chinese) will make its maiden flight later this year. It will be sent to space by a CZ-3B, together with the first two experimental satellites for the Beidou global constellation planned to be completed by 2020. Yuanzheng 1 is China's first liquid-fuelled general upper stage with a multiple re-starting capability and will be able to work for 6.5 hours after launch.
- The first CZ-3C enhanced model will make its maiden flight by the end of the year, to send the Chang'e 5 pathfinder into a circumlunar orbit. This model will have a stretched core stage (1.5 m longer) and strap-on boosters (0.8 m longer) and will increase its GTO capability from 3.8 tonnes to 3.9 tonnes.

- In February, it was reported that the “large thrust solid motor” for the solid launch vehicle completed a review and entered the phase of engineering model development. It was supposed to be the 120 tonne, 2 m diameter solid motor to be used on the CZ-11 responsive mobile small launch vehicle. The motor is developed by the 4th Academy of CASC (or AASPT).

Satellites

On 21 January, the FY-3C polar orbit meteorological satellite completed in-orbit testing and was delivered for trial operation. It was concluded that its overall performance is better than FY-3A and 3B. FY-3C was launched on 23 September 2013.

On the ground, development of FY geostationary meteorological satellites was making progress. The FY-2 08 completed its mechanical test successfully in February, marking its development as nearly complete. Prior to that, it had already completed electrical testing at the beginning of 2014. Meanwhile, FY-4, the new generation geostationary meteorological satellite, completed a critical propulsion system hot test-firing on 19 February. Later, a prototype of FY-4’s lightning imager completed its acceptance review on 5 March. The imager is able to capture 500 images per second, to make it possible to measure the frequency and strength of the lightning.

In March, the 3D digital model of the experimental satellite for the Beidou global constellation was delivered. It marks a major progression for China in the field of satellite design and manufacturing. The first of the five experimental satellites is expected to be launched in October this year by an enhanced CZ-3C.

It was reported in February that the 200 mm diameter LIPS-200 ion electric thruster had undertaken a long duration test-firing of more than 10,000 hours. LIPS-200 was developed by the Institute 510 of CAST and was successfully tested in space on the SJ-9 satellite. The LIPS-200 and follow-on products are planned to be used on China’s new generation communication satellites, including DFH-3B, 4, 5 and 7. To further verify its performance and working life, a new long duration test for its evaluation model started on 25 December 2013, and is expected to last 11,000-15,000 hours with 6,000-8,000 cycles of ignition and shutdown.

During the meeting held in San Diego, California, U.S., by the Special Committee (SC) 104 of RTCM (The Radio Technical Commission for Maritime Services), China submitted a proposal on the differential message standard (BDS RTCM 10402.4 and BDS RTCM 10403.2) that was accepted by the Committee. SC 104 is responsible for Differential Global Navigation Satellite Systems (DGNSS). The move will help to improve interoperability of Beidou with other navigation systems.

During 18 - 24 February, the data management sub-system of the DAMPE (DARK Matter Particle Explorer) completed its acceptance testing. In the annual meeting of the Space Science Pioneer Program held by CAS on 24 February, it was emphasised that 2014 will be a critical year for four satellites currently in development. They are HXMT (Hard X-Ray Modulation Telescope), QUASS (QUantum Experiments at Space Scale), DAMPE and Shijian 10 (SJ-10), all of which are to be launched in 2015.

Manned Space Flight

In February, it was reported that the full-system hot test-firing of the propulsion system of the Tianzhou cargo spaceship was made successfully. The test simulated orbit manoeuvre, rendezvous and docking, attitude control and de-orbit operations. Tianzhou is based on the Tiangong 1 module, and will be in-orbit tested with the Tiangong 2 space laboratory, and will service the future Chinese Space Station (CSS) to be completed around 2020. It was the first time that any particular development progress of the cargo vehicle was reported. In mid-March, a cargo vehicle was stacked on top of the CZ-7 second stage, and modal and vibration testing carried out.

At the same time in March, the Tiangong 2 space laboratory, formerly the back-up of Tiangong 1, completed a leak inspection, marking the completion of the final assembly of the vehicle. According to Zhou Jianping, Chief Designer of the Chinese manned space programme, it will be launched by the end of 2015.

In orbit, Tiangong 1 made its first two orbit manoeuvres in this year on 18 and 19 February, respectively, raising its orbit by about 40 kilometres to approximately 373 x 387 kilometres (USSTRATCOM data). This highest-ever orbit, implies that the mini-station will work for a long period in its extended mission phase. This implication was supported by the report about the sixth working meeting of the Tiangong 1 Operation and Management Committee, held in Beijing on 11 March, in which the committee reviewed the 2014 plan for Tiangong 1, and confirmed that it is expected to work until the end of the year, at least.

On 2 March, the China Manned Space Agency announced that it has opened the Tiangong 1 application data to the public. There is a huge amount of data, including ground images and space environment data, obtained by Tiangong 1 since its launch in 2011. The Technology and Engineering Center for Space Utilisation (CUS) of the Chinese Academy of Sciences (CAS), is in charge of the processing and distribution of the Tiangong 1 application data. CUS will provide public users with data in Grade-1 and Grade-2, free of charge, on its official web site (www.msadc.cn). Commercial agents of the Tiangong 1 application data will provide a paid data service for domestic and international commercial users. It was reported that the space



Tiangong 2 in ground testing. (credit: spacechina.com)

lab is equipped with a hyper-spectral imager with the highest resolution and spectral parameters available in China.

Also, CUS has completed a proposal for the application system of the planned manned space station. In mid-February, the CUS proposal was reviewed and approved by an expert group, setting a foundation for future work.

Lunar and Deep-Space Exploration

On 11 and 12 January, the Yutu rover and the lander were awoken from their hibernation after the lunar night, and started their second lunar day. The rover continued to drive towards the south, and all payloads on the two spacecraft have started formal scientific work. Although there was unofficial information indicating that the topographic camera had a malfunction, all other equipment appeared nominal. On 23 January at 4:00, Yutu successfully tested UHF communication with the lander from about 20 metres away. It was the first “talk” between two Chinese space vehicles on a celestial body. In the early morning of 24 and 25 January, the lander and the rover respectively, entered hibernation mode. But official media announced that Yutu had encountered an abnormality on a “mechanism” just before the second lunar night.

On 12 February, after a failed attempt on 10 February, Yutu woke up and resumed its full status before hibernation, which was seen as a miracle, but the mechanism malfunction still exists, preventing the rover from any movement. As all its scientific payloads worked well, it carried out fixed-point observations during its third lunar day. On 22 February, Yutu entered its third dormancy. It woke up again on 14 March. Although still hampered and its planned three months of working life exceeded, it continued working at its final position before it went into the fourth hibernation on 24 March. In spite of the rover issue, the lander has worked very well since it’s landing.

On 1 March, Ye Peijian, Chief Scientist of the Chang’e 3 programme, told Xinhua in an exclusive interview, that the cause of Yutu’s problem was identified as a control circuit malfunction in its driving unit.

On 11 January 2014, CAS released some high-resolution images and scientific data obtained during Chang’e 3’s first lunar day. On 23 March, images taken by Yutu from its final position were released. In early March, NASA released new images captured by its own LRO spacecraft that clearly showed Yutu’s final position and the track from December to January.

On 14 February, Chang’e 3’s elder sister, Chang’e 2 that had orbited the Moon and the SEL2 point and had flown by Toutatis, a Near Earth Object (NEO), reached a distance of 70 million kilometres from the Earth. It will continue its travel to as far as 300 million kilometres from the Earth and will return to our mother planet in 2029 at a distance of 7 million kilometres.

Development of Chang’e 5, the lunar sample return vehicle, made quiet progress at the same time. On 24 March, an independent review on key technologies of the Chang’e 5 re-entry and recovery began. It is a rare case in China that a space project was reviewed by an independent expert group.

Advanced Technology

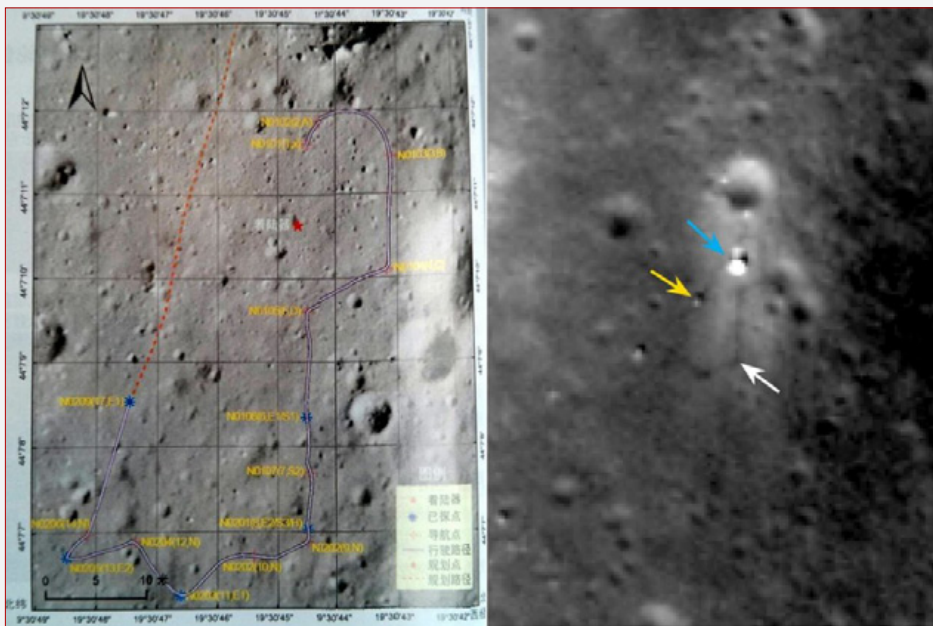
It was reported in early March that China’s largest space camera, developed by CAST, completed thermal vacuum testing. However, there were no details given, such as its aperture and ground resolution, or which spacecraft will carry it.

In mid-February, Chinese media captured a few news reports about the companies and universities involved in a mystery project, and concluded that a successful high-speed autonomous approach and landing test of an unknown vehicle was made in late 2013. These reports were consistent with

messages revealed by some CALT staff via Weibo (a Chinese twitter-like service) in late September 2013, that a CALT developed vehicle, code-named Aotian 1, completed a remarkable test. As the event was linked to CALT, the mystery vehicle is supposed to be space-related, probably a winged or lifting body re-entry vehicle.

On 22 February, an air-breathing engine, developed by AAPT and involved with the Institute 11 of CALT, made a successful free jet shakedown, marking AAPT and CALT’s leading position in the area of hypersonic propulsion in China, and showed great progress in the development of an important engine model.

In January, it was reported that Beihang University (formerly BUAA), has built a Bioregenerative Life Support System (BLSS) laboratory named Yuegong 1 (Moon Palace 1). It is a closed



Yutu’s full traverse map. On the left is a map released by CAS showing the actual (solid white line) and planned (dashed red line) route of Yutu. On the right is the image taken by NASA’s LRO from lunar orbit on 17 February 2014 showing Yutu and its track. (credit: CAS, NASA)



environment and is able to simulate a future lunar base. In December 2013, the ACC (Astronaut Centre of China) completed a 30-day simulated lunar surface stay in its 300 square-metre closed laboratory. Yuegong 1 was seen as a more sophisticated follow-up. While on 1 March, Ye Peijian, Chief Scientist of the Chang'e 3 programme, denied that China had a plan to build a lunar base in the future.

International Cooperation

On the 10 January, a record breaking 33 heads of space agencies followed the invitation of the IAA for a Heads of Space Agencies Summit, taking place in Washington, D.C. It was preceded by the International Space Exploration Forum (ISEF) on Ministerial level on the 9 January. The Chinese delegation, led by Xu Dazhe, Administrator of CNSA, and Wang Zhaoyao, Director General of CMSA, attended the forum and summit. Xu Dazhe took part in the three symposiums of ISEF and made keynote speeches. It was another opportunity, after the IAC 2013 in Beijing, that Xu and the NASA Administrator Charles Bolden could meet face-to-face. When asked by a journalist, Bolden ruled out the possibility for China and the U.S. to cooperate in human space flight, or for China to participate in the ISS. But he added that life has changed, and that China can partner with any of the other ISS International Partner organisations. Such a subtle change from the NASA side hints at a probable change of the current situation with respect to space cooperation between the two countries in the near future.

On 9 January, the Theodore von Kármán award, founded in 1982 by the IAA (International Academy of Astronautics), was given to Chinese space expert, Wu Meirong, in recognition of her 50-year participation in space science and technology, and in addition, outstanding contributions to international space cooperation. She is the first female space technology expert in the world to receive the award that is often referred to as the "Nobel Prize of Aerospace Science". Originally from Changzhou, Jiangsu province, Wu graduated from the Moscow Power Engineering Institute, and is Chief Expert and Honorary Director General of the China Centre for Resources Satellite and Data (CRESDA).

CNES and CNSA signed an agreement on the CFOSat (China-French Oceanic Satellite) project during a French-Chinese



Professor Wu Meirong who was awarded the Theodore von Kármán award on 9 January. (credit: IAA/ CRESDA)

summit in Paris on 27 March, and the two nations' Heads of State witnessed the signing. According to the agreement, CNES will provide the Surface Waves Investigation and Monitoring, or SWIM, instrument, a wave-scatterometer, and would also provide X-band telemetry equipment, on the ground and on the satellite. While CSNA will provide the satellite platform and launch service of the 700-kilogramme satellite on a Chinese Long March rocket planned to launch in 2018, and will build the SCAT wind-measurement scatterometer. In the longer term, CNES and CNSA agreed to investigate a future joint venture in space-based astronomy, with the Space Variable Objects Monitor (SVOM) to study gamma-ray bursts. The two agencies agreed to meet in June to work out the details of the mission, which would be launched as early as 2020 on a Chinese Long March rocket.

The First CAS-ESA Joint Scientific Space Mission Workshop, organised by the National Space Science Center (NSSC), CAS, was held on 24 February in Chengdu. 98 scientists from 10 European countries and China, participated in the workshop. The participants engaged in extensive and in-depth discussions in the field of space astronomy, solar physics, space physics, fundamental physics, etc. The workshop was in response to an earlier ESA-CAS agreement to issue a joint call for the joint mission, to be released by the end of 2014. The second workshop will be held 24 - 26 September 2014 in Denmark.

On 18 March, a review on the optical telescope project for the Asia-Pacific ground-based Optical Satellite Observation System (APOSOS) was completed in Changchun. The telescopes, developed by the Changchun Institute of Optics, Fine Mechanics and Physics, CAS, will be delivered in August 2014 and will be installed in Pakistan, Peru and Iran, to observe and track LEO objects and debris. Dr. Maqbool Ahmad Chaudhry from APSCO (Asia-Pacific Space Cooperation Organization) who is in charge of the APOSOS, attended the review meeting.

Commercial Space

In late January, it was reported that the LaoSat 1 project had completed its critical design review (CDR) and had switched to the manufacturing phase. The CAST-developed LaoSat 1, will be the first flight model using the new DFH-3B bus, and will be the first operational satellite developed in China equipped with an electric thruster. In February, CAST delivered the 3D digital model of the satellite's propulsion module, which will be followed by that of the service module and communication module. On 28 March, witnessed by Lao officials and representatives from APMT (Asia-Pacific Mobile Telecommunications Satellite, a holding subsidiary of CALT) who was the prime contractor of the satellite, the ground-breaking ceremony for the ground station of LaoSat 1 occurred. LaoSat 1 is expected to be launched in October 2015.

Another satellite which passed CDR was Apstar 9. In early March, the CDR for its antenna sub-system, the last sub-system to be reviewed, was completed, which will be followed shortly by satellite manufacture.

According to the lease agreement signed by APT Satellite and China Satellite Communication (Chinasat) in November 2011, the Chinasat 5A comsat at 142°E was renamed to Apstar 9A



on 14 January. APT plans to use this satellite to accumulate customers for the planned new Apstar 9 comsat.

Around 21 January, the Chinasat 5E, originally Apstar 1A launched by a CZ-3 in July 1994, moved to a “graveyard” orbit that is about 250 kilometres higher than normal GEO.

On 29 January 2014, Antrix Corporation Limited, the commercial arm of the Indian Space Research Organisation (ISRO), signed a Launch Services Agreement with DMC International Imaging (DMCii), the wholly-owned subsidiary of Surrey Satellite Technology Limited (SSTL), UK, for the launch of three DMC-3 Earth Observation Satellites being built by SSTL, on-board ISRO’s Polar Satellite Launch Vehicle (PSLV). The DMC-3 will be leased to Beijing-based Twenty First Century Aerospace Technology Company Limited (21AT) for a period of seven years. According to SSTL, the satellites provide unparalleled one metre high-resolution imagery with a high-speed data downlink and 45 degree off-pointing capability.

Miscellaneous

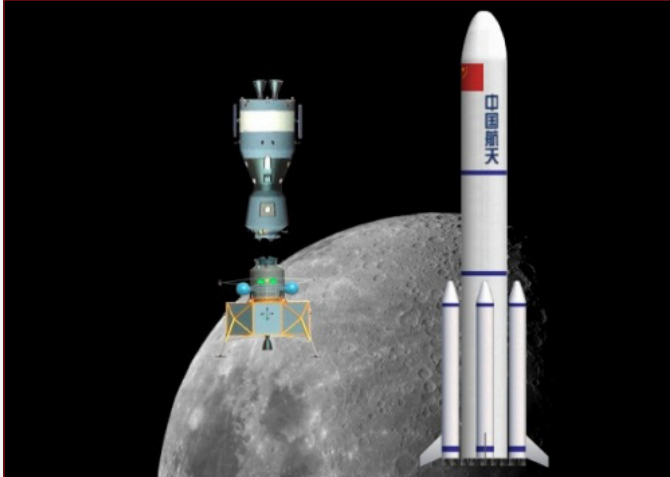
Ground Facility

In Wenchang, Hainan, construction and equipment installation of the launch facility in the new launch centre has entered its final phase. In February, the CZ-5 and CZ-7 mobile launch platforms completed assembly. The CZ-5 platform has a length of 27.5 m, width of 23 m and height of 8.7 m. While the CZ-7 platform is 26 m long, 23 m wide and 8.7 m tall. They were transported to Hainan before the end of 2013. The complete assembly took about two months. The 58 m tall umbilical towers, to be installed on the platforms to provide support of fueling, gas, air conditioning and electric power to the launcher vehicle, have also been transported to the launch centre in January.

(Chen Lan)

China's Apollo Dream

by Chen Lan



Early Light

On 20 July 1969, three Americans made history by setting foot on the Moon, the closest celestial body to the Earth. The Apollo 11 manned lunar landing was one of the most significant events in the 20th century that turned a new page of human history. However, at that moment, on the other side of the Earth, one billion Chinese people were trapped in the chaos of the Cultural Revolution. Only a very few of them were aware of this historic event. At that time, China had not even launched an object into space. But it was only nine months later when China launched its first satellite, DFH-1. For people in China and in the world of 45 years ago, a Chinese human lunar mission was far beyond imagination. In many Western people's minds, China was a poor, ignorant and backward country and had nothing to do with any advanced technologies and especially with space exploration. A Chinese copy of the Apollo mission was not even a dream. It was just an illusion.

This impression changed a little in 1975. In that year, China successfully launched and recovered a two-tonne-class satellite. This event raised speculation that China was developing its own human space capability. Influenced by crazy progress in the space race during the 1960s, some even predicted that China would make its first human space flight by 1980, and complete a manned lunar landing by the end of the last century. This prediction has been proven far too overly optimistic. Actual progress was much, much slower. China did have a human space programme in the 1970s (Shuguang) but it was suspended before 1980. In fact, over-optimism was not only true for China, but also for the leading spacefaring countries of the time. No-one has set foot on the Moon since Apollo 17 in 1972. The prospect of returning to the Moon became dimmer and dimmer, and the Moon looked further and further away.

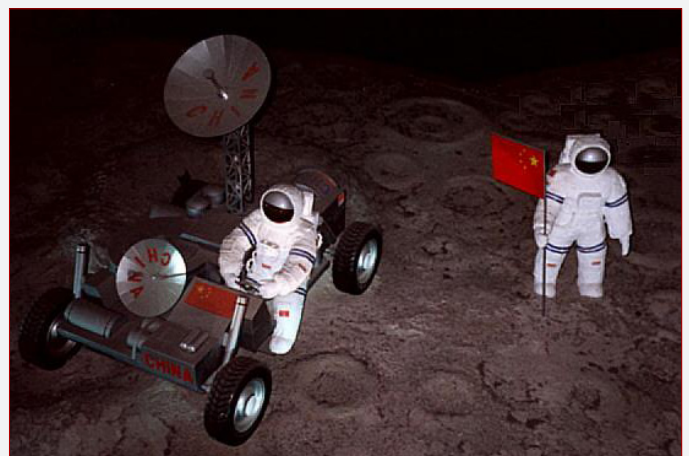
On 20 November 1999, China launched the first Shenzhou manned spacecraft and recovered it 21 hours and 23 minutes later. China's human space programme became a hot topic

again. A few months later, Expo 2000 was held in Hannover, Germany. To many people's surprise, space became the centre-piece of the China Pavilion. China not only displayed a model of an ambitious modular space station, but also two taikonauts on the lunar surface, one of whom was planting a Chinese national flag and the other driving a lunar rover. There was no official explanation on what the model really meant. At roughly the same time, Chinese scientists started to talk about the future lunar mission and even a lunar base in the Chinese media. Later developments have shown that most of these reports represented a personal point of view, or false reports that became mixed up with the unmanned lunar exploration programme (later named Chang'e). The model in Hannover was more symbolic than serious, which has been proven by the case of the space station model that had nothing to do with the space station design now made public. However, all these could be seen as clues that China, at that time, may have started internal and unofficial discussions on a manned lunar plan. The Chinese started to dream of landing on the Moon, though this was, and is, still very, very, far away.

First Serious Proposal

The first serious study related to a manned lunar mission was made public in 2005. On 19 and 20 November 2005, the 2nd annual meeting of the Specialty Committee on Deep-space Exploration of the China Astronautics Society was held in Beijing. Zhang Xiaoping and two other authors from the Academy of Aerospace Propulsion Technology (AAPT, the 6th Academy of CASC - China Aerospace Science and Technology Corporation), published a paper entitled *The Scheme of Propulsion System of Chinese Manned Lunar Rocket*. In this paper, the authors proposed three configurations of the rocket with a launch mass of about 2,800 - 3,000 tonnes and sea-level thrust of 35,000 - 40,000 kN. The three options were:

- **Option A:** 3.5-stage configuration with 5 m diameter



Models of taikonaut and lunar rover, displayed in the China pavilion in Expo 2000 in Hannover, Germany. (credit: Make Wade)

core stage. All stages and four strap-on boosters have a diameter of 5 m. The first core stage and boosters share a structurally similar design (like the Delta's Common Booster Core), and each provides a thrust of 7,000 - 8,000 kN from two LOX (liquid oxygen)/hydrocarbon (kerosene or methane) engines. The second stage uses LOX/hydrocarbon or LOX/LH2 engines to provide a thrust of about 5,000 kN, and the third stage is equipped with LOX/

LH2 engines with a total thrust of 1,000 kN.

- **Option B:** 3.5-stage configuration with 8 m diameter core stage. The first core stage has four 4,500 - 5,000 kN thrust LOX/hydrocarbon engines and the 5 m diameter booster each has one engine. Diameter and configuration of the second and the third stages are the same as Option A.

- **Option C:** 2.5-stage configuration with 8 m diameter core stage. The first core stage has four 1,500 - 2,000 kN thrust LOX/LH2 engines and the 5 m diameter booster each has two LOX/hydrocarbon engines providing 7,000 - 8,000 kN thrust. The second stage, in 5 m diameter, is equipped with LOX/LH2 engines with total thrust of 1,000 kN.

Table 1. AAPT Super-Heavy Launch Vehicle Proposal (2005)

	Option A	Option B	Option C
Launch Mass (tonne)	2,800-3,000	2,800-3,000	2,800-3000
Launch Thrust (tonne)	3,500-4,000	3,600-4,000	3,400-4,000
Boosters (number of)	4	4	4
Diameter (m)	5	5	5
Engine (each)	2 New	New	2 New
Propellant	hydrocarbon	hydrocarbon	hydrocarbon
Thrust (tonne, each)	700-800	450-500	700-800
1st Stage			
Diameter (m)	5	8	8
Engine	2 New	New	New
Propellant	hydrocarbon	hydrocarbon	cryogenic
Thrust (tonne)	700-800	4x 450-500	4x 150-200
2nd Stage			
Diameter (m)	5	5	5
Engine	4 YF-100	4 YF-100	2 YF-77
Propellant	hydrocarbon	hydrocarbon	cryogenic
Thrust (tonne)	4x120	4x120	2x50
3rd Stage			
Diameter (m)	5	5	
Engine	2 YF-77	2 YF-77	
Propellant	cryogenic	cryogenic	
Thrust (tonne)	2x50	2x50	

The paper concluded that Option B was the best choice among these three. It also proposed to develop a 5,000 kN (500 tonne)-class staged combustion LOX/kerosene engine, or a LOX/methane gas generator cycle engine with the same thrust, to be used as the super rocket's first stage. As for its second and third stage, the paper suggests using four YF-100 LOX/kerosene engines and two YF-77 cryogenic engines (YF-77) respectively, that were in development for the CZ-5.

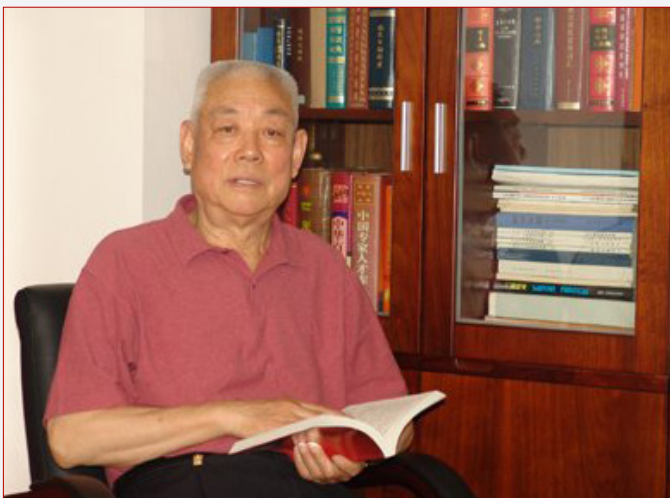
The paper did not indicate the launcher's orbit capability and other design requirements. They may be provided by other research groups or simply set following the design of the Saturn 5 and the N-1.

In 2006 in the 8th International Conference on Lunar Exploration and Utilisation in Beijing, Zhang Xiaoping, Zhang Guitian (a leading Chinese rocket engine scientist), and two other co-authors re-published the paper. But

this paper has only adjustments to the text, and has no major changes in launcher configuration. In April 2009, the same authors of the 2005 paper published a new paper in the *Journal of Rocket Propulsion* with a major optimisation of the three options. Their specifications are listed in Table 2. Note that the maximum thrust of the engines was reduced to 3,200 - 3,500 kN. The diameter of the second stage in Option B had increased to 8 m, and a new 1,500 kN cryogenic engine would be used for the second and the third stages.

CALT Takes the Leading Role

CALT is the most important launch vehicle developer in China. There is no reason for CALT to be behind AAPT in super-heavy vehicle research. In fact, in November 2006, Long Lehao, a renowned rocket scientist from CALT, mentioned in an article (*China's Space Access Capability: Current Status and Future Prospect*, Issue No. 11, *Engineering Science*) that an initial study



Zhang Guitian, China's renowned rocket engine expert. (credit: Chinese internet)



“Curiosity is The Essence of Human Existence”

By Hartmut Saenger

The TECHNIK MUSEUM Speyer, a technical museum in the South of Germany, is famous for its display of an original Russian Buran space shuttle, the original Soyuz TM-19 capsule, a scale model of the Columbus laboratory and the Spacelab training module. Since June of last year, it also has a piece of Moon rock in its collection. On the occasion of the inauguration of the new permanent exhibition area “The Moon”, NASA’s Apollo astronaut Eugene A. Cernan visited the museum and had a 3.4 Billion year-old piece from Earth’s neighbour in his luggage. The 177.258 gramme rock was collected by Apollo astronauts Dave Scott and Jim Irwin on 1 August 1971 at station 4, during the second lunar excursion walk of the Apollo 15 mission. Cernan, Commander of the Apollo 17 mission, left that rock in the TECHNIK MUSEUM Speyer, as a highlight of this special exhibition “The Moon” dedicated to the Apollo missions. On an artificial lunar surface, the first and the last lunar landings are represented. Cernan was part of the last manned lunar mission in 1972 and in his position as the Commander of the mission, was the last human to leave Moon.

After his talk, he allowed an extensive time for attendees of the inauguration to ask him questions. He gave a quite detailed answer to Hartmut E. Saenger’s (space author and editor for German space magazine “Raumfahrt Concret”) question:

“Mr. Cernan the next man on the Moon could be a Chinese? What do you think about it?”

Eugene A. Cernan's reply:

"Well, here you are right: The next man on the Moon may speak Chinese. And I guess that won't be so bad because I want to go to Mars, and we will. I am convinced that will be an international effort. And it will start with an international effort composed of those nations, American, Europe, that we call a Western civilised nation, maybe joined by Japan. And maybe joined by China. But in the interim it appears there is no particular special interest or drive within the Western world to go back to the Moon. And that hurts! That deeply hurts. I say that because recently I testified in front of Congress with Neil Armstrong, and we said that America has no real space programme today. We have a magnificent space laboratory up there, but we can't even get there until we borrow and pay for time from Russia. We can't even get our own piece of cargo there. But 50 years ago we walked on the Moon. And from what I best understand, Europe doesn't either. I am not

going to profess, that I know much about goals, missions or any plans. Talk! We all talk about going back to the Moon and on to Mars, but none of us is really doing anything about it. I will tell you how bad it is right now back at home, the last operational launch pad we launched on, the 39 A - I launched on 39A and 39B - NASA is now leasing. Is anyone interested in leasing a launch pad? This is how critical it is in my mind. Now having said all of that: the Chinese I can credit. Because their Asian mentality sets a goal and commits to it, and they remain steadfast, and if it takes 5 or 10 years it's gonna take 5 or 10 years. In the United States, every four years when we have an election we tend to cancel and restart, and cancel, and restart again. You cannot do that in space. Space has got to be a long-term commitment to the future. That is not so much about your future or my future, but it is more about the future of our kids. Let me end this by saying, I am a firm believer that whoever goes to the Moon next, that we will indeed in addition to that, go to Mars. I think we need to go to the Moon first because there is a lot we need to understand before going to Mars. But I firmly believe that there is a young boy, or a young girl out there - your kids, your grandkids, mine, somebody's - with the indomitable will and courage to one day take mankind, humankind, back to where we belong, back to where we have never gone before. It is in our psyche, it is in our nature. Curiosity is the essence of human existence. Who are we? Where are we? Where do we come from? Is

there life in outer space? Was there water on Mars? Was there life on Mars? We are naturally curious and this state of human beings goes back thousands and thousands of years. We see some of the evidence of this curiosity here is this museum. If that curiosity, the desire to discover, to know the unknown didn't exist I don't know where I would be today. I have no idea where I would be. Would Columbus have discovered America? I don't know! Today's efforts in space and the teamwork here in the museum are important. Never stop thinking about the future. “The dream of yesterday is the hope of today and the reality of tomorrow.”, as Goddard stated. Kids are the hope of the future. We need to stimulate their dreams to do things they didn't think would be possible. When JFK said we want to go to the Moon, there were many people who thought it could not be done. Guess what, we did it. I don't care what language we speak, what passport we hold, we are all the same. We can do it and we will do it!



Eugene A. Cernan during his talk in TECHNIK MUSEUM Speyer, Germany. (credit: Hartmut Saenger)

had been done with the conclusion that a manned lunar landing requires a super rocket with a launch mass of 2,800 tonnes, ground thrust of 35,000 kN and LTO capability of 50 tonnes. It is also necessary to develop a 500-600 tonne-class LOX/kerosene engine and a 200 tonne-class cryogenic engine. It was not until early 2008 that more details of the CALT research was made public. A paper entitled *Research on the Technical Approach of Manned Lunar Mission*, by Long Lehao, was published in Issue No. 1, 2008, *Missile and Space Vehicle*. Unlike the AAPT study that was focused on launcher and engines, it revealed the first serious research work on all the important aspects of a manned lunar mission. The paper studied four mission profiles with different launcher configurations and rendezvous and docking options. The following is a summary:

- **Direct to Destination (DTD) Approach:** The flight profile is identical to Apollo and the spacecraft is also similar, including a crew module, a lunar lander and a service module, with a total mass of 50 tonnes. It uses a single rocket to send the spacecraft into lunar orbit and needs a lunar orbit rendezvous and docking after the lunar surface mission is completed. There are four options for such a Saturn V-class super launcher (see Table 3 for details). It asks for the development of a new 400-500 tonne LOX/kerosene engine or a new 120 tonne LOX/LH2 engine.
- **Earth Orbit Rendezvous (EOR) Approach:** This approach needs multiple launches to put the spacecraft and separate parts of the lunar transfer stage (or EDS, Earth Departure Stage) into low Earth orbit, and assemble them there by multiple rendezvous and dockings. There are also two launcher options. The first option is to use the enhanced CZ-5 in which the four YF-100 and two YF-77 engines will be installed on the first and second core stages, and four 3.35 m diameter strap-on boosters will be used, each has two YF-100s. It will provide 1,440 tonnes

Table 2. AAPT Super-Heavy Launch Vehicle Proposal (2009)

	Option A	Option B	Option C
Launch Mass (tonne)	2,900	2,700	2,800
Launch Thrust (tonne)	3,500	3,200	3,400
Boosters (number of)	4	4	4
Diameter (m)	5	5	5
Engine (each)	2 New	New	2 New
Propellant	hydrocarbon	hydrocarbon	hydrocarbon
Thrust (tonne, each)	2x350	400	2x350
1st Stage			
Diameter (m)	5	8	8
Engine	2 New	New	New
Propellant	hydrocarbon	hydrocarbon	cryogenic
Thrust (tonne)	2x350	4x400	4x150
2nd Stage			
Diameter (m)	5	8	5
Engine	4 YF-100	New	New
Propellant	hydrocarbon	cryogenic	cryogenic
Thrust (tonne)	4x140	4x150	4x150
3rd Stage			
Diameter (m)	5	5	
Engine	New	New	
Propellant	cryogenic	cryogenic	
Thrust (tonne)	150	150	

of thrust and is able to deliver 50 tonnes to LEO. This option needs four launches and three dockings in LEO. The second option is to develop a 100 tonne-class super-heavy launcher. It is essentially the first option (see Table 3) in the DTD approach without the third stage and with minor changes in length and propellant mass. Two launches, one for the first stage of the EDS and another for the spacecraft and the second stage of EDS, and one LEO docking is needed. Once the EDS and spacecraft combination is assembled, the follow-on mission profile is the same as for the DTD approach (or Apollo mission profile). Please, note that the lunar orbit rendezvous and docking after lunar surface operation is always required, even though it is called the EOR option.

- **Lunar Orbit Rendezvous (LOR) Approach:** In this approach, three launches are needed to deliver the payloads into lunar orbit requiring two dockings to assemble them. The first launch is for the 10 tonne-class descent stage of the lander (including a pressurised crew cabin). The second launch is responsible for the 5 tonne ascent stage of the lander and the 5 tonne service module. The last launch is for the 10 tonne re-entry capsule for the crew. Once assembly in lunar orbit is complete, the follow-on mission profile is the same as that of the Apollo mission. The launcher needed for this option is also based on CZ-5. It is essentially a two-stage CZ-5 (without strap-on boosters) as its second and third stages, with the addition of a new first stage using four YF-100s and four boosters installed with two YF-100s.



Long Lehao, China's renowned launch vehicle expert. (credit: Chinese internet)

Table 3. Early CALT Super-Heavy Launch Vehicle Proposal for the DTD Approach

	Option A	Option B	Option C	Option D
Launch Mass (tonne)				
Launch Thrust (tonne)	3,500	3,200	3,680	3,500
LTO Capability (tonne)	50	50	50	50
Boosters (number of)	6	4	4	
Diameter (m)	5	3.35	5	
Engine (each)	New	New	2 New	
Propellant	LOX/kerosene	LOX/kerosene	LOX/kerosene	
Thrust (tonne, each)	500	400	2x400	
1st Stage				
Diameter (m)	5	7.5	8.5	10
Engine	New	New	4 New	7 New
Propellant	LOX/kerosene	LOX/kerosene	LOX/LH2	LOX/kerosene
Thrust (tonne)	500	4x400	4x120	7x500
2nd Stage				
Diameter (m)				7.5
Engine	4 YF-100	5 YF-77	4 New	5 YF-77
Propellant	LOX/kerosene	LOX/LH2	LOX/LH2	LOX/LH2
Thrust (tonne)	4x120	5x50	2x25	5x50
3rd Stage				
Diameter (m)				7.5
Engine	4 New	4 New		4 New
Propellant	LOX/LH2	LOX/LH2		LOX/LH2
Thrust (tonne)	4x25	4x25		4x25

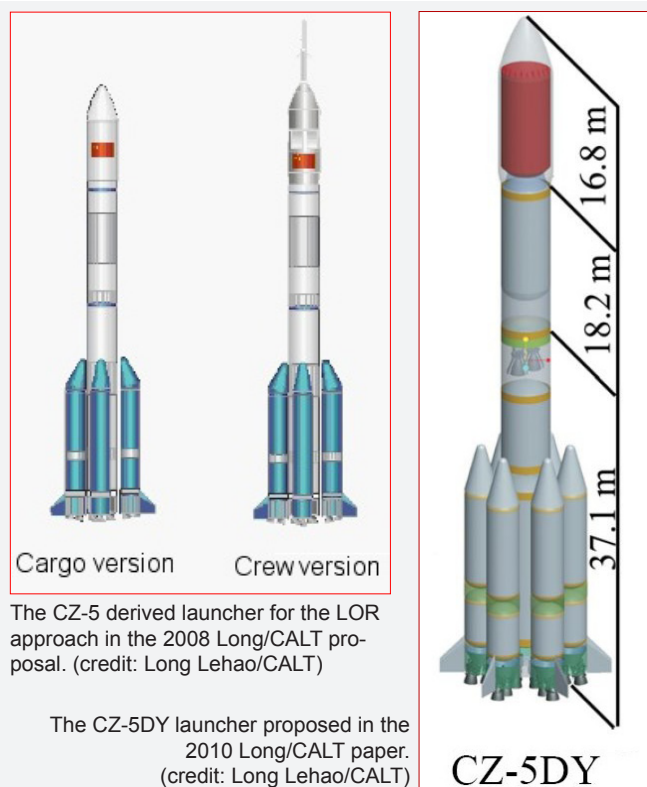
It is able to deliver 17 tonnes to LTO and 10 tonnes to lunar orbit. There is also another launcher option by adding two additional boosters to increase the lunar orbit capability to 15 tonnes.

• **Mixed EOR and LOR Approach:** In this approach, both the manned crew module and the lander have a mass of about 15 tonnes. They will be sent to the lunar orbit separately using a similar launch system. For each module, three CZ-5E (the largest CZ-5 variant with LEO capability of 35 tonnes) launches are needed - one for the crew module/lander and two for the two EDS stages. They will be assembled by two rendezvous and dockings in LEO. In lunar orbit, the crew module and the lander perform another docking. Using the 50 tonne LEO-class launcher in the EOR approach would reduce the total number of launches from 6 to 4.

The paper proposed a two-step manned lunar programme. The first step is to complete a manned lunar landing mission using the LOR approach that needs only a CZ-5 based launcher and would not need the development of new engines. And the second step is to develop a heavy-launch vehicle and establish a lunar transportation system using the DTD or the EOR approach. For the first step, the author also proposed three phases. The first being to send a Tiangong-class lab to lunar orbit to verify the launch system. The second phase is an unmanned mission with lunar orbit rendezvous and docking. And a manned lunar landing mission will be the last phase. At the end of the paper, the authors call for the development of key technologies, especially the 500 tonne-class engine, as early as possible.

Baseline Design Takes Shape

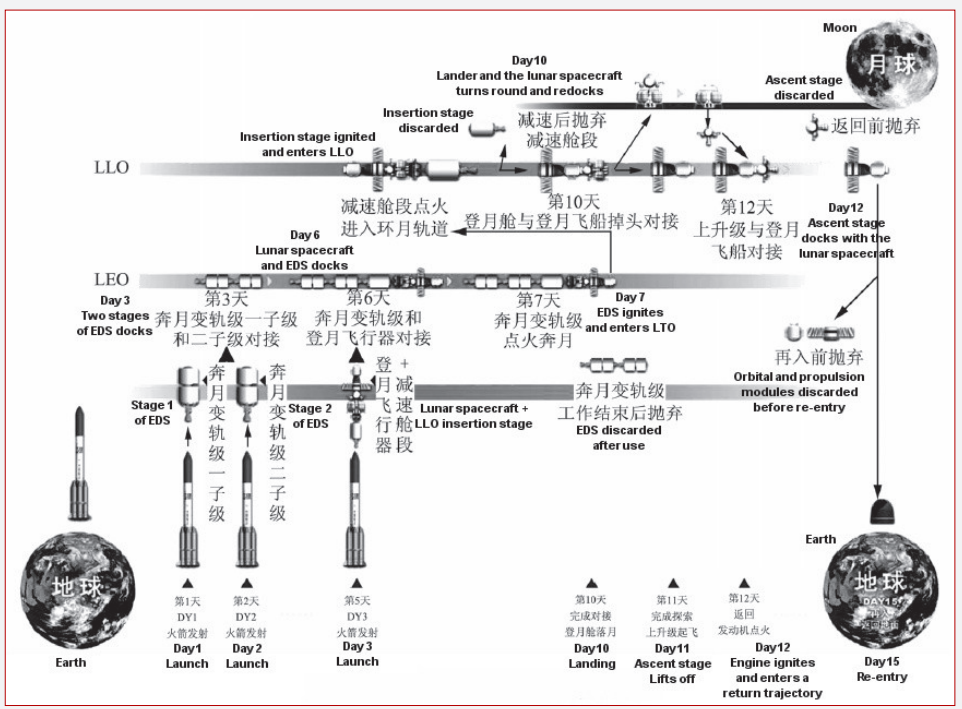
The Long Lehao proposal, or what can be seen as the CALT proposal, continued to evolve over time. In 2010, Long published a new paper in the Issue No. 6 of *Missile and Space Vehicle* entitled *On Issues of China Manned Lunar Exploration*. This paper kept the same two-step approach in which the first step is to realise a manned lunar landing mission with 2-3 people around 2025, while the second step is to establish a transportation system capable of sending and bringing back 4-6 crew to/from the Moon, and support them to stay on the lunar surface for a long duration, in the 2030s.



The CZ-5 derived launcher for the LOR approach in the 2008 Long/CALT proposal. (credit: Long Lehao/CALT)

The CZ-5DY launcher proposed in the 2010 Long/CALT paper. (credit: Long Lehao/CALT)

GO TAIKONAUTS!



The manned lunar landing mission profile using CZ-5DY shown in the 2010 Long/CALT paper. (credit: Long Lehao/CALT)

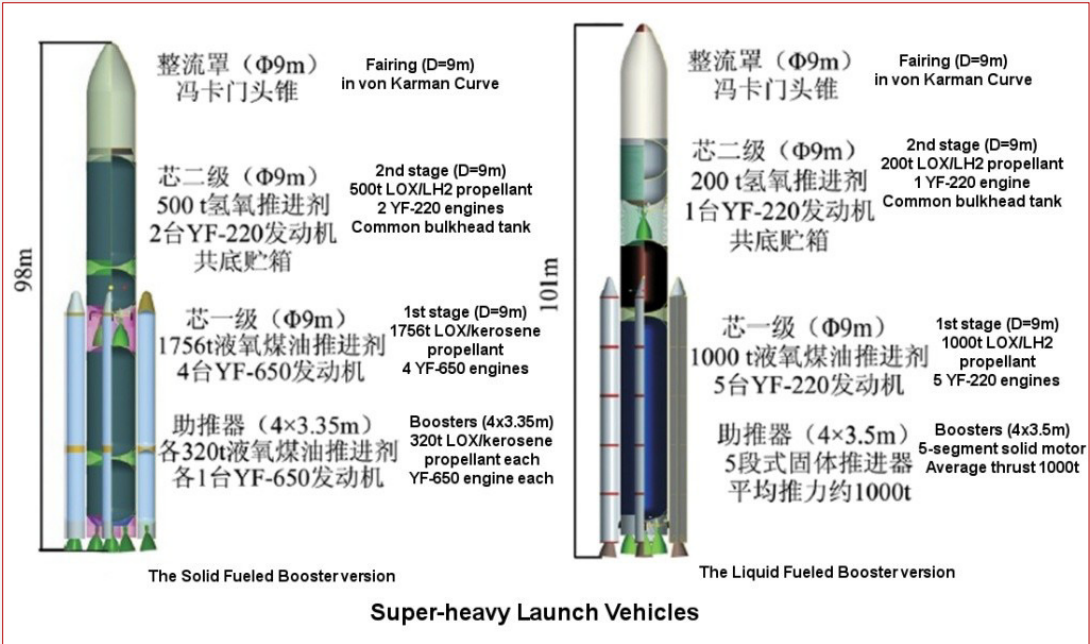
launch with the lunar spacecraft including a crew module, a service module, a lander and a lunar orbit insertion stage. These would be assembled through two rendezvous and dockings. Long named this enhanced CZ-5 launcher CZ-5DY, here DY means lunar (Yue - Moon) landing (Deng - land, as verb) in Chinese. The mission profile is shown in the diagram here.

For the second step, Long proposed a two-launch EOR approach and detailed two super-heavy launcher designs in the paper. These two launchers, with one using liquid-fuelled boosters and the other solid rockets as boosters, are purely for cargo, and are impressively larger and probably the largest Chinese launchers ever proposed. Both have a 9 m diameter core. Launch mass and ground thrust of the both launchers are around 4,000 tonnes and 5,000 tonnes respectively. Their LTO, GTO and GEO capabilities are 52, 66, 36 tonnes respectively.

For the first step, Long's 2010 paper switched to the EOR approach from the 2008 LOR approach. The launcher is also based on CZ-5, similar to the first launcher option in the 2008 EOR approach but the number of 3.35 m diameter boosters was increased to six and the number of YF-77 engines on the second stage increased to four. It has a height of 72 m and a launch mass of 1,600 tonnes, and would be able to send 50 tonnes to LEO. Using this launcher, two unmanned launches are required to put the two stages of the EDS to LEO and one manned

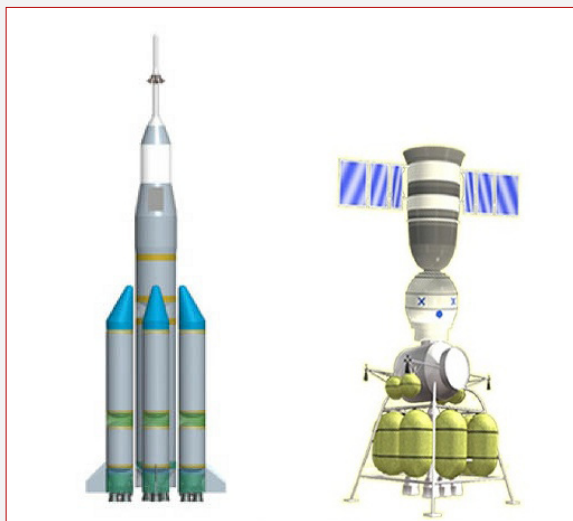
Their engines are remarkable. Labeled YF-650 and YF-220, the proposed LOX/kerosene and LOX/LH2 engines used by the two launchers imply thrusts of 650 and 220 tonnes (the latter turned out to be 200 tonnes later). This would be a giant leap forward for China from the existing YF-100 (120 tonne-thrust) and YF-77 (50 tonne-thrust) engines. The proposed 5-segment solid boosters are also impressive, having a thrust of 1,000 tonnes. In addition, the paper proposed a separate CZ-5A launch for

the crew vehicle that would dock with the EDS at Earth orbit.



Two super-heavy launch vehicles (left: solid, right: liquid-fuelled) proposed in the 2010 Long/CALT paper. (credit: Long Lehao/CALT)

Just two months later, Long and two co-authors published another paper entitled *Heavy Launch Vehicle and Its Application* in Issue No. 1, 2011 of *Missile and Space Vehicle*. This paper discussed only the super-heavy launcher, planned for the second step as described in the 2008 and 2010 paper. It compared 7 configurations and concluded that the all-kerosene and solid + cryogenic (ground stage) configurations were the best choices, the same conclusion



The CZ-5A manned launch vehicle and the Shenzhou derived lunar spacecraft in the 2010 Long/CALT paper. (credit: Long Lehao/CALT)

as the 2010 paper. The paper provided more parameters as listed in the first two columns in Table 5. Compared with the 2010 proposal, the two launchers had minor changes. Height of the solid version increased to 108 m from 101 m and the engine designator YF-650 becomes YF-660. Launched from Wenchang, the two launchers are able to deliver 130 tonnes to LEO with an inclination of 110 degrees, and 50 tonnes to LTO. It is interesting to note that the authors also discussed possible unmanned and manned Mars missions, and planetary missions using this super rocket.

The 2010/2011 Long Lehao/CALT proposal seemed an important milestone representing that a certain consensus had been made within CALT or in an even larger circle. It sets a baseline for work afterwards and became the origin of the CZ-9 design revealed semi-officially by CALT in 2012.

Other Studies

The manned lunar landing mission not only involved AAPT and CALT, but also attracted other space organisations and universities in China, including CALT's long-time rival SAST.

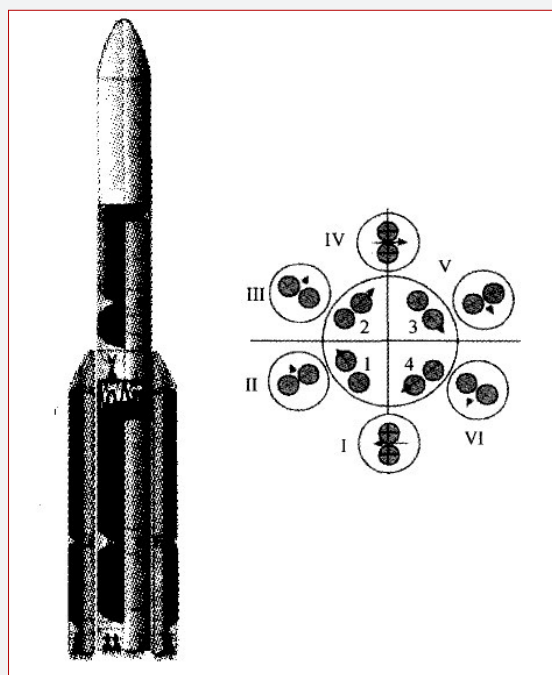
Researchers from the Institute 805 of SAST published a paper entitled *Study on Modes of Manned Lunar Landing Mission* in the January issue, 2009 of *Journal of Astronautics*. Similar to the 2008 CALT paper, it also compared DTD, LOR, EOR and mixed LOR/EOR approaches with seven options. It calculated mission failure and loss of crew possibilities, and concluded that the two-launch, cargo and crew separated option (similar to the Ares 1/ Ares V design) is the best choice for future Chinese manned lunar exploration. As the super-heavy launcher is difficult to be developed in a short time, it proposed to use the 4 or 3 launch EOR+LOR approach for the so-called "limited scale mission", or short-stay mission like Apollo had done.

In 2012, a new SAST paper, entitled *Research on General Scheme of Launch Vehicle for Manned Lunar Mission*, appeared in the Issue No. 4 of *Aerospace Shanghai*, SAST's

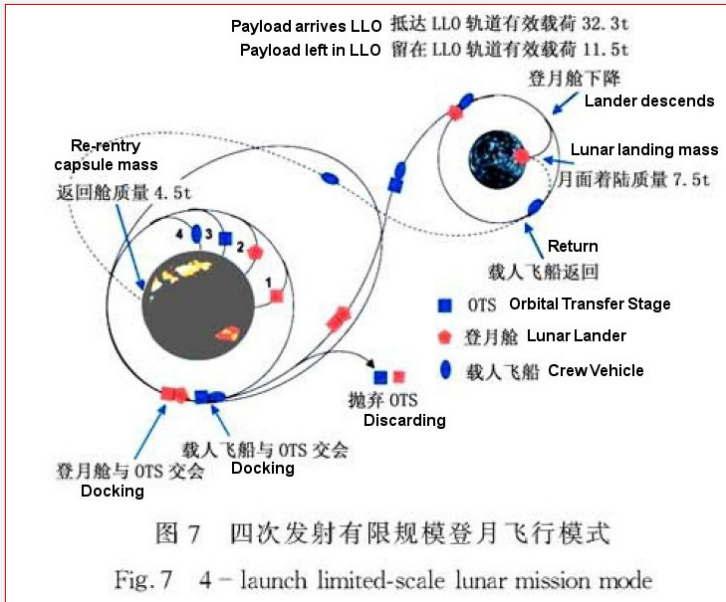
own academic publication. The paper assessed requirements of the launcher for manned lunar landing missions and current Chinese launch vehicle technologies. It concluded that the three-launch mission profile is the most appropriate choice for China - notably consistent with the near-term solution in the above 2009 SAST paper. To support such a mission, the author of the paper proposed an 80-100 tonne-class launch vehicle with a core stage diameter of 7 metres. It asked for the development of a 400 tonne thrust LOX/kerosene engine with designator of YF-400, and a new cryogenic engine with a thrust of 70 or 100 tonnes. This configuration is quite interesting because its capability is between CALT's CZ-5DY and CZ-9 proposals. Was SAST trying to compete with CALT for the super launcher design in a differentiation strategy? In fact, this SAST proposal is more capable than the CZ-5DY and less difficult to develop than the CZ-9.

Outside of CAS, BUAA (Beijing University of Aeronautics and Astronautics, also known as Beihang University) published a paper in the Issue No. 1, 2011, *Journal of Aerospace Power*. The paper, entitled *Basic parameters analysis of first stage engine system for heavy lift vehicle*, analysed propulsion requirements of the manned lunar launcher and proposed four configurations with a thrust of 20,000 - 50,000 kN and LEO capability of 75 - 168 tonnes. The recommended configuration is quite similar to CZ-9 that has a 8 m diameter core with four 500 tonne-class kerosene engines and four strap-on boosters with one engine.

The National Defence Science and Technology University made a study focused on the mission profile and published its result in the Issue No. 5, 2012, *Aerospace Shanghai*. The paper, entitled *Analysis on Manned Lunar Mission Flight Mode*, has a similar conclusion to what CALT and SAST had done, that the two launch, cargo and crew separated option is the best choice.



The super-heavy launch vehicle proposed by SAST in 2012. At the right is the engine arrangement of the ground stage. (credit: Cai Yifei/SAST)



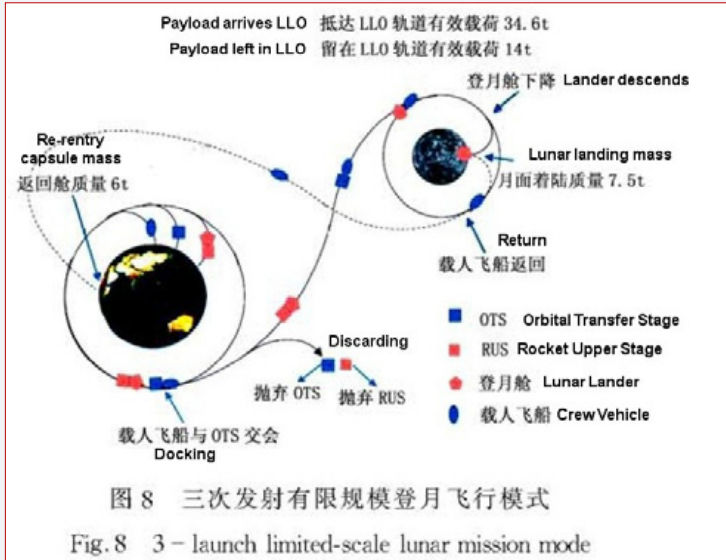
Three manned lunar landing mission profiles proposed by SAST in 2009: the 4-launch limited scale mission, the 3-launch limited scale mission and the 2-launch large-scale mission. (credit: Sheng Yinghua, Zhang Xiaodong, Liang Jianguo, Zhao Jincai/ SAST)

While considering current technology limitations, the four-launch EOR approach is more realistic for near-term manned lunar landing missions.

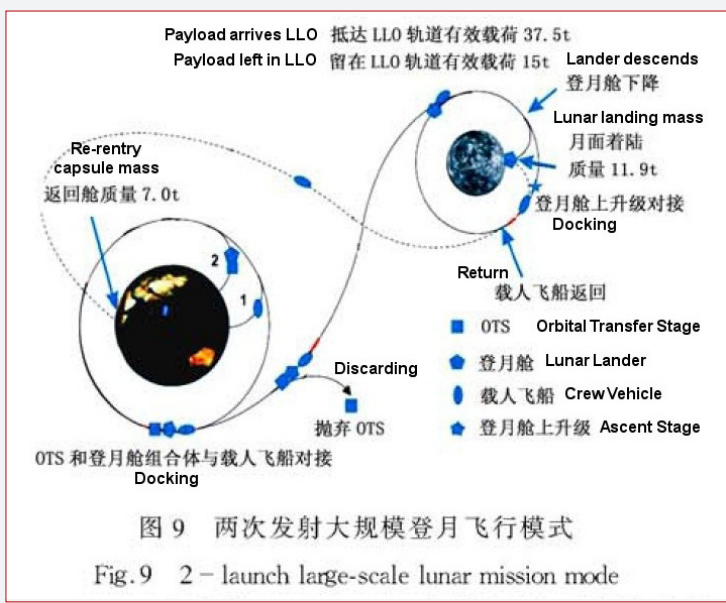
Although SAST and other research bodies have put efforts into studying manned lunar mission architectures, it is unlikely that CALT will lose its leading role in the field.

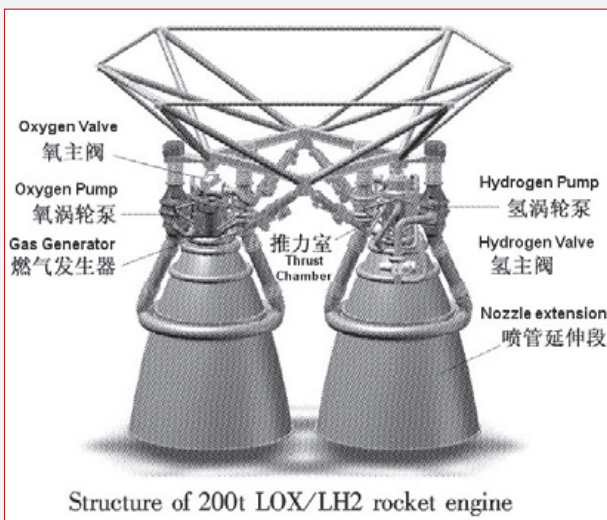
Propulsion First

Assigning a designator to an engine usually means the existence of a formal project, or that it has been funded. That the YF-650/YF-660 and YF-220 designators appeared in the 2010/2011 CALT papers was not accidental. Chinese space industry has an understanding of the difficulties in engine development and had reached a consensus since the early years that engine development must start much earlier than the development of a new launcher, which is simply concluded as a philosophy called "Propulsion First". It happened on the manned lunar programme too, representing substantial progress. Since 2010, we have seen more and more clues and evidence indicating that pre-study or even hardware development of the new engine for the super rocket have been underway.

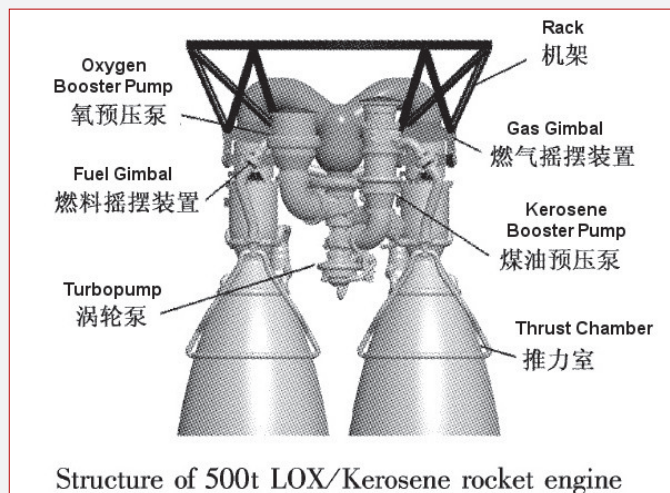


In fact, many academic papers related to the 500 tonne-class engine have been published by AAPT after its 2005 proposal. In 2011, three AAPT authors including Zhang Xiaoping who published the first paper related to the manned lunar mission in 2005, published a paper in Issue No. 1, 2011, *Human Space Flight*. The paper is entitled *Research on High Thrust LOX/kerosene Rocket Engine, A Main Power System of Manned Lunar Project*. In this paper, the authors detailed their proposal of a 600 tonne-class thrust LOX/kerosene engine. The engine will inherit technologies developed for the YF-100 and will use a stage combustion cycle and after-pump gimbaling mechanism for thrust vectoring. It will have one gas pump, two gas generators and two thrust chambers. So it will be easy to derive a 300 tonne-class engine using all the same components except for the gas pump. Its ground thrust is 6,600 kN that is consistent with the designator of YF-660 (or YF-650) in the CALT papers. Table 4 lists their primary parameters.





The YF-220 engine. (credit: Tan Yonghua/AAPT)



The "YF-480" engine. (credit: Tan Yonghua/AAPT)

Also in 2011, Tan Yonghua, Head of AAPT, published a paper entitled *Research on power system of heavy launch vehicle in China* in Issue No. 2, 2011, *Journal of Rocket Propulsion*. In this paper, the author not only mentioned the 6,600 kN LOX/kerosene engine that is identical to the above paper, but also provided details of the proposed 200 tonne-class cryogenic engine. The new LOX/LH2 engine will use a gas generator cycle and after-pump gimbaling and will provide a thrust of 2,000 kN.

A particularly interesting development happened on 18 June 2012 when China Space News reported that CASC had completed a review on the proposal of a new engine, designed by AAPT, on 20 June 2011, one year before the report. To prepare the review, AAPT built a wooden mock-up that took them six months. The wooden engine consumed 20 cubic metres of wood. When it was finally assembled, many experts were shocked by its size, the report stated. It was for the first time confirmed that the new engine has virtually left the drawing board. At the end of the year, a photo emerged on the Chinese internet showing a Chinese space official inspecting AAPT with a very large engine in the background. Speculated from its size, it is very likely the 500-600 tonne-class LOX/kerosene engine mock-up reported in June.

In September 2012, another report stated that Institute 11 of AAPT had delivered the first marked-up 3D design files of the engine for the super-heavy launcher. AAPT formed the Integrated Product Team (IPT) in February 2012 and established

digital design specifications, completed system static parameter calculation, ignition process simulation, 3D modelling and interface size determination for the engine's major components. On 29 May 2013, China Space News had another report that the gas gimbaling installation on the 500 tonne-class LOX/kerosene engine had made a successful hot test-firing. It was a major breakthrough on one of the new key technologies - after-pump gimbaling. It also marked that the super engine project has basically completed concept analysis, key technology study and determination, and entered the phase of component design, manufacture and testing. The report also revealed that the engine development started in 2010. So far, the existence of a formal development programme for the super-engine had been confirmed. But it is still unknown to what level, AAPT, CASC or governmental level, the project is funded.

Research and development of the 200 tonne-class cryogenic engine was far behind the kerosene engine. In 2012, a paper entitled *Fundamental Research on System Scheme of Next-generation High Thrust LOX/LH2 Rocket Engine*, published in Issue No. 1, *Missile and Space Vehicles*, disclosed some specific parameters of the cryogenic engine (see Table 4). On 29 January 2013, CALT announced that it will develop a 220 tonne thrust LOX/LH2 engine to be used in the future super-heavy launch vehicle. But there have been no reports except for academic papers regarding substantial development.

With respect to a segmental solid booster, China has been working on it for years. China successfully test-fired a 1 m diameter, 2-segment solid motor demonstrator in April 2010 and a 2 m diameter, 3-segment motor in July 2011. They were developed by the Academy of Aerospace Solid Propulsion Technology (AASPT), or the 4th Academy of CASC. But the larger solid booster for the manned lunar launch vehicle is still a concept. AASPT published a paper in Issue No. 1, *Human Space Flight*, entitled *Study on Large Solid Booster Technology for Heavy Launch Vehicle*. In this paper, it proposed a 49 m long, 3.5 m diameter, 5-segment solid booster with a thrust of 1,000 tonnes.

Table 4. Parameters of Planned New Engines

	YF-330	YF-660/650	YF-480	YF-220
Sea Level thrust (kN)	3,300	6,600	4,800	2,000
Vacuum thrust (kN)	3,594	7,187	5,218	2,460
Sea Level impulse (m/s)	3000	3000	3000	
Vacuum impulse (m/s)	3,267	3,267		4,165
Thrust chamber pressure (MPa)	20	20		10.5
Mass (kg)				3080

Note: YF-480 is an assumed designator according to its thrust.



Officials inspect AAPT. A large engine mock-up, suspected to be a 500 tonne-class engine, is in the background. (credit: AAPT)



The 1 m diameter segmental solid motor. (credit: Ye Dingyou, Gao Bo, Gan Xiaosong, Wang Jiannu/AASPT)

Long March 9 and A Scaled Down Plan

In early March 2011, during the China's National Congress's annual session, Liang Xiaohong, a top official in CALT revealed that China was undertaking pre-studies of a heavy launch vehicle with a LEO capacity of 130 tons. It is mainly for manned lunar landing and deep-space exploration. According to the report, the studies started in early 2011 and the project is expected to be approved during the twelfth five-year plan (2010-2015). From then on, there were a lot of reports related to the ambitious plan but there has been no news for formal approval of this very expensive programme.

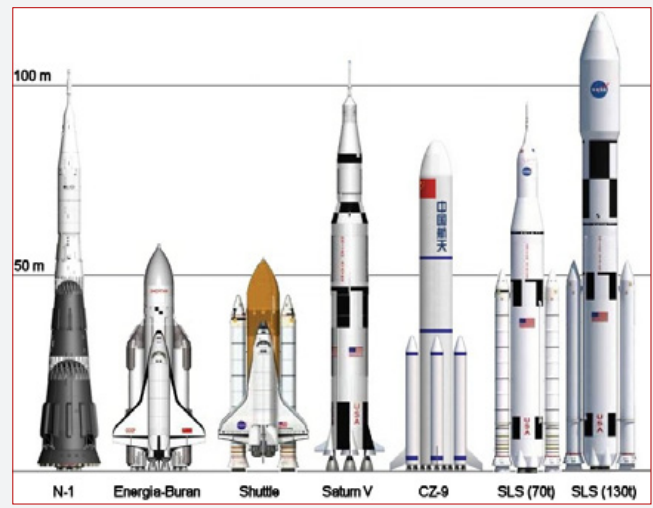
In early 2012, a report from CASC entitled *Social Responsibility Report on 2011* revealed two launcher designators in an illustration, one of which is Long March 9 (CZ-9), the super-heavy launch vehicle with an estimated height of more than 80 m, a core stage with an estimated diameter of around 8 m and four strap-on boosters with an estimated diameter of 3.35 m. The illustration showed that the solid booster design may have been

dropped. Although assigning the designator was later proven to be related to only internal funding for pre-study inside CASC, it was actually a signal that the manned lunar landing mission had been more or less with the government's support. Another message, revealed during the same time period, was that the planned super-heavy launcher had been downsized. The 660 tonne-class engine disappeared from the media and was replaced with the "500 tonne-class" engine that was confirmed to be 480 tonnes exactly, in a paper entitled *Research on Large Thrust Liquid Rocket Engine*, published on the October 2013 issue of *Journal of Astronautics*.

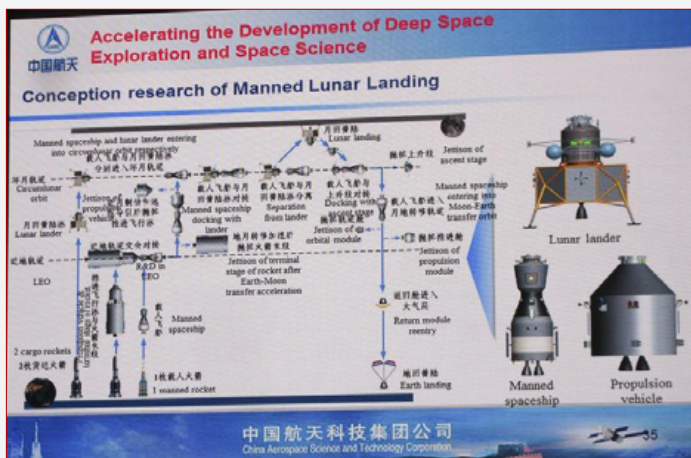
Although there was an unofficial message circulating on the internet in mid-2013, stating that the human lunar landing project had failed to be approved in a recent Chinese government decision-making process, during the 64th International Astronautical Congress (IAC 2013) held in Beijing on 23 - 29 September 2013, Chinese officials, in plenary speeches, still listed the manned lunar mission and the super-heavy launch vehicle as future objectives. They also showed two slides



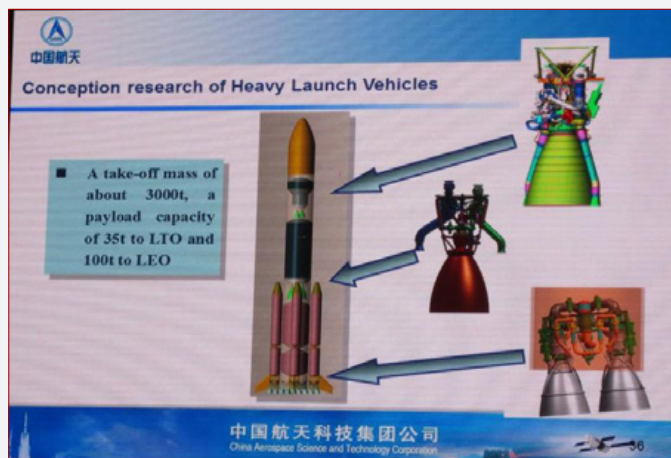
The illustration in the "Social Responsibility Report on 2011" of CALT, showing the CZ-9 designator for the first time. (Credit: CALT)



Comparison of CZ-9 and other super-heavy launchers in history and in development. (credit: Go Taikonauts!/NASA)



The PPT slide showing the Chinese manned lunar landing mission profile in IAC 2013. (credit: CASC/Go Taikonauts!)



The PPT slide showing the super-heavy launch vehicle in IAC 2013. (credit: CASC/Go Taikonauts!)

Table 5. CALT Super-Heavy Launch Vehicle (CZ-9) Specifications

	Solid + Cryogenic Proposal	All-kerosene Proposal	Final Scaled Down All-kerosene Proposal
Launch Mass (tonne)	4,150	4,100	3,000
Launch Thrust (tonne)	5,000	5,200	3,840
Height (m)	108	98	83 (estimated)
LEO Capability (tonne)	133	130	100
LTO Capability (tonne)	50	50	35
Boosters (number of)	4	4	4
Diameter (m)	3.35	3.35	3.35
Engine (each)	New	YF-660	YF-480
Propellant	Solid	LOX/kerosene	LOX/kerosene
Thrust (tonne, each)	1000	650	480
1st Stage			
Diameter (m)	9	9	8.5 (estimated)
Engine	5 YF-220	4 YF-660	4 YF-480
Propellant	LOX/LH2	LOX/kerosene	LOX/kerosene
Thrust (tonne)	5x200	4x650	4x480
2nd Stage			
Diameter (m)	9	9	8.5 (estimated)
Engine	YF-220	2 YF-220	2 YF-220
Propellant	LOX/LH2	LOX/LH2	LOX/LH2
Thrust (tonne)	200	2x200	2x200
3rd Stage			
Diameter (m)			8.5 (estimated)
Engine			2 YF-77
Propellant			LOX/LH2
Thrust (tonne)			2x50

Note: YF-480 is an assumed designator according to its thrust.

with more details of the plan. One presentation slide showed a Moon landing flight profile using two cargo launches and one manned launch, a newly designed Apollo-like manned spacecraft, and two dockings using both Earth Orbit Rendezvous (EOR) and Lunar Orbit Rendezvous (LOR) approaches. Another slide showed that the super-heavy rocket (Long March 9), a three-and-a-half stage launcher, will have a launch mass of around 3,000 tonnes, and LEO/LTO capability of 100 and 35 tonnes respectively.

If one compares the new details from IAC 2013 with the last proposal (2011 CALT proposal), many differences can be found that are listed below:

- The launch vehicle has a to three increased number of stages but is significantly smaller, as circulated from early 2012. Its take-off mass decreased to 3,000 tonnes from 4,100 tonnes in the 2011 proposal. LEO and LTO capabilities were reduced to 100 tonnes and 35 tonnes respectively (previously 130 tonnes and 50 tonnes). Also, engine thrust is supposed cut as well, from 650 tonnes to about 500 tonnes. More specifications were revealed



in the above mentioned paper in the October 2013 issue of *Journal of Astronautics* (see last column of the Table 5).

- The mission profile was also changed. It is now a mixed EOR/LOR approach with two cargo launches and one manned launch. One CZ-9 will send the lunar lander directly to the circumlunar orbit. Another CZ-9 will launch the EDS together with a lunar orbit insertion stage into LEO and wait for the manned vehicle, launched by a manned version of CZ-5, for a LEO docking. Once they are docked, the EDS will send the manned vehicle - insertion stage combination to a translunar trajectory (or LTO). At lunar orbit, it docks with the lander and then performs the “standard landing procedure” (refers to Apollo for simplicity) until the return to the Earth.
- It was the first time a new design of the crew vehicle was seen. In contrast with the Shenzhou type spacecraft with an enlarged propulsion module seen in previous proposals, the new design’s re-entry capsule looks more like an Apollo command module and the orbital module changed from cylindrical to cone-shaped.

The reason behind the changes could be both technological and financial. The new mission profile looks like a merging of the CZ-5DY based short-term approach and the CZ-9 based eventual solution, eliminating the unnecessary cost of developing two different systems. The smaller launcher also reduced cost and technical risks. The only loss is that CZ-9 will never be the largest rocket in world history - it really does not make sense.

Long Waiting Continues

There were also many papers related to the Chinese manned lunar missions that were submitted to IAC 2013. Unfortunately, some of them were outdated, for example, Long Lehao had a paper entitled *Heavy Launch Vehicle and Its Application*, that was almost identical to his 2011 paper at *Missile and Space Vehicle*, except for translation from Chinese to English. Two papers, one

on mission profile analysis and one on solid boosters, looked also like a repeat of old papers in Chinese. However, some other papers are quite interesting, indicating extensive work has been done in China for the human lunar mission. One paper presented an in-depth analysis on dynamic characteristics of the two-stage EDS and the docking mechanism. Although this analysis is based on an early 3-launch, 2-docking EOR proposal, it still has great value for any future docking with a large mass. Another paper did an orbit calculation and optimisation for a possible lunar landing at the Moon’s far-side in the future.

At the same time when the research on a manned lunar mission moves on, China’s robotic lunar exploration has made rapid progress. In December 2013, Chang’e 3 made a successful landing on the Moon. The mission was seen as very successful even though the Yutu rover encountered a malfunction in the second lunar day. If you look at the Chang’e 3 lander, you will find that it seems unreasonably large, and quite similar to the Apollo lander. Furthermore, the lander of the planned lunar sample vehicle Chang’e 5 is almost identical to that of the Chang’e 3, with the addition of an ascent stage. Its mission profile is almost identical to that of Apollo. The logic behind such designs is very clear - using robotic lunar vehicles as a prototype and test-bed for the future manned vehicle, which will significantly reduce development cost and save time. It is also a proof that Chinese space planners have seriously placed the manned lunar landing as an ultimate objective.

In early December 2013, just after the successful launch of the Chang’e 3 lunar probe, Chinese media reported that China’s manned lunar programme had been cancelled. Days later, officials from CLEP (China Lunar Exploration Program) denied the report, saying cancellation was completely untrue because the plan has not yet been approved and consequently does not exist at all.

From January to April 2014, Liang Xiaohong, Head of CALT, disclosed more information on the project on many occasions. He said that they had been pushing for the super-heavy



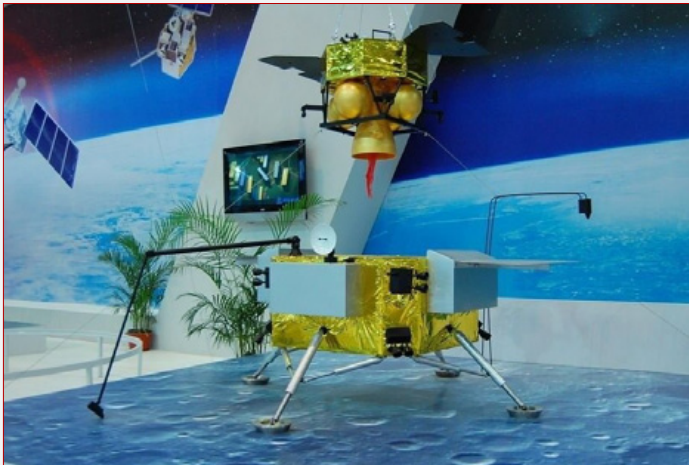
The Chang'e 3 lander on lunar surface. (credit: CLEP/Xinhua)



launcher project's approval and funding since 2013, which is expected to be completed in 2014, or at the latest by 2015. If all goes smoothly, its maiden flight will take place as early as 2028. He did not mention the manned lunar mission, but people all know that the launcher is primarily for that purpose. It shows that China will not change its course easily once a long-term plan has been drawn up. Other signs of the manned lunar project being kept alive at a certain level is a report in early April 2014, that a team led by the Joint Deep-Space Research Centre of the Ministry of Education, was developing a prototype of a manned lunar rover that was publicly displayed in an exhibition; and a news on Beihang University's Bioregenerative Life Support System laboratory named "Yuegong 1" (Moon Palace 1) that was interpreted by the media as a lunar base prototype. The key decision may be made just after 2017 when the last step in the robotic lunar plan - the sample return mission – is completed in

2018. Considering its foreseeable huge cost and less practical returns, this should be a tough political decision. No one knows what will happen, even in China. Any changes, including a permanent delay or cancellation, will not be a surprise.

Even without counting the early days, the Chinese manned lunar programme has evolved for more than eight years since the first serious proposal was made public in 2005. Compared with the Apollo programme, this was long. But if compared with other manned lunar efforts, for example the Constellation Project of the U.S. that is now halted, it was not that long. The expected government approval of the mega launcher will be a very important milestone. But still, it will just be the end of the beginning. We have to wait for more than a decade, at least, to see if the Chinese Apollo dream is to be realised. So, let's be patient, and patient.



Scale model of the Chang'e 5 lander and the ascent stage displayed in an exhibition. (credit: Chinese internet)



The manned lunar rover, developed by a joint team of the Ministry of Education, displayed in an exhibition. It adopted a foldable design. (credit: Chinese internet)

An Agreement to Disagree

by Andrew Johnson

This article highlights recent events of significance regarding the evolution of the U.S.-China relationship in space and the ideological divide between NASA and Congress.

Background of the restrictions

A provision included in appropriation bills originating in the 2011 Continuing Resolution (i.e. NASA's 2012 Fiscal Year budget) prohibits any form of bilateral cooperation between NASA and any organisation remotely linked to the Chinese space programme. According to the provision, drafted by Congressman Frank Wolf (R-Va.), the agency cannot, "develop, design, plan, promulgate, implement, or execute a bilateral policy, programme, order, or contract of any kind to participate, collaborate, or coordinate, bilaterally in any way with China" [1].

The policy immediately met opposition from NASA administrator Charles Bolden who - in a testimony to Congress in November 2011 - stressed that, "Some level of engagement with China in space-related areas in the future can form the basis for dialogue and cooperation in a manner that is consistent with the national interests of both our countries, when based on the principles of transparency, reciprocity and mutual benefit" [2]. As a result, an interesting 'agreement to disagree' between NASA and Congress has characterised the agency's view of (and response to) the restrictions (hereafter referred to as the Wolf Amendment).

Recent developments

(1) A dialogue between NASA administrator Charles Bolden and CNSA administrator Xu Dazhe at January's International Space Exploration Forum.

(2) The establishment of a "Forum for New Leaders in Space Science" between the Chinese Academy of Sciences and National Academy of Sciences (CAS-NAS).

(3) The recently announced retirement of congressman Frank Wolf.

(1) Bolden Meets with Xu Dazhe

In autumn last year, during the 64th International Astronautical Congress (IAC) in Beijing, Charles Bolden met with Bai Chunli, the President of the Chinese Academy of Sciences (CAS). The academy's website stated that the two administrators "exchanged frank opinions on pragmatic co-operation in relevant fields in the future" [3]. It was reported that the two countries will continue cooperating on space geodesy, but details on the extent of these efforts remain muted.

At this year January's International Space Exploration Forum (hosted by the U.S. State Department) Charles Bolden had an encounter with CNSA Administrator Xu Dazhe. At the conclusion of the gathering, Bolden told the press that NASA was in the process of trying to "find different ways we can be a partner to them (China)", later stating that the Wolf Amendment is "not going to change; not today, anyway" [4]. While from a legislative point of view nothing significant has occurred since 2011 to compel a revision of the Wolf Amendment, NASA has maintained an obvious ideological disquiet with the legislation.



During the Heads of Agency summit in Washington, a public event involved all heads in 4 roundtable discussions. In the roundtable on "Low Earth Orbit and Beyond", both Charles Bolden and Xu Dazhe participated. From the left: moderator Clayton Mowry, President Arianespace Inc.; Luis Valero Artola, Secretary General of Industry and Small and Medium Enterprises, Ministry of Industry, Energy and Tourism in Spain; Xu Dazhe, Administrator China National Space Administration; Kiran Kumar, Director Space Applications Centre on behalf of Koppillil Radhakrishnan, Chairman of ISRO - Indian Space Research Organisation; José Raimundo Braga Coelho, President Brazilian Space Agency; Marius-Ioan Piso, President Romanian Space Agency; Seung Jo Kim, President Korea Aerospace Research Institute; Jean-Yves Le Gall, Director General CNES - French Space Agency; Charles Bolden, NASA Administrator. (credit: Go Taikonauts!)

The meeting is significant because it signifies NASA's commitment to an on-going dialogue despite the Wolf Amendment. The reason Bolden was allowed to meet with Xu is because the ISE Forum was an event funded and hosted by the U.S. State Department, which does not prohibit such a meeting.

(2) NAS-CAS "Forum for New Leaders in Space Science" Programme

The Wolf Amendment also prohibits "any joint scientific activity between the two nations that involves NASA or is coordinated by the White House Office of Science and Technology Policy (OSTP)" [1]. But science has a tendency to resist confinement to boundaries.

The recently announced NAS-CAS "Forum for New Leaders in Space Science" is focused on building "informal bridges between the space-science communities in China and the United States" [6]. The development resembles the trajectory of early U.S.-Soviet space cooperation, which began in 1959, when the National Academy of Sciences and the Soviet Academy of Sciences established bilateral cooperation [7]. U.S.-Soviet scientific cooperation on topics including Earth, atmospheric and solar physics served as a confidence building mechanism between the two countries. The exchange of scientific information contributed to increased confidence and the eventual establishment of formal space cooperation.

(3) Wolf to retire from Congress

The Wolf Amendment was established based on some combination of concerns regarding the transfer of sensitive technology and a genuine distaste of the Chinese government's approach to human rights and treatment of political dissidents. It is clear that the latter aspect of these concerns is primarily motivated by Wolf's ideological vendetta with the Chinese government, which he has maintained through thick and thin. Remarks made by Frank Wolf, himself have made this obvious. For instance, when interviewed about the reasoning behind the restrictions in 2011, Wolf stated that, "frankly... it boils down to a moral issue. ... Would you have a bilateral program with Stalin?" [1]. We should not be surprised that Wolf has allowed his distaste with the Chinese government to leak into his policy decisions.

In January, Congressman Frank Wolf - Chairman of the House Appropriations Commerce-Justice-Science (CJS) that oversees NASA's budget - announced that he will not seek re-election in 2014 [8]. It remains to be seen whether Mr. Wolf's departure will result in a significant congressional change of posture towards China. This seems unlikely given that the U.S. House of Representatives is home to a highly motivated chorus of policy makers who have wholeheartedly maintained anti-China positions on everything from trade and finance to technology and corporate mergers.

Addressing the 'perceived risks'

In addition to shutting down important channels of interagency communication between NASA and its Chinese counterpart, the restrictions have created an environment of heightened suspicion and general mistrust between the two countries. In

order to understand the rationale on which the restrictions have been predicated, one must be aware of the prism of American politics through which analysts and policy makers have come to view China's space programme. Of the numerous concerns maintained by opponents of bilateral collaboration, the fear that China could use the partnership to steal sensitive technologies and undermine U.S. national security is by far the most prominent. But NASA officials and policy makers have been unable to agree regarding the extent to which bilateral cooperation with China poses a legitimate risk to U.S. national security. Congressman Wolf has stated that "We don't want to give them [China] the opportunity to take advantage of our technology, and we have nothing to gain from dealing with them" [1].

While Wolf's logic is not uncommon among policy makers, a strong case has been made that regulators are overstating the risks associated with U.S.-China bilateral cooperation in space. Not surprisingly, a proponent of this view is former NASA Administrator Michael Griffin, who recently stated that "the risks of the United States giving away technology are far lower from a national security perspective than the risks of not being engaged with the world" [9].

It is a fallacy - and incidentally a very common one - to assume that any form of collaboration with China necessarily puts U.S. national security at risk. The all-too common justification for this suspicion rests on the idea that the act of cooperative exploration presents risks that cannot be mitigated. Policy makers seem to be ignoring the fact that the partnership could be developed along the same trajectory that the U.S.-Russia bilateral relationship has developed: free of improper technology transfer and threats to national security.

In a testimony to the Senate Commerce Science and Space Subcommittee on 9 April, former astronaut and International Space Station Commander Leroy Chiao, reminded the committee of this fact, stating that "safeguards are put in place so there are no improper technology transfers" during U.S.-Russia collaboration in space [5].

Another notably persistent criticism of China's space programme (from the U.S. point of view) is its close ties to the military. While curiosity regarding the programme's organisational structure is justified, the resulting characterisation of the programme is too often distorted by U.S. regulators.

The U.S.-China Economic Security Commission's (USCC) 2013 Annual Report, states that the close relationship between China's space-industrial complex and the PLA suggests that "even ostensibly civilian projects, such as the Shenzhou missions and the Tiangong-series space labs, support the development of PLA space, counter space, and conventional capabilities"[10].

In a testimony to the U.S.-China Economic Security Review (USCC), Scott Pace - Director of the Space Policy Institute at George Washington University's Elliott School of International Affairs - made the following remarks, "China's human space flight efforts are managed by elements of the PLA and require industrial capabilities that are the same as those used for military programs. Thus it might be more accurate to say that China has civil space activities, such as science and exploration, but does not have a civil space program" [11]. Pace is correct to

point out that there are “elements of the PLA” involved in the organisational structure of China’s space programme, but his assertion regarding the absence of a clearly distinguished civil space programme can be disputed.

Leroy Chiao addressed this commonly held concern during his 9 April testimony, stating that while China’s space programme indeed has connections to the PLA, these connections do not justify a refusal to cooperate altogether because “we’re [NASA] going to be working on civil space together, and they [China] have a clearly delineated civil space part of their organization” [5].

However, the USCC’s view has apparently been taken as creed. The view is reflected in a December 2013 letter from Frank Wolf to the Director of National Intelligence James Clapper, which states that “China does not separate civilian and military space programs; it has one space program. Thus, its purportedly civilian space accomplishments suggest concomitant military applications as well” [12].

Contrary to the prevailing misconceptions, China does distinguish between civil and military space programmes, albeit subtly. The distinction is an important and all-too often misunderstood fact. While not immediately apparent, a detailed consideration of the structure of the Chinese space programme reveals that it is comprised of two parts: the China National Space Administration (CNSA) and China Manned Space Administration (sometimes referred to as the China Manned Space Engineering Organization (CMSEO - recently renamed CMSA)). Thus, it has become necessary for one to distinguish between the CNSA and CMSA when referring to the entity we call “the Chinese space programme”.

CNSA is a civilian space agency responsible for robotic and

science missions including the Chinese Lunar Exploration Programme (CLEP), Earth observation and scientific satellites. When analysts claim that China’s space programme is “overseen by the People’s Liberation Army (PLA)” or “managed by elements of the PLA” (as stated by Mr. Pace), they are referring to the fact that the General Armaments Department (GAD) plays a key role in a wide variety of space activities including launch, mission control, tracking, telemetry and control facilities. CMSA (to be distinguished from CNSA) is an internal structure of the GAD and is primarily responsible for mission critical tasks such as the control of the Shenzhou capsule and Tiangong module.

As a result of this structure, Zhang Youxia - the Director of CMSA - is also the appointed Director of the GAD. The director of CNSA - Xu Dazhe - is both Deputy Director of the State Administration of Science, Technology, and Industry for National Defense (SASTIND), and Vice Minister of the Ministry of Industry and Information Technology (MIIT). For this reason, Dean Cheng, the Heritage Foundation’s Senior Research Fellow for Chinese political and security affairs, has described CNSA as “a third-tier bureaucracy” since it is a substructure of SASTIND and MIIT [13].

Indeed, several technology-intensive civilian programmes - including commercial aviation and nuclear power generation - maintain close structural ties to the military. NASA has acknowledged the difficulty posed by the differences in the way China allocates responsibility within its programme. Following his visit to China for talks with the country’s space officials in 2010, Bolden issued a public statement in which he noted the structural differences between NASA and the Chinese space programme, stating that the country was “struggling right now with how they split up responsibility for programs” [12].

However, a substantial portion of defence analysts and politicians prefer to maintain their own interpretation of China’s space ambitions. For instance, Lt. Gen. Ronald Burgess of the Pentagon’s Defense Intelligence Agency, claims that China’s true interest in space is to “deny or degrade the space assets



On 9 April 2014, the U.S. Senate Committee on Commerce, Science, and Transportation’s Subcommittee on Science and Space held a hearing entitled: “From Here to Mars.” The hearing featured experts on NASA exploration strategy, international cooperation in space, and commercial space efforts. From the left: Mr. William H. Gerstenmaier, NASA’s Associate Administrator, Human Exploration and Operations; Ms. Susan Eisenhower, Chairman Emeritus - The Eisenhower Institute, President of The Eisenhower Group, Inc.; Dr. Leroy Chiao, former NASA Astronaut and Commander of International Space Station Expedition 10, Special Advisor for Human Spaceflight in The Space Foundation, and Chairman National Space Biomedical Research Institute User Panel; Mr. Jeffrey Manber, Managing Director NanoRacks, LLC. (credit: U.S. Senate)



Dr. Leroy Chiao during the hearing by the U.S. Senate Committee on Commerce, Science, and Transportation’s Subcommittee on Science and Space on the topic: “From Here to Mars”. (credit: U.S. Senate)

of potential adversaries and enhances China's conventional military capabilities" [14]. Unfortunately, Lt. General Burgess' extreme view is a common one and has gained ground as a result of China's May 2013 test of what many believe was the launch vehicle component of a new high altitude ASAT weapon [15]. Despite on-going criticism, China has made clear the intentions of its space programme. China's 2011 White Paper states that the purpose of the space programme is to "meet the demands of economic development, scientific and technological development, national security and social progress; and to improve the scientific and cultural knowledge of the Chinese people, protect China's national rights and interests, and build up its national comprehensive strength" [16]. To be clear, there is no ambiguity in the statement regarding the utility of space programme for the purposes of national security.

It should be noted that to one degree or another, the line which fully distinguishes sensitive technology (with potential defence applications) from non-sensitive technology, has blurred significantly in recent years. This is not only true for China, but all nations of the Earth who wish to tap the commercial and economic gains that come from the production and operation of space-based assets.

Joan Johnson-Freese, a professor at the U.S. Naval War College - a critic of the federal government's use of ITAR - has noted that, "The rest of the world is perfectly willing to work with China, and China has advanced relatively far indigenously. What they cannot do, they can buy" [14]. Freese's comments reflect an important point about the U.S.-China dialogue too often ignored by policy makers. Namely, that many of our closest allies - including both the European Space Agency and Russian Space

Agency, Roscosmos - have already established channels for dialogue and cooperation with the Chinese space programme (including both CNSA and CMSA). If any interaction with the Chinese space programme is assumed to involve an associated interaction with the Chinese military, then many of the United States' closest allies have already taken a step in that direction.

Another inconsistency, is the fact that military contact between the two nations bordering the Pacific Ocean on either side is anyhow already established. One of the latest took place in February 2014 when Chinese troops observed the U.S.-led military exercises "Cobra Gold 2014", an annual Thai-U.S. co-sponsored joint and multinational drill. Troops from Singapore, Japan, South Korea, Indonesia and Malaysia also participated in that exercise.

The utility of limited cooperation is exemplified in a section of the USCC's 2013 Annual Report called "Select Military to Military Engagements", which states that, "Department of Defense (DoD) [is] seeking to expand and deepen its engagement with the Chinese military in non-sensitive areas of mutual interest." The report praises the benefits of a "familiarity at the operational level, which reduces the risk of conflict through accidents and miscalculations; builds lines of communication at the strategic level that could be important during a crisis; contributes to better overall bilateral relations; and creates opportunities to obtain greater contributions from China to international security" [10].

It remains to be seen why similar limited engagements cease to apply in the realm of interagency communication in the context of space.



A joint table-top exercise of humanitarian assistance and disaster relief between the Chinese and American armed forces was held in Chengdu, capital city of southwest China's Sichuan province, from 29 to 30 November 2012. The drill subject is joint humanitarian rescue and disaster relief after an earthquake, and the drill includes four stages such as task initiation, force projection, joint rescue and relief operation, and task handover and evacuation. This is the 8th humanitarian assistance and disaster reduction exchange activity held by the Chinese and American armed forces since 1997. Military personnel from the two countries participated in the drill. (credit: PeopleDaily/ Chinamil.com)

On 20 August 2013, Chinese navy sailors stand on the guided-missile destroyer, Qingdao, right, before departure for a naval drill at a military port in Qingdao in east China's Shandong province. Three Chinese ships are sailing east to join rare naval drills with the United States as Beijing ramps up its military diplomacy amid regional territorial disputes and other tensions. (credit: AP Photo)



Conclusion

While recent developments suggest that NASA is looking for ways to engage China on space-science related issues, it is deeply regrettable that the deck remains stacked against any form of bilateral cooperation in the realm of manned spaceflight any time soon. The stakes aren't just high for the future of U.S.-China cooperation in space, but all of Earth's spacefaring nations. Space exploration is one of the few human activities - and from a geographical perspective the only such activity - for which all nations share common ground (Earth).

During the Apollo-Soyuz test project on 17 July 1975, U.S. astronaut Donald Slayton and Russian cosmonaut Alexey Leonov shook hands 138 miles above the Atlantic ocean, despite the fact that the two countries had been on the brink of nuclear fallout. The ASTP and all that resulted from it have made clear that progress under the banner of cooperation is well worth the effort.

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Strategy Recommendations for Planning International Cooperation on the Chinese Space Station

by Jordan J. Foley



(credit: Adrian Mann)

The ultimate challenges facing the People's Republic of China (PRC) and the Chinese Communist Party (CCP) are how to domestically maintain the power of the state while increasing individual liberties; and facilitating its international rise while avoiding direct confrontation as it is expanding global influence. Within the past decade, China has experienced a steady progression of technology resulting in prestigious accomplishments for the manned space programme. To reassure the world of its benign rise, China is seeking collaboration in the exploration and utilisation of outer space. This paper provides a

critical examination of the technology and politics of the Chinese Space Station (CSS) endeavour and investigates areas of conflict that could potentially affect China, such as spheres of influence, status and prestige, resource competition, and fundamental disagreements over the international system. I argue that only if it can be effectively managed as a platform for international cooperation and global leadership, CSS can achieve subsidiary benefits for the Chinese government in domestic and foreign policy. In building a prosperous socialist society China must use science, technology, education, and culture as means for achieving political ends. However, inviting international partners in the process of constructing and operating a space station presents an expansively demanding policy problem. China must determine if there are tangible benefits associated with different scales and scopes of space station cooperation. The key policy problem is finding a model that is effective for fair and rational cooperation based on mutual benefit, transparency, reciprocity, and cost sharing, while striking a balance with partners over ownership, intellectual property, and utilisation rights. Through first hand professional and cultural experience in China and translations of various Chinese academic journals, I construct an analytical assessment of PRC space activities and recommend effective strategies to support scientific and technological innovation for intentional cooperation on CSS.

In the future, CSS missions should include a greater depth of coverage with the intent of providing access to the media for the people, body politic, and youth. Increasing camera bandwidth to make video and audio content of its exploration



Chickens and Ducks (Chinese translation: in the cloud - mutual benefits; From the duck - international cooperation) (credit: Jordan J. Foley)



Cooperation (credit: Jordan J. Foley)



programme available to the web will be a feasible technical project. This data should then be transmitted with the intent of informing the public, building support, and inspiring the youth for ultimate consumption by the Chinese people and, especially if it is an international platform, the rest of the world. A new Patriotic Education Campaign should focus on Chinese Science & Technology (S&T) accomplishments, with a special section on manned spaceflight to encourage creativity and innovation in the classroom. I am a contributing curriculum designer and lecturer for the Shenzhen based non-profit, Aspiration. My syllabus consists of Chinese space programme history and special science sections on the technical aspects of certain spacecraft, like Shenzhou, Chang'e, and Long March rockets. The Capstone Project divides the class into groups to design an experiment for the future CSS. The students spend several weeks preparing their experiment and then present it at the end of the programme. If China wants to renovate its education system to support innovation, then programmes like Aspiration need to be more widespread.

China's continued difficulties in governing its own ethnic minority areas, such as Xinjiang, hints at the possibilities of a campaign to better assimilate those peoples into Chinese society. By sending ethnic minority astronauts to CSS, an ensuing propaganda campaign could serve to strengthen national identity and pride in these groups. Further, minorities are underrepresented among college enrolments and college graduates in science and technology. The existing scholarships for ethnic minorities to attend college are in place, but the Ministry of Education should implement a high profile programme to draft ethnic minorities into an astronaut candidate programme out of high school. Of course, the high standards applying to astronaut candidates, such as fluency of the English language, possessing a master degree or higher, and so on, will not be lowered. These select students would compete for the limited number of slots as they progressed through college and higher education. From a young age, they would be geared toward proficiencies necessary for astronauts. By inspiring its ethnic populations, China could better manage those areas through education opportunities.

The model for cooperation on CSS is not yet determined. There are several suggestions, but it is unlikely that any agreements are made in the near future. China is advertising openness and inclusion in the space station effort, but in reality, the PRC will be much less blithe regarding the legal framework. It is suggested that China pursue a hub and spoke model similar to the International Space Station (ISS). China should control the majority share, establish a chain of command, and be in a position similar to the U.S. on ISS. An important thing to note is that it is likely that ISS will remain in orbit when CSS is operating. China should vigorously pursue technical and operational interfaces with the ISS while both are in orbit. Cooperation may not be on the level of the Shuttle-Mir or even Apollo-Soyuz programmes, but any increased interaction with the ISS Partners will make possible later cooperation on CSS.

In the meantime, cooperation on CSS will most likely be limited to regional, non-ISS nations. The Soviet INTERKOSMOS missions of the 1970s and 1980s should serve as an effective model for future Asia Pacific Space Cooperation Organization (APSCO) missions. Countries joining China on CSS should be expected to provide their own experiments and focus research on their home country. Chinese experiments should remain separate from APSCO guests. If China defines sovereignty more like on ISS, where supreme authority rests in the hands of the owner of a given element, and independent nations operate their given areas, but exercise jurisdiction with partners in mind, then cooperation will be much more open. These levels of openness, however, will not further Chinese strategic goals. Chinese rule over major elements should only be yielded to a nation that is commensurate to Partners' technical contributions on the ISS. The ISS framework, however, is a useful model, and those studying space social sciences in China have admitted so. The same scholars have posited that if China were accepted as a Partner in ISS, then it would not have pursued an independent space station. Learning from ISS, China should create a China-Hub/APSCO-Spoke framework.

China will not simply collaborate for the sake of collaboration. China will also not reject any goodwill offer from another developing country to join the CSS. The PRC's close friends in the developing world are interested in the Chinese space programme. Hence, the political gesture of training astronauts for missions could have significant benefits for China. In the event that another country lags far behind China in S&T, then China must figure out what can be exchanged for training and cooperation. Perhaps natural resource rights, business contract preferences, and related agreements could be part of the exchanges. The UN should also be included in selecting all non-spacefaring states. An agreement with the UN should also coincide with Comprehensive Test-Ban Treaty (CTBT) ratification to symbolise China's commitment to become more in line with the international system. These actions, carried out simultaneously, would gain the Chinese a higher level of influence in the United Nations system.

Based on contemporary national and international conditions, cooperation on CSS will most likely resemble past INTERKOSMOS missions to Salyut. A China-centered space station allowing APSCO and the UN selection of Member States to send their astronauts to CSS will present the image of responsible international actor China is pursuing. Meaningful technical cooperation will be limited, as it was with INTERKOSMOS, but the diplomatic advantages will be well worth the investment. CSS is also a flexible platform. In the event that major spacefaring nations decide to partner with China, the space station can accommodate them. In the near future, the Chinese Space Station will be an effective regional foreign policy tool that serves a greater grand strategic purpose.

The author is an active duty U.S. Naval Officer. Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the United States Government.

“Exploration of space becomes a global effort in the real sense of the word.”

Interview with Dutch-born NASA astronaut Lodewijk van den Berg



The official NASA portrait of STS-51B/Spacelab-3 Payload Specialist Lodewijk van den Berg. (credit: NASA)

Lodewijk van den Berg was born on 24 March 1932 in Sluiskil, The Netherlands, where he also spent his early life. He earned a Master of Science in chemical engineering from the Technical University Delft, The Netherlands, in 1961. After coming to the United States he continued his studies leading to a Masters and Ph.D. in Applied Science at the University of Delaware. After joining industry he specialised in the growth of single crystals of Mercuric Iodide from which nuclear detectors can be fabricated that operate at ambient temperatures.

Lodewijk van den Berg was selected in 1983 as a Payload Specialist Astronaut to perform crystal growth experiments in the reduced gravity environment of space. Van den Berg was a co-investigator on the Spacelab-3 mission Vapour Crystal Growth System (VCGS) experiment. In that capacity, he is responsible for the crystal growth aspects of the VCGS experiment. Van den Berg has intimate knowledge of VCGS and Fluid Experiment System (FES) hardware and has participated in all major design and science reviews of those systems. He has broad experience in crystal growth and characterisation including vapour transport, solution and melt growth techniques. He is an international authority on vapour growth techniques, with emphasis on mercuric iodide crystals and its application in the nuclear industry as gamma ray detectors.

He is presently an independent consultant providing support in the areas of material purification and crystal growth. In November 2013, Lodewijk van den Berg was invited as the keynote speaker at the annual Space Days conference in Germany's North-Eastern town of Neubrandenburg. Since he was flying to space with the first Chinese-born NASA astronaut, GoTaikonauts! took the opportunity to interview him after the conference.

Source: NASA/Dr. Van den Berg



The official NASA portrait of STS-51B/Spacelab-3 Payload Specialist Taylor Gànjùn Wáng. (credit: NASA)

Taylor Gànjùn Wáng was the first space traveller of Chinese descent. NASA selected him within the group of scientists on 1 June 1983 to fly as a Payload Specialist on the Spacelab-3 mission. He launched from Kennedy Space Center, Florida, on the Space Shuttle Challenger mission STS-51B/Spacelab-3 on 29 April 1985 and spent 8 days in space. The seven-man crew aboard Challenger conducted investigations in crystal growth, drop dynamics leading to containerless material processing, atmospheric trace gas spectroscopy, solar and planetary atmospheric simulation, cosmic rays, laboratory animals and human medical monitoring. Challenger returned 6 May 1985 to Earth on Edwards Air Force Base, California.

Wang was born 16 June 1940 in Jiāngxī Province in South-East China. His family moved in 1952 to Taiwan and later to Hong Kong. After getting his academic education in the U.S. and starting his scientific professional career there, he became naturalised as a U.S. citizen in 1975.

Wang studied physics at the University of California, Los Angeles, where he received his Bachelor, Master, and PhD in low temperature physics - “Superfluid and solid-state physics” in 1971. In 1972 he joined the California Institute of Technology's Jet Propulsion Laboratory (JPL) as a senior scientist, where he was responsible for the inception and development of containerless processing science and technology research.

Wang conducted drop dynamics experiments in ground-based laboratories employing acoustic levitation systems, neutral buoyancy systems and drop towers, and in the near weightless environment provided by JSC's KC-135 parabolic airplane flights as well as SPAR (Space Processing Applications Rocket) sounding rockets. He was the Principal Investigator (PI) for the SPAR Flight Experiment #77-18 “Dynamics of Liquid Bubble” and #76-20 “Containerless Processing Technology”. These flights have helped to define the experimental parameters and procedures in the DDM - NASA Drop Dynamics experiments performed on Spacelab 3 for which he also was the PI. He is the inventor of the acoustic levitation and manipulation chamber for the DDM.

Source: NASA

Go TAIKONAUTS!

GoTaikonauts!: You have been in space in 1985. This is quite some time ago, but from your talks and your presentation during the Neubrandenburg Space Days, I have seen, that your memory is still very vivid. Why is that?

Lodewijk van den Berg: It is one of these things that you never forget. Since there is a lot of documentation, and also on video, that always can bring memories back. Some memories even, you almost forgot.

GoTaikonauts!: You have been the first Dutch-born in space, strictly speaking. Does this mean anything to you?

Lodewijk van den Berg: Yes, this is correct. Of course it means something. Traditionally the idea was, I do not know how it was with the Russians, but especially with the U.S.-Americans, that the crew members would say: I come from there and there. The main thing about this was, that they wanted to recognise that the people from the area they came from supported them, educated them, made them the person they were to a large degree. So they always wanted to have those people recognised in all their after-flight activities and statements that they made. And that for me is the important thing.

But then things changed a bit in particular here in Europe, they started that game of who was the first in Germany, and who was the first in France, and whatever. No matter what their activities in space were. This is an incorrect way to look at it. This might have a value as well, but not as much as saying: I am from there and there, that you want to recognise that those are the people that made you the person you were, so that you would be able to physically and psychologically to go into space. That is what still is for me the



The Space Shuttle Discovery and its science module payload are featured in the insignia for the STS-51B/Spacelab-3 mission. The seven stars of the constellation Pegasus surround the orbiting spacehip above the flag draped Earth. Surnames of the seven crewmembers encircle the scene. The artwork was done by Carol Ann Lind. (credit: NASA)

whole background. Yes, I definitely recognise everything what the Dutch in general and especially the people in the region where I grew up, what they have done for me.

GoTaikonauts!: It was then a very unique situation with your crew anyhow. Because you also had the first Chinese-born astronaut in your crew. I would assume that it does add a certain flavour of culture to the whole crew set-up.

Lodewijk van den Berg: It did! That was very interesting. Because first of all you have the U.S.-Americans who came from different regions of the United States. The United States are less uniform than many people realise. So they by themselves, brought different aspects to the whole flight atmosphere and the crew. And then they swore-in a former Dutchman and they swore-in a former Chinese. And that changed things even more. For example: you state in advance what kind of food and drinks you like. This guy introduced us to Chinese green tea. He advised everybody that it was good for stress and whatever else, to have some Chinese green tea. So we tried that and we really got a liking for the Chinese green tea. It was relaxing. So, just to give you an example. I cannot give you an example of specific Dutch food

which was on board. Because they did not store pickled herring or things like that. I just went along with the standard supplies. It is an interesting thing - at least at that time it was like this but I am sure it is still like that. Everybody is entitled to their favourite food. And this is what they set up.

GoTaikonauts!: Do you still fancy green tea?

Lodewijk van den Berg: Yes, I still do!

GoTaikonauts!: But you have never been to China?

Lodewijk van den Berg: I have never been to China, but the United States being the United States, many things of the Chinese culture are now generally accepted in the whole United States. In every grocery store you can buy Chinese green tea.

GoTaikonauts!: This is an interesting aspect. Although China seems to be already in the U.S., the U.S. is still hesitating to include China in the international space exploration efforts. It is a good idea to keep China out of that business or is it not the right time yet to include them?

Lodewijk van den Berg: I hesitate to comment on that. In general, you just say, okay, why not? Especially as a former astronaut you would think everybody is the same and all people are basically the same. Why not fully accept them as a member of the world's society.

There seems to be at some level, reluctance to say okay, we are totally open and we will work together with the Chinese. Now, from my perspective I can to a certain degree understand that. From what I have read and from what I have seen on TV, how the Chinese are making official statements, they are not really playing with an open hand either. There is something going on here. What it is, I don't know.

GoTaikonauts!: Nevertheless, you have been probably the first person in the world to openly promote the idea of putting scientific space exploration on the level of the United Nations. What is behind that idea?

Lodewijk van den Berg: Yes. Because that would give, I think, more



The seven men-crew of NASA's Spacelab-3/STS-51B mission. On the front row are Astronauts Robert F. Overmyer (left), Commander; and Frederick D. Gregory, Pilot. On the back row, left to right, are Don L. Lind, Mission Specialist; Taylor G. Wang, Payload Specialist; Norman E. Thagard and William E. Thornton, both Mission Specialists; and Lodewijk van den Berg, Payload Specialist. (credit: NASA)



Lodewijk van den Berg during the interview in Neubrandenburg, November 2013. (credit: Bernhard Tiedt)

official substance to the effort that everybody on Earth should work together to get things done, to promote space exploration. It becomes more and more clear that as years go by, further space exploration is going to become very expensive. And we need a lot of talent. And it is also becoming clear that for whatever reason the existing active groups in space, by that I mean for example the United States, Russia and the European Union, they cannot be responsible for that anymore, and cannot afford it anymore just by themselves. And the Chinese have an enormous amount of talent and resources available to help out with that. On the basis of that indeed, exploration of space becomes a world effort, a global effort in the real sense of the word, not just talking politically global this and global that, but involving the globe - it might be Indians, it might be Indonesians - who knows.

GoTaikonauts!: Is this your vision of the future?

Lodewijk van den Berg: Yes. Yes. It might take 50 years. Who knows? But look at the United Nations, they are already more than 50 years old. And for example, they finally became active in having some kind of United Nations peace corps to help out States which are being threatened by uprisings, and to help out in areas where there is terrorism, and thousands of people get killed. That also took at least 50 years, but it is now generally accepted.

GoTaikonauts!: Getting back to your mission. Did you have a special relationship with Taylor Wang?

Lodewijk van den Berg: Yes, because we were officially, and really officially not even quote-quote, officially, the science crew members. Our training to some degree deviated from the training of the career astronauts that took care of the ship, and the power supplies, the electronics, and whatever else needed to be taken care of so that we scientists could do our jobs undisturbed. Very often we had training with the four of us - two for each position. That was very interesting. We had very unique experiences. For example there were some meetings in Washington DC and the Chinese guy said, okay we just had the wonderful standard American dinner with steak, potatoes and a little bit vegetables. Tomorrow we will have a real Chinese dinner. He knew a restaurant close by Washington, which was really authentic Chinese. He took us there. He took the lead and right away talked with the owner in the proper Chinese language and went with the owner to the kitchen and selected the duck he was going to cook for us, and things like that.

You could see that this was different from when you and I would go to a Chinese restaurant.

GoTaikonauts!: Do you remember something during the work with him on board the Space Shuttle. Was there something special?

Lodewijk van den Berg: Oh yes, and this is very well known. (he laughs). He was a very quiet, relaxed man. He almost never showed any emotion. But then something did not work well with his experiment. With the help of the ground, he spent actually two whole shifts trying to repair it. And it finally worked. All of the sudden he woke everybody up, because he was yelling and screaming: It works! It works! (he laughs).

GoTaikonauts!: How do you explain your experience of flying in space?

Lodewijk van den Berg: It should be easy, if you try it. Whenever I am asked, I say, it is hard to answer, the only answer is: you have to try it! It is a flippant answer. Sometimes I give an analogy for that. My analogy is as follows: People ask you what does it feel like to be in space. You can talk about it and can talk about it. But it is so hard to get it across. The analogy is: here on ground you have two women. One of them has had a child and one of them has not. And the woman without the child asks the woman with the child what is it like to have a child. What does it feel like? The woman with a child can talk and talk and still doesn't get everything across. Now if you have two women, each of them had a child, they don't even have to talk about it they just look at each other's eyes and that's it. This is the same what you have with other astronauts. You don't need to talk about it. They just look each other into their eyes and there is a bond. Immediately! This was the same with the Vietnamese guy here during the conference. I barely could talk with him. Sometimes, we needed two interpreters, one from Vietnamese to Russian, and one from Russian to German and from German to English. But instantly we had a bond. I don't know whether you noticed that. We had a good time without saying much.

GoTaikonauts!: Wouldn't it be nice if everybody on Earth would feel this bond because we are all from planet Earth.

Lodewijk van den Berg: Well it is kind of historically grown. On planet Earth people have made things kind of difficult. As an example, think of the official relations between the United States and China, or Germany and China, or whatever. There is some reluctance there. It should all be nice. Something like that, even in a familiar setting where people can easily communicate with each other, that takes generations. When you look at the history of the United States, it is almost like a compact history lesson. They imported people in the millions from all kind of areas of the world, including Chinese and Russians. Every time that a new wave came in, the new wave took at least two generations to be accepted. And even today, for the Latin-American immigrants to be accepted will take a while. It is much easier for them because it is said these guys are coming from the same hemisphere. As far as the immigrants mainly from Europe are concerned, having been assimilated for at least two or three generations, there is no difference anymore. They all play the same game. As a matter of fact they are going in the reverse. There are more and more semi-official voices who are saying keep your own stuff from your own culture: the language, the way of living, the way of thinking, food is a prime example.

Right now we need people who speak Chinese. And do not forget your Chinese heritage. Keep up your Chinese!

For further information on Lodewijk van den Berg, have a look at: <http://www.youtube.com/watch?v=DivQh8CNUDA>

TEDxDelft - Lodewijk van den Berg - How a crystal growth scientist became an astronaut.

This recording of a presentation given by Lodewijk van den Berg in autumn 2011 at Delft University in Delft, The Netherlands, is a fresh short talk about how he was selected as an astronaut, about his mission, why human spaceflight is important and how the future of space exploration could look like. On this occasion, van den Berg was explaining his vision of "Take a real global view!", he was advocating the incorporation of China into space research and he called for "increased efforts that benefit the whole world, globally in the real sense of the world: planet-wide space programmes."

What if...?

Searching for Evidence - An Attempt to Analyse the “Space Science & Technology in China: A Roadmap to 2050”

by Jacqueline Myrrhe and Dr. William Carey

China’s space programme has been accused of many opaque objectives, including numerous negative associations, such as military goals, space dominance, space super-power ambitions and similar.

Searching for evidence, it may be possible to support one or the other above postulates. There was the 2007 ASAT test, and there are programmes about which very little is known, e.g. the 13 May 2013 launch from the Xichang Satellite Launch Center. Also, China often surprises the public by revealing projects never heard of before in the West, such as the Kaituoze 1 small launch vehicle, launched on 25 September 2013.

Lacking the journalistic access to and the ability to read first-hand information sources in China makes it convenient to construct accusations of negative connotation and to propagate the assumption that China is driven by unfair reasons in its conquest of space. Any Earth observation satellite launched is declared as being a spy satellite, any sounding rocket test is suspected to be an ASAT test or a space weapon.

During President Xi Jinping’s mid-April visit to the People’s Liberation Army air force headquarters in Beijing, he was “asking the air force to speed up its transformation into a strong power with an integrated air and space capability” [1] - something that has been in existence for a long time in the U.S. and Europe. He also “called on military leaders to run the military in accordance with the law and enforce strict discipline to improve scientific management of troops” and “cleaning up undesirable work styles - formalism, bureaucracy, hedonism and extravagance” [2]. Wouldn’t this also be needed and appreciated in the West?

The interpretation of some media was that China’s President Xi Jinping is “pushing for increased militarization of China’s space programme” [3] or even worse: “China’s president urges greater militarization of space” [4] and as a consequence to ask: “What will US do to counter China’s space offensive?” [5].

What if China’s space programme is simply based on the analysis of the progress made in space by other countries and subsequently gained benefit from during the last 50 to 60 years?

What if China’s space programme is simply based on the lessons learned from mankind’s previous space efforts, if it is based on the recognition that not only revolutions are locomotives [6], but also space exploration is a locomotive, pulling all areas of society - technology, innovation, science, economy, culture - into new territory, and by doing so, advances mankind as a whole?

What if China is simply in the middle of applying space technology to the needs of a country fast approaching 1,5 billion people, or rather on a “march”, of becoming a modern, developed and attractive society? Also this is nothing new, in particular not for China, after Deng Xiaoping, the visionary of the 1970/80s, stated that science and technology are the first

productive force for a country’s economy - no matter whether it is a country in the West or East, South or North.

Which road will lead into the future?

Looking for evidence, one should not leave out one first-hand account which is the 120-page document by the Chinese Academy of Sciences (CAS): “Space Science & Technology in China: A Roadmap to 2050”, edited by Huadong Guo and Ji Wu. Its analysis may help to understand what China is up to when it comes to space.

On the initiative of the President of China’s Academy of Sciences, Yongxiang Lu, a project for the definition of science and technology roadmaps was set-up in the autumn of 2007. The CAS (founded in 1949) is China’s highest academic institution in the natural sciences.

Although a national mid- and long-term science and technology plan existed already by that time, it became evident that certain urgent societal issues, such as energy, agriculture, aging of the population, oceanic resources, environmental protection, must be addressed with a longer-term view.

The reasoning for the need of a strategic approach is determined by the following description of China’s societal future in 35 years from now: “China has established the goal of making itself into a moderately developed country around the year 2050. If the economy maintains a steady growth rate, then the size of its economy will rank first place in the world. The interests of its citizens and the social equality will be firmly guaranteed. The growth rate of the population will have considerably slowed down or even have become negative, but will have also suffered from a serious aging crisis. Environmental deterioration will be restrained. Its opening to the world and its cooperation with other countries will reach an unprecedented level, both in depth and in extension. In science and technology, the innovative power of the country will occupy a leading position in the world, such that many important discoveries and great breakthroughs will be made by Chinese, and China will also contribute a great deal to making Asia the epicentre for science and technology, thus the phrase ‘Made in China’ will be replaced by ‘Created in China’. At the same time, China will also bear more responsibility in the world and contribute a respectful amount to the promotion of civilization and to pursuing a stable coexistence between man and nature.” [8]

Apart from this general vision, in the area of space science and technology questions regarding the future would also need to be answered: “What will be the whole plan for China’s space technology? What is the objective? Will it just follow the previous approach of developed countries? Will the traditional chemical fuel propellant still be used in future deep-space exploration? ...” [8]

Although in total 18 key areas [*] were listed, space science and technology and its applications received particular attention, recognising that “space science, applications and technology are research fields which are essential for China’s development.” [8]

[*] The eighteen key areas are: energy; water resources; mineral resources; marine resources; oil and gas; population and health; agriculture; eco-environment; biomass resources; regional development; space; information; advanced manufacturing; advanced materials; nano-science; big science facilities; cross-disciplinary and frontier research; national and public security.

Therefore, the roadmap activity was initiated, aimed at predicting the future developments of science and technology in accordance with the needs of the Chinese nation for the next 20 - 30 years. The intended roadmap work can be summarised as the objective: “to address the needs of both, the nation and society, the continued growth of economy and national competitiveness, the development of social harmony, and the sustainability between man and nature.” [8]

One year of work to define the future

The overall work of the development of the roadmaps followed a carefully thought through schedule, and took a little over one year. After the Academy had established the organisational structure for this task, three time-frames were defined: immediate term until 2020, mid-term until 2030 and long-term until 2050. The work should be focused on the national level, and should include an explanation of objectives, research approaches, human resources, addressing of enabling science, and strategic and feasible key technologies. In the next step, experts in science policy, management, IT and documentation, were selected along with middle-aged chief scientists together with younger colleagues, to form a special research group lead by an “outstanding scientist with a strategic vision, strong sense of responsibility and coordinative capability.” [8] Research groups on different levels and working groups across the disciplines, were put into place to analyse foreign experience on roadmap research and domestic experience in strategic planning. Detailed discussions of Chinese research priorities and objectives preceded the formulation of the strategic goals, the sketching of the technical routes and the definition of the capabilities for achieving the goals. Then, consultations with national and international experts were scheduled. Over a time period of twelve months quite some effort went into peer reviews, further evaluations, commenting, plenary meetings, symposia and revisions and consultations, before the series of 18 reports - one for each of the initially determined key areas - among them the “Space Science & Technology in China: A Roadmap to 2050”, were published. In mid-2009 the document was published in Mandarin and in 2010, published by Springer in English.

The roadmap is supposed to be a long-term support to the different developments fitting into China’s reality. It is a forward-looking, strategic research taking the national interest into account, with the aim to drive the economic prosperity of the country, and eventually take the world lead in certain research disciplines. Science, technology, innovation and management

have to be interconnected with the economic societal base. Space has to become a tool for the benefit of Chinese society, and the achievement of the overarching goals and synergistic efforts as laid out in the roadmap. An analysis of the recent history of science and economy brought to light that the growth by purely extending the economic production has reached its limit. China’s economic and social development will largely depend on science and technology through scientific discoveries, through the realisation of so-called “Mega Projects”, and through new inventions and technological innovation. This holistic approach is the strength of the document: it includes not only the science and technology of relevance for the future, but also the respective roadmap to meet the objectives, a description of environmental changes, research needs, technology trends and developments in innovation as well as technology.

In order to observe the changes in society and to compare them with the roadmap’s objectives, a revision of the document is planned at least every five years.

Going along the road with a map in your hand

Where do you come from? Where do you go? What do you want to achieve on the way? In order to ask these fundamental questions, work on the roadmaps also took as a starting point, the outlook for the Chinese society by 2050:

“The vision of China’s space science, application and technology to 2050 is ... to radically elevate the status of space science, applications and technology in the nation’s development, in the course of following the national demands and key scientific and technological questions, such that by 2050 they may play key roles in national development, being able to provide effective and irreplaceable solutions to the major problems facing the nation.” [8]

The national demands and the strategic role of space science, application and technology were then analysed:

1. As a global power, how to take on the responsibility of making significant contributions to science and civilisation of mankind? [8]

The authors recognise, that the current scientific and technological contributions from China are inadequate with its position in the world. Space science is at the forefront of science and although faces the most challenges it also has the potential for the greatest discoveries.

2. How to promote the development of high-technology in China and make China a technological advanced country? [8]

To challenge the underdeveloped state of science and technology in China, emphasis will be put on research fields that have immense transformative character to stimulate related high-technologies. This implies the direct advancement of astronautic technologies.

3. How to protect the environment and realize a stable

coexistence between mankind and nature? [8]

Currently, China is lacking data stream from multi-parameter satellite instruments for environmental observation. One of the 16 Mega Projects of the “Outline of National Medium- and Long-term Science and Technology Development” is the constellation of a high-resolution Earth observation system which would play a key role in the provision of data in response to climate change, the monitoring of water resources, the survey of renewable energy sources, the monitoring of soil changes of arable land, and natural disasters.

4. How to improve the quality of life and realize sustainable development? [8]

The quality of life of China’s population will be significantly improved over the course of the next decade. Space technologies and applications will contribute numerous services for housing, medical care, education, etc.

After identifying the national needs, and global trends in space science and technology, the strategic experiences of other nations were discussed, compared with and listed against China’s national needs. The following conclusions were identified:

- “Space powers put more and more emphasis on space ventures, taking it as an important strategic field that represents the comprehensive national power and the status of the country;
- Investments in space activities increase rapidly;
- International cooperation in civil space especially in space science has been enhanced;
- More and more countries have devoted much effort to undertake space activities, to develop space technology and industry, increase their scientific and economic strength, and elevate their international status and enhance their influence in the region.” [8]

In that context, the current status, the advantages and disadvantages of China’s space science, application and technology were addressed. At the end of this process, the actual roadmap could be put together.

Status Quo - Projects - Actions

The last five decades have seen numerous Chinese space activities. Several space science and technology branches were started from scratch.

The national High-Tech Research and Development Programme, the so-called Programme 863, was launched in the mid-1980s, and the manned space flight programme in 1992. As a result, China could develop the re-entry capability for satellites and could realise its manned space programme.

The 11th Five-Year Plan from 2006 - 2010 and the Outline of National Medium- and Long-term Science and Development from 2006 - 2020 comprised the implementation of an Earth-observation system containing a full set of high-resolution remote sensing capabilities. Gradually, this Mega Project was put into action. Another Mega Project is the national satellite

remote sensing ground network system, also underway. This also applies to the airborne remote sensing system, which will be built into the space infrastructure of the high-resolution Earth observation system. One more Mega Project taking shape is the independent navigation and positioning system. The second generation of satellite navigation and positioning system sees the light of day and is also considered as one of the Mega Projects.

Despite these successes of the past, the document mentions on at least 10 occasions that, China’s “space science, applications and technology is still lagging behind that of developed countries in many respects. Therefore, priority needs to be put on this strategic field that directs and supports the economic, social, scientific and technological development of the nation. It is expected that progress in this field will stimulate the advancement of the other relevant high-tech fields, which is demanded for resolving problems confronting our nation’s development.” [8]

From “Made in China” to “Created in China” - The Science Goals

To meet the 2050 vision defined in the previous sections, the importance of developing explicit goals in the three domains of space science, applications and technology was recognised and highlighted:

Strategic Goal of Space Science
Making significant contributions to human civilisation [8]

Strategic Goal of Space Technology
Providing strong support for science exploration and space information applications [8]

Strategic Goal of Space Application
Being an indispensable support for the national decision-making [8]

To establish these goals the current key questions at the forefront of the three domains were identified, which if successfully addressed, would provide China with the opportunity to contribute significantly at a global level to the advancement of science and technology within the 2050 timeframe. It is strongly emphasised throughout the Roadmap, however, that such contributions would be a significant driving force for the modernisation of the country, and particularly for its economic and societal development, i.e. the end objective being to ensure a sustainable development of China’s economy, society, science and technology.

The roadmap document states that since the beginning of the space age in 1957, the Chinese people have made little contribution to space exploration (despite significant progress and achievement during the 30 years of Reform and Opening up) – an incredibly self-effacing statement – and stresses that by 2050, China, as it is expected to be the largest economy in the world by that time, is obliged to make its contribution to human civilisation. The “big” scientific questions such as: the Origin of the Universe; Origin of Life; the Sun and the Solar

System; and Fundamental Physical Laws are summarised to identify those areas that China will focus on. The initial steps in the roadmap to 2020, will focus on a series of space science satellites covering a broad range of scientific research. During the period between 2020-2030 emphasis will be placed on building up facilities to perform independent research, reaching a flight-rate of 2-3 science missions by 2030. By 2050, major breakthroughs relating to the “big questions” are expected to have occurred, enabling China to become a leading country in space science research.

Origin of the Universe: Understanding the origin of the Universe will be addressed through the following four programmes:

1. Black Hole Probe (BHP) programme: These missions include the following:
 - Hard X-ray Modulation Telescope (HXMT).
 - Space Variable Objects Monitor (SVOM).
 - Gamma-ray Burst Polarization (POLAR) - on China’s space laboratory.
2. Diagnostics of Astro-Oscillations (DAO) programme: These missions include:
 - X-ray Timing and Polarization (XTP).
 - Planetary Transits and Oscillations of stars (PLATO).
 - Astrodynamic Space Demonstration of Relativity Using Optical Devices (Astro-D).
3. Portraits of Astrophysical Objects (PAO) programme.
4. Dark Matter Detection (DMD) programme.

The initial phase (2010-2020), will focus on building-up the DAO and DMD observational systems of the above-mentioned programmes, based on Low Earth Orbiting (LEO) satellite platforms, together with their associated ground segments, in addition to continuing China’s space programme policy to actively participate in international cooperation. Specific mention is made of the initiation of the PAO and DMD programmes utilising the Chinese Space Station (CSS).

In the period 2020-2035, improvement of the LEO systems, completion of the DAO programme, and implementation of a DMD experiment on the CSS is highlighted. Also initiation of the PAO programme based on satellite arrays centered at the L1/ L2 (Earth-Moon) Lagrange Points, and construction of a lunar observatory (implemented concurrently with China’s Lunar Exploration Programme).

With respect to the period 2035-2050, emphasis will be on the establishment and utilisation of multi-waveband satellites, and additional observational facilities on the Moon and at L1/L2 Lagrange Points.

Origin of Life: In addition to addressing the fundamental science questions, gaining an understanding of the conditions for the construction of a lunar base in preparation for a future manned exploration of Mars is a key objective. Bearing this in mind, in the period 2010-2030, the emphasis will be on utilising space microgravity platforms, as well as ground-based facilities to understand the effects of the space environment (particularly microgravity and radiation) on humans, together with the development of Controlled Ecological Life Support Systems (CELSSs). It is noted that this type of research has the potential

to also bring significant terrestrial benefit.

Between 2030-2050, establishing CELSS facilities to research the issues facing a long-term presence of humans on the Moon, and eventually on Mars.

Sun and Solar System: The strategy here is comprised of two strands; a purely national effort, and through joint international cooperation, and is based on two programmes: the Solar Microscope Programme and the Solar Panorama Programme.

Between 2010-2020, to implement the two solar programmes and the following missions: Solar Space Telescope (SST); Small Explorer for Solar Eruptions (SMESE); Solar Radio Array at extremely Low Frequency (SRALF) and Solar Explorer for High-Energy and Far-Infrared radiation (SEHEFI).

In the period 2020-2050, to complete implementation of the solar programmes and the following missions: Space Optic Interferometric Telescope (SOIT); Super High Angular Resolution Principle X-ray telescope (SHARP-X); and Global Solar Exploration (GSE).

In addition, a Sun-Earth Connection (SEC) programme will be implemented through the following major missions: In the period 2010-2030; KuaFu and Solar Polar Orbit Radio Telescope (SPORT) and Magnetosphere-Ionosphere-Thermosphere (MIT). Beyond 2030, China will utilise the lunar-based observatory to monitor the Sun and the Earth, and expand the ground-based Chain of Meridian Project into a space environment monitoring network.

Key milestones identified in relation to the investigation of the origin and evolution of the Solar System are shown in the following table:

Approx. Date	Milestone
2009	YingHuo-1 Mars orbiter on the Russian Phobos-Grunt mission **
2012	First soft lunar landing and surface exploration
2014	Second soft lunar landing and surface exploration
2015	Explore the space around Mars and multi-target exploration of asteroids (on the way to Mars)
2017	Return of first lunar samples
2018	Return of second lunar samples
2020	Launch of planetary science laboratory, and carry-out in-situ planetary exploration
2025	Carry-out direct surface exploration by landing on Mars
2030	China’s first manned lunar landing
2033	Return of first samples from Mars
2035	Implement exploration of planets/secondary planets and asteroids beyond Jupiter
2040	Construct the first short-term continuously manned lunar base
2050	China’s first manned Mars landing

** The Yinghuo 1/Phobos-Grunt mission failed in 2011

Fundamental Physical Laws: Here the emphasis throughout the period 2010-2050 is on the utilisation of various microgravity platforms to perform research in fundamental physics in such areas as fluids, granular media, materials science, combustion, gravitational waves, quantum information and cryptography, dark energy, cosmic neutrino background.

Small Centre with Big Network - The Space Applications Goals

In this part of the roadmap, the benefits of achieving the identified goals are made in relation to the China of today. It is acknowledged that China's problems in balancing economic development and supply of energy, and resource utilisation while minimising damage to the environment, will become more acute in the future. In addition to China's individual energy concerns, the deleterious effects of global change are also noted - as is quoted in the document, "There are no national boundaries for the impact of global change" [8]. Although fossil fuels have been the main energy source in China to date, their large contribution to global warming means that China is coming under increasing pressure to reduce its greenhouse gas emissions, i.e. the current situation is unsustainable if China wants to continue its growth. In addition to the above, China will also face challenges with respect to water shortages and pollution, and desertification. Natural disasters are also a problem. Located between two large seismic belts, the circum-Pacific and the circum-Indian, China is a country of many earthquakes. For example, the Sichuan earthquake in 2008 (measuring almost 8 on the Richter scale) caused extensive damage. And only last year, 2013, the southwest of China experienced sufficiently heavy rainfall to cause widespread flooding, with Sichuan again, suffering significant damage. The roadmap foresees two application elements to address the issues described above: An advanced multi-parameter Earth observation system, and a Digital Earth Scientific Platform and Earth System Simulation Network. In addition to the development of man-made Earth observation satellites, it is also noted that the Moon represents a natural Earth observation platform, and has always been a dream of Chinese scientists to use it as such!

A "small centre with big network" is envisaged as an effective way to share space infrastructures, information and technologies via high-speed networks. The "small centre" referring to the network nodes in Beijing, Kashi and Sanya; and the "big network" refers to the central nodes, research institutions, application systems and public services accessible through the network nodes. This complete system will be implemented in four steps: 1 – the initial construction stage (<2010); 2 – a case study and demonstration stage (2010-2020); 3 – a usage extension stage (2020-2030); and the full operational stage (2030-2050).

Providing Strong Support - The Space Technology Goals

The emphasis in this part of the roadmap was a focus on overcoming those technological hurdles that would slow down or prevent the achievement of the space science and applications goals identified in the previous sections. Key technologies identified included:

1. Ultra-high spatial/spectral/sensitivity technologies in support of astronomical observations and space-based research.
2. Precision spatial/time standards, for support to global positioning for example.
3. High-speed laser communication technologies to facilitate the massive data transmission demands of the future.
4. Nano and miniaturisation technologies to reduce the costs and increase the performance of future spacecraft.
5. Near-space vehicles such as high-altitude balloons, stratospheric airships and sounding rockets to facilitate the scientific exploration of near-Earth space.
6. Autonomous navigation and flight technologies to enable deep-space exploration.
7. Advanced experiment platform and life support system for a manned space station enable space-based research and manned deep space exploration.

There is a strong emphasis here on the phased development over the 2010-2050 timeframe of scientific balloon, sounding rocket and stratospheric airship technologies. But the overall focus is on the development of technologies to realise a sustainable permanent human presence in space. Technologies such as high-precision spatial and time standards, inter-satellite and space-to-ground high data rate transmission, component miniaturisation, autonomous navigation and high-efficiency propulsion technologies (e.g. nuclear propulsion).

Elevate Humanity

Published five years ago, the document "Space Science & Technology in China: A Roadmap to 2050" gave the already-running and diverse space programmes a home, a place to fit in, a framework to be part of. By letting science and technology purposely serve the nation, China is in the position to make the best out of these powerful tools, and bring the Chinese civilisation back to the place where it used to be for millennia - the world stage.

One should never forget that the decade-long Cultural Revolution left behind a highly-backward infrastructure. One should also not forget that this period of time had only finished by 1976, a time when Western nations in Europe, the U.S. and Japan enjoyed their maximum economic development and prosperity gained in the 20 years following the end of World War II. China is still playing catch-up. But, despite the lost period from 1945 to 1976, the nation is progressing at an incredible speed. To use science and technology as the driving force is legitimate as the UK, the U.S., Japan have done and nowadays also emerging countries in Africa, Middle and South America and other parts of Asia are doing. It is interesting to compare other national strategies with the Chinese one - see boxes on the next pages with summaries of the **ACI - American Competitiveness Initiative** and **Nigeria Space Roadmap 2005**. The different strategies have much in common.

So, what is at stake here? That China becomes as capable and advanced as the U.S.? That in the future the world would be a world of nations on the same level of technology and economy,

American Competitiveness Initiative - Leading the World in Innovation

To build on our successes and remain a leader in science and technology

(published by: Domestic Policy Council - Office of Science and Technology Policy, February 2006)

Objective

Keeping our competitive edge in the world economy requires focused policies that lay the groundwork for continued leadership in innovation, exploration, and ingenuity.

- As other countries build their economies and become more technologically advanced, America will face a new set of challenges.
- Especially in the fields of physical sciences and engineering - advances in these areas will generate scientific and technological discoveries for decades to come.
- The bedrock of America's competitiveness is a well-educated and skilled workforce.

Today's revolutionary technologies and many of our most popular consumer products have roots deep in basic and applied research. Long before there were computers or the Internet, scientists were unlocking the secrets of lasers, semiconductors, and magnetic materials upon which today's advanced applications were built. This enterprise was fuelled in large part by Federal investment in basic research that was necessary but not necessarily profitable for the private sector to undertake over the long term.

With only about five per cent of the world's population, the U.S. employs nearly one-third of all scientists and engineers and accounts for approximately one third of global R&D spending (U.S. R&D spending of over \$300 billion is as much as the rest of the G-8 nations combined). The U.S. is among the world leaders in R&D spending and the number of scientists and engineers.

It also requires a long-term vision to strengthen Federal support for the Nation's innovation enterprise.

America's economic strength and global leadership depend in large measure on our Nation's ability to generate and harness the latest in scientific and technological developments and to apply these developments to real world applications.

These applications are fuelled by: scientific research, which produces new ideas and new tools that can become the foundation for tomorrow's products, services, and ways of doing business; a strong education system that equips our workforce with the skills necessary to transform those ideas into goods and services that improve our lives and provide our Nation with the researchers of the future; and an environment that encourages entrepreneurship, risk taking, and innovative thinking. By giving citizens the tools necessary to realize their greatest potential, the American Competitiveness Initiative (ACI) will help ensure future generations have an even brighter future.

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The American Competitiveness Initiative commits \$5.9 billion in FY 2007 to increase investments in research and development, strengthen education, and encourage entrepreneurship. Over 10 years, the Initiative commits \$50 billion to increase funding for research and \$86 billion for research and development tax incentives. The American Competitiveness Initiative funds increased professional development for teachers, attracts new teachers to the classroom, develops research-based curricula, and provides access to flexible resources for worker training.

Investments and Policies:

- Federal investment in cutting-edge basic research whose quality is bolstered by merit review and that focuses on fundamental discoveries to produce valuable and marketable technologies, processes, and techniques;
- Federal investment in the tools of science - facilities and instruments that enable discovery and development - particularly unique, expensive, or large-scale tools beyond the means of a single organization;
- A system of education through the secondary level that equips each new generation of Americans with the educational foundation for future study and inquiry in technical subjects and that inspires and sustains their interest;
- Institutions of higher education that provide American students access to world-class education and research opportunities in mathematics, science, engineering, and technology;
- Workforce training systems that provide more workers the opportunity to pursue the training and other services necessary to improve their skills and better compete in the 21st century;
- Immigration policies that will continue to enable the United States to attract the best and brightest scientific minds from around the world to work alongside the best and brightest American scientists;
- Private sector investment in research and development that enables the translation of fundamental discoveries into the production of useful and marketable technologies, processes, and techniques;
- An efficient system that protects the intellectual property resulting from public and private sector investments in research; and
- A business environment that stimulates and encourages entrepreneurship through free and flexible labour, capital, and product markets that rapidly diffuse new productive technologies.

“The role of government is not to create wealth; the role of our government is to create an environment in which the entrepreneur can flourish, in which minds can expand, in which technologies can reach new frontiers.”

President George W. Bush, May 2001

Nigeria Space Road Map 2005

National Space Policy and Programmes - Federal Ministry of Science and Technology Abuja

- Mankind has enormously benefited from the advances in space technology. Nigeria, has remained a nation of consumers of products and services.
- The country is currently not in the position of the technical know-how to participate actively and independently in space related activities as a service provider.
- Nigeria is the most populous African country. It has abundant natural (renewable and non-renewable) resources and can be classified among the world's richest countries. Yet, Nigeria imports food, crude oil and other relevant goods.
- Floods, landslides, tidal waves, sand-storms, coastal erosion, and other man-made disasters have been recorded in the past.
- Space technology has enhanced the living standard in countries which have developed the necessary capabilities.
- There is a growing recognition that Space Science and Technology (SS&T) is the dominant engine of economic growth with historically high rates of return on investment.

Since there is a strong relationship between all developed nations' space programme and their industrialisation Nigeria should harness efficiently and effectively advances in Space Science and Technology to ensure its development.

The Vision

- **To make Nigeria build indigenous competence in developing, designing and building appropriate hard and software in space technology as an essential tool for its socio-economic development and enhancement of the quality of life of its people.**
- **The nation shall achieve this through research, rigorous education, engineering, development, design and manufacture of appropriate hardware and software in space technology, including transport and payloads, such as satellites, telescope and antennas for scientific research and applications.**
- **The government shall foster bi-lateral and international cooperation in all aspects of space science and technology to ensure that Nigerian scientists and engineers will benefit from global developments.**

Mission Statement

Use the gained space capabilities as a tool for:

1. developing and managing agriculture and forestry resources through establishment of a database for project planning, crop performance assessment, yield production for sustainable food production thereby assuring food security;
2. assessment and management of the National Resources (air, land, minerals, water) such as oil exploration, exploitation and management, assessment of the quality and quantity of both surface and sub-surface water and monitoring of marine water;
3. development of an effective and efficient communication system;
4. enhancement of transportation and tourism enterprises;
5. development of education and health care delivery system both rural and urban;
6. development and management of energy resources;
7. human safety and mitigation of disasters;
8. national defence and security.

Objectives

Develop a modern and industrialised economy, which is responsible for:

- creating jobs that pay living wages;
- propel Nigeria into one of the 20 largest economies in the world by 2020;
- become a key player in the global economy.

Nigeria Space Road Map-2005

- Produce a Nigerian astronaut by 2015.
- Launch a satellite manufactured in Nigeria by 2018.
- Launch a satellite manufactured in Nigeria from a launch site in Nigeria on a launch vehicle manufactured in Nigeria by 2025.

and a situation in which peers are dealing with peers, instead of leaders with followers?

What if the Chinese Dream is similar to the American Dream? When President Barack Obama and Chinese President Xi Jinping, met in June 2013 on the grounds of the Annenberg Retreat at Sunnylands, they had an intensive exchange on how to "chart the future of China-U.S. relations." Xi posited that the "Chinese dream" of economic prosperity and national renewal is closely connected to the "American dream." And indeed, since President Xi took office, he is always referring to his very own policy agenda of "Realizing the Chinese Dream.", which includes, "the Great Renaissance of Chinese National Culture", and is a consistent continuation of one of Deng Xiaoping's long-term objectives. "The overriding goal, to which all others are subordinated, is to achieve a 'society with modest and broadly distributed prosperity', and in so-doing, create the economic conditions for a renaissance of Chinese culture. The former

idea was a concept from the Confucian classics, resurrected by Chinese intellectual Kang Youwei in the 1880s. China's first President, Sun Yatsen, popularized the idea of a Chinese national renaissance during his successful effort to overthrow China's last imperial dynasty, and establish the Republic of China in 1911. ... But he [Xi] also sets some rather explicit goals, such as doubling 2010 national GDP and per capita income levels by 2020. A longer term objective is to 'build a prosperous, strong democratic civilization' and a 'harmonious modernized socialist nation' by mid-century. The phrasing is slightly updated, but these are the exact same objectives set by Deng Xiaoping when he started the process of 'reform and opening up' in the late 1970s." [7]

What at first sight appears to have a national focus, is about to evolve into a global affair. China's rise and emergence as a super-power, along with the peaceful coexistence of all nations is going to have an impact at the global level. It is about preventing

a Neo-Cold War - one which would see everyone on the whole planet loose, including those who initially benefitted from a new spiral in a 21st century high-tech arms race.

“The past 250 years’ industrialisation has resulted in the modernization and better-off life of less than 1 billion people, predominantly in Europe, North America, Japan and Singapore. The next 50 years’ modernization drive will definitely lead to a better-off life for 2-3 billion people, including over 1 billion Chinese, doubling or tripling the economic increase over that of the past 250 years, which will, on the one hand, bring vigour and vitality to the world, and, on the other hand, inevitably challenge the limited resources and eco-environment on the Earth. New development mode must be shaped so that everyone on the Earth will be able to enjoy fairly the achievements of modern civilization.” [8] For that, space might become the best tool we have.

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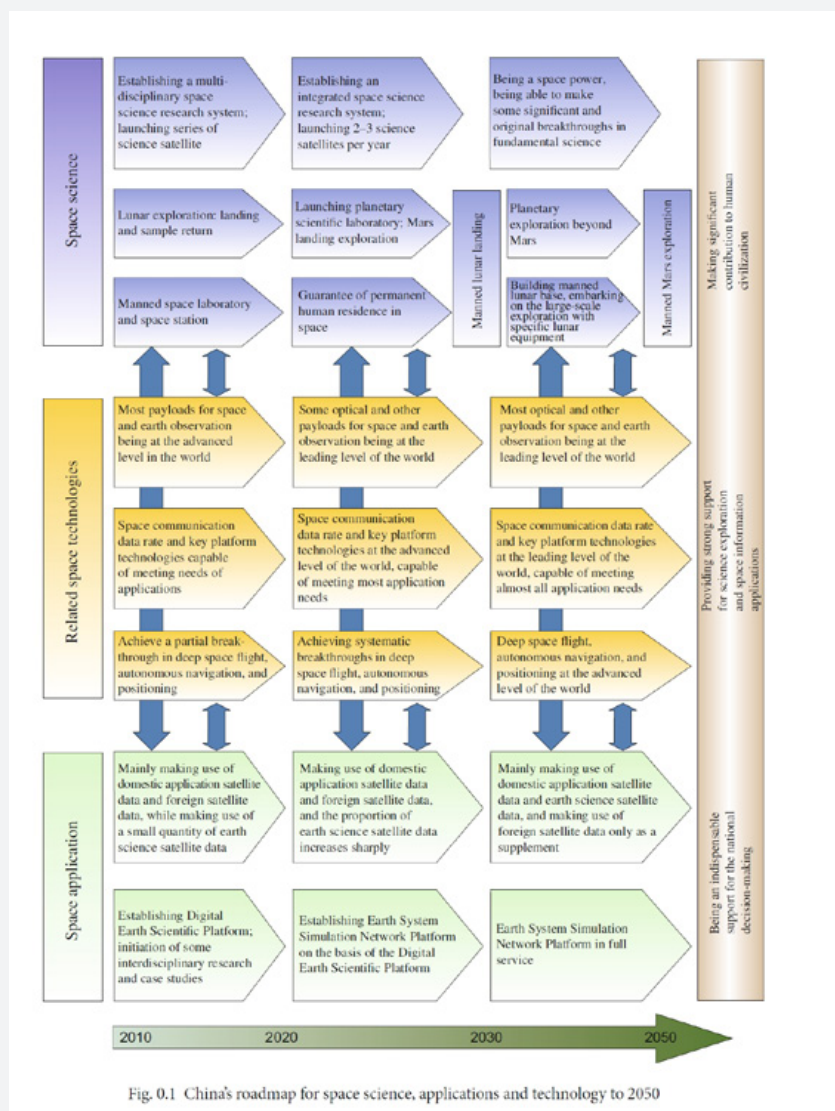
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<http://www.foxnews.com/tech/2014/04/15/china-president-urges-greater-militarization-space/>

[5] What will US do to counter China’s space offensive?
<http://washingtonexaminer.com/what-will-us-do-to-counter-chinas-space-offensive/article/2547339>

[6] “Revolutions are the locomotives of history.” Karl Marx

[7] Gregory Kulacki: China in Focus #16: Continuity and Change under China’s Chairman Xi <http://allthingsnuclear.org/china-in-focus-16-continuity-and-change-under-chinas-chairman-xi/>

[8] “Space Science & Technology in China: A Roadmap to 2050”, Springer 2010



The roadmap. (credit: CAS)

Fig. 0.1 China’s roadmap for space science, applications and technology to 2050

Movie Review - Fei Tian (Flying Apsaras)

U.S.-China space cooperation - An attempt to achieve the impossible

by Dietmar Roettler, Tony Quine, Jacqueline Myrrhe

The SPACE DREAM

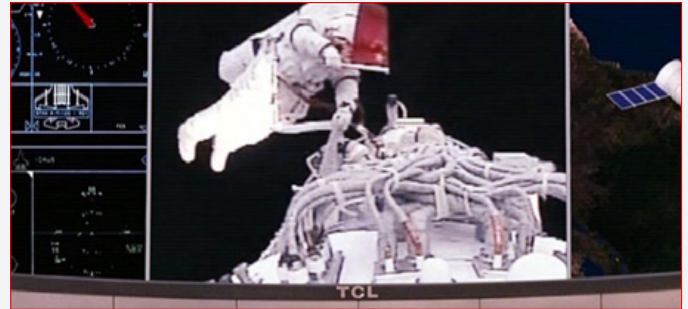
By Dietmar Roettler

- DVD technical data: Duration: 108 min, format 16 : 9, language: Mandarin, sub-title: Mandarin/English (cannot be switched-off)
- Bonus: Premiere Show in the presence of the real taikonauts, duration: 60 min, format 4 : 3, language: Mandarin
- Directors: Wang Jia and Shen Dong, first release: 1 July 2011
- Chinese cinema trophies: "Golden Rooster Award" for "Best Movie 2011" and Huabaio Film Award in the category for "Outstanding Director"

The film opens with Chinese taikonaut Zhang Tiancong (actor: Liu Zhibing) together with his two crew members, Li Dawei and Zhou Guanxiong, in training for the next manned mission within the Chinese space programme. The mission is supposed to be the Shenzhou VII space flight, which includes the first spacewalk. Tiancong and his fellow taikonauts have already been nominated before for the Shenzhou V and VI missions. At home, his wife Dandan and his daughter Siyu had to experience the "normal" taikonaut's family life. Despite being often and sometimes for a long time on their own, and despite experiencing the frustrations after Tiancong's missed flight opportunities, they have been supportive throughout all the years.

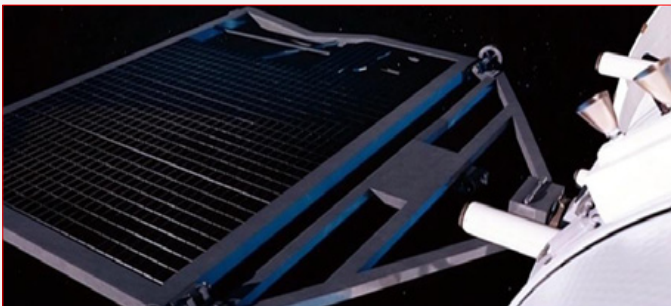
Although Tiancong is the best in performance again, he gets rejected and has to watch the mission as back-up crew. Bitter, that Tiancong and his crew have reached their age-limit for rookies (first flyers). As a consequence and after thinking long and hard, Dawei and Guanxiong decide to leave the Chinese taikonauts' corps and take high-ranking positions elsewhere. Not so Tiancong. He has put his whole heart into space, it is his passion and dedication. He would love to stay on for becoming the trainer for the new generation of taikonauts. However, Tiancong needs to explain this to his wife who has talked openly about divorce, in case Tiancong would not commit to a normal professional life. When his crewmates and friends notice that Tiancong is struggling to explain the situation to his wife, they organise a "visitors tour" of the taikonaut training centre for Dandan. When she sees all the training facilities and when she was explained the hardship taikonauts have to go through, she realises that Tiancong never bothered her with the difficult details of the training programme, but she also recognises what it means to her husband to be a taikonaut. This friendly tour opened Dandan's eyes and she has no objections anymore. Almost at the same time, her daughter Siyu decided to leave the prestigious Beijing University to join the military pilot school. Of course the parents have to sign the application form and once again, Dandan has to make a hard decision.

Tiancong becomes the trainer of four young male and two female taikonauts. Together, they have to undergo 58 school units and



credit: Huaxia Film Distribution Co. Ltd, China Film. Co. Ltd., August 1 Film Studio.

36 demanding training units. One part of the training leads the seven Chinese to the Gagarin Training Centre in Star City near Moscow. They are scheduled for parabolic flight training. This scene includes one of the few humorous encounters. The Chinese team has to board the IL-76 together with Indian and U.S.-American aspirants. The Russian instructors are giving all explanations and commands in Russian. One of the U.S.-American participants could not resist complaining that the



credit: Huaxia Film Distribution Co. Ltd, China Film. Co. Ltd., August 1 Film Studio.

instructors should use an international language. The Russian instructor's Russian reply was clear and straightforward: "Before coming to the Gagarin Training Centre, it is obligatory to learn Russian for at least two years because in Star City, the official language is Russian".

At home in China, Tiancong's mother is about to die. She has been diagnosed with a brain tumour. A long time ago, Tiancong had promised to his mother to fly to space and to take her pine seeds with him. Despite the serious situation and the enormous importance in China to join a dying family member, Dandan decides not to inform Tiancong about the situation and not to bring him home from Moscow. Dawei takes Tiancong's place and pretends to be her son. Dawei, speaking as Tiancong,

tells the dying mother that he was assigned to a space flight. Tiancong's mother is not aware that it is Dawei talking to her and this news gives her confidence to be ready for leaving this world.

Tiancong is still busy with other training units, such as survival training and simulated water landing. Nobody mentions his mother to him. His daughter has passed her helicopter pilot training with the highest marks. On the day of her graduation, Tiancong gives her a book by Steven Hawking as a present. During a risky disaster-relief campaign, Siyu caught a cold, and in a short meeting with her father, he becomes infected. The timing could not have been worse, as Tiancong was again on the selection list for a space flight, the Shenzhou IX space mission, the first mission to dock with the space laboratory. The infection however, removes him from the flight.

Three years later, (in reality this would be 2016) China is about to establish a small space station consisting of a core module and space laboratory. The modules are launched automatically from Hainan. Four days later, the Wentian I space craft launches from the Jiuquan launch centre to dock with the orbital complex. Again, Tiancong, together with two of his trainees is listed as a back-up or in case of need, of a rescue crew.

All seems to go well until Wentian I is hit by space debris. The solar panels are damaged which left the space craft without energy and manoeuvring capacity. The laconic comment from a staff member at the control centre: "Even space is not peaceful."

This paves the way for Tiancong's big chance. He launches with Wentian II, his back-up crew-members and the little flask with pine seeds into space to rescue the crew and damaged space ship. Down on Earth, his relatives in the village, where he was born only learn from the TV broadcast that Tiancong is in space. Tiancong's brother grabs the laptop where the broadcast is running to rush to the mother's grave and show her that Tiancong has kept his promise.

In orbit, Wentian II docks to the space station and prepares for rescue. From now on, the movie follows a hectic showdown: the whole space complex is catching up with the damaged Wentian I space ship. Tiancong, during an EVA attached to the robotic arm, is approaching Wentian I. He exchanges the solar panel. Wentian I is now able to dock to the space station, and the two crews are united.

After the work was done, the crews get connected via a live video link to the mission control centre. Here, Dandan and Siyu just arrived to talk to Tiancong. Tiancong, who has been, according to his own records, a taikonaut candidate for 7,596 days of his life, is asked by his daughter how he could stay motivated for more than 20 years.

He does not really give an answer but describes what he feels:

"For my daughter's question I have no answer. I know there'll be flowers and applause greeting me. But out of my own heart I know I'm not a hero. I'm just doing a special career. I like this job which is full of passion and challenges. I also find in the job the meaning and joy of life. When my 20-year dream was realised, when I came up here orbiting in space, I truly know the Universe



is so big and the Earth is so small. Human exploration of the world is boundless. We are just taking the first step.”

This is the story. There is not much humour or even self-irony built into the plot. In exchange, there is much pathos and a solid amount of propaganda (or with modern words: patriotism). However, anyone who is accustomed to Hollywood movies should be used to that. Despite these flaws, the story around the family is described with a lot of warmth. It is only a pity that the acting is just average. Watching the movie gives a good insight into how these space flight achievements are embedded into the Chinese national self-confidence. Twice it is emphasised that after developing the two bombs and the first satellite, this performance can be considered as a big national achievement. As somebody who has experienced Eastern and Western social environments, I would like to recommend the movie without prejudice. Because, if you really want, it is possible to recognise and respect astronautics as a pan-human cultural achievement, no matter which nation takes the lead for a certain moment in time. This is not the worst case scenario in a world where the most nations emerged based on warfare and are therefore bound together on a doubtful base. Considering that even in the US, apart from some pride, the Moon landings have not much left for the wider public.

For all technically-interested people: as far as I can judge, the movie was filmed at many original space locations, in particular the training locations. In between there is lot of footage from the Shenzhou flights, (i.e., launches, Shenzhou VII EVA). The launch and the docking of the future missions are well animated, although the laws of physics were not always taken into consideration, like during the catch-up with the space station. For all who are less focused on technical facts, the movie gives extensive insight into the Chinese space programme, its organisational structure and the Eastern technical culture.

The only drop of bitterness: The subtitles are only in Mandarin and English.

Flying

By Tony Quine

I first became aware of this movie in late 2010, when still images, behind the scene reports, and rushes began appearing on various Chinese websites. Throughout the first half of 2011, I followed progress and provided a couple of reports to 'Spaceflight' magazine, interviewing a couple of the actors and obtaining a good deal of interesting information from Asia Speed of Light Technology Company, who had been engaged to provide various scale, and full size, models to support the production.

The movie was released in China in June 2011, and I obtained a high-definition, English language, sub-titled version a few months later.

From the outset, I had been intrigued by the way in which the storyline was portrayed as being very closely linked to both the history, and the planned future, of the real Chinese manned

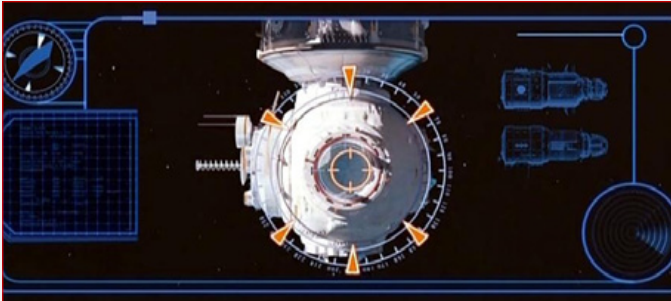


credit: Huaxia Film Distribution Co. Ltd, China Film. Co. Ltd., August 1 Film Studio.

space programme. At that time, it should be recalled, the real Tiangong 1 and Shenzhou 8, 9 and 10 missions were still in the future.

Indeed, the early trailers referred to the two manned space flights which are central to the plot, as Shenzhou 10 and Shenzhou 11, although in the final versions, they became 'Station 1' and 'Station 2'.

The main plot follows a Chinese astronaut, Zhang Tiancong, who was part of the 1998 selection group and who has served as a back-up on each of the Shenzhou 5, 6 and 7 missions. Early in the movie, his fellow back-up elect to leave the team and return to their Air Force careers. Zhang is left to decide if he should stay, and compete with new, younger astronauts, while



credit: Huaxia Film Distribution Co. Ltd, China Film. Co. Ltd., August 1 Film Studio.

whilst introducing fictional characters. This is not science fiction, but a movie about believable characters in the setting of the Chinese space programme.

The plot parallels the 'original timeline' very closely. Zhang is appointed to act as trainer and mentor to a new group of astronauts, five men (including him) and two women, which exactly parallels the real selection events of 2010, while remaining in contention for future assignments, himself.

Although the precise time line and dates of subsequent events are not 100% clear, the viewer can estimate from the appearance of Zhang's daughter, who is a school girl in 2008, and is a qualified military pilot, and future astronaut, by the time the movie concludes, so it seem that the climax is probably set in approximately 2015/6?

It is clear that the filmmakers had access to the facilities of the Chinese Astronaut Training Centre in Beijing, and also to the launch pad facilities at the Jiuquan Satellite Launch Centre (JSLC).

This results in sequences of the 'astronauts' training and preparing for launch and very realistic settings. The scenes at JSLC are particularly dramatic and tense.

Overall, the producers pursued very high production values and attention to detail, although for some reason, real spacesuits were not made available and those used are not totally convincing against a backdrop where everything else is very carefully reproduced.

The scenes in orbit are extremely well shot, using a combination of models and CGI, and whilst 'Gravity' has subsequently set new benchmarks for such scenes, this Chinese movie stands comparison, although the storyline, and scenes themselves, are not as dramatic.

Although the movie is essentially a promotional device for the Chinese space programme and a means to showcase Chinese technical progress, it is also a form of entertainment, so an exciting climax to the story was essential, and it is perhaps, at this point where the plot and reality diverge.

It was perhaps stretching credibility a little too far that China would have a 'spare' Long March/Shenzhou combination ready to launch a rescue mission, and that they would have the capability to replace damaged solar panels on the initial mission, and then have both Shenzhou dock with a large orbiting space station.

The characters of Zhang, his wife and daughter are well developed and credible – one could easily imagine Zhang alongside real astronauts of his era, such as Nie Haisheng or Jing Haipeng, and they are seen in a variety of settings, dealing with family and domestic issues, as well as the astronaut training scenes.

However, the other astronaut candidates are almost incidental, their characters are not developed at all, and most have hardly any dialogue. The two female astronauts are treated as little more than 'eye candy'; although competing to be China's first

acting as their mentor or also go back to the Air Force.

The plot tries to capture the way this choice, and his eventual decision, impact his wife and daughter, as well as Zhang himself, as time ticks against him. There are numerous scenes and subplots which capture the sacrifices and setbacks which are necessary to remain in contention for assignment to spaceflights, and it seems reasonable to assume this reflects the reality of spending many years in the real Chinese astronaut team, where flight opportunities are few and far between.

The plot is clever and credible, in that it takes as a starting point the conclusion of the successful Shenzhou 7 mission in 2008 and uses real imagery and mission badges from earlier flights



woman in space, no effort is made to convey anything of their back stories or their motivation.

Overall though, I was glad I'd made the effort to obtain a copy of the movie, and whilst it is essentially a promotional or even propaganda tool, it is well produced, the story is a clever mix of fact and fiction, and to the average viewer, is probably a plausible enough storyline, and an entertaining way to spend 90 minutes.

Please, also compare the review by Tony Quine in *Spaceflight Vol 53* March 2011 (p. 86): "Chinese space drama mixes fact and fiction", and the report about the filming efforts by Xu Weilong from the company *Asia Speed of Light Technology Company Limited*: "Chinese space film drama" in *Spaceflight Vol 53* September 2011 (p. 348-350).

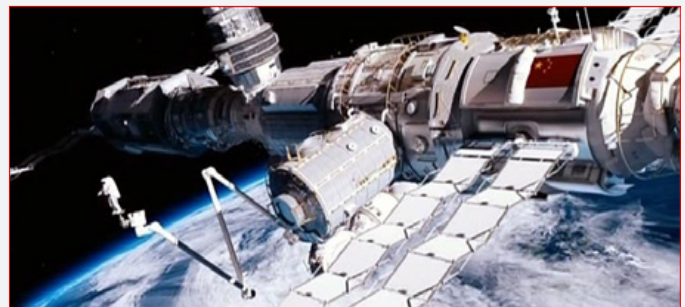
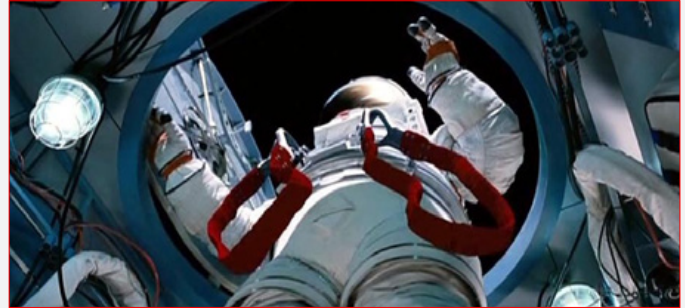
The female view - A home match with Chinese characteristics

By Jacqueline Myrrhe

During the IAC2013 in Beijing there was a little booth selling exciting Chinese space memorabilia. Those were all nice things, very stylish and not too expensive. Among them was also a book with incorporated stamps, a medal and a movie DVD. The kind lady at the booth even pointed it out that there is a DVD with a "good movie" included. Yes, yes, I thought, I am always happy to watch Chinese drama-soaps. Back home, the book got put on the bookshelf and ... almost forgotten. I admit that I am not a "science fiction" fan, in particular not for action movies or thrillers which pretend to be "science fiction". Until today I am a firm believer that I have not missed anything by skipping "Gravity", "Armageddon", "Star Wars", you name it...

It was only because a friend got back to me and recommended watching that movie, called "Fei Tian" that I finally took the initiative to watch it. And indeed it was a worthwhile activity and it gave me a nice surprise, because "Fei Tian" is different!

Fei Tian is about taikonaut Zhang Tiancong who is always the back-up, despite his performance showing that he is always the best. But somehow fate is not with him. Sometimes even not his family, because his taikonaut career sets the priorities in the life of the family trio, his wife, his daughter and him. Getting older and older and still not having flown to space, he has to take a decision: staying on as the oldie and becoming the trainer for the youngsters, the next generation of taikonauts, or trying a terrestrial re-launch to make a career in the air force. His wife told him clearly what she wants to see. This does not help to make the decision easier for him. For him - the taikonaut through and through - who cannot imagine any other professional occupation than being involved in China's human space programme. With a little help from his friends, Tiancong's wife can be persuaded to accept her husband's passion for space. Tiancong stays on. Years are passing by and all of the sudden there is an opportunity arising for him to make his space dream come true. Again, he gets assigned to a space mission, but only for the rescue mission in case things are going wrong. And things do go wrong. Our protagonist has to lead the rescue mission to get his trainees out of trouble. No problem for him who knows each



credit: Huaxia Film Distribution Co. Ltd, China Film. Co. Ltd., August 1 Film Studio.

command, each part of the space craft by heart ... - and soul. In a way, a happy ending.

"Fei Tian" gives an unexpected insight into the Chinese space programme. The whole sequence of events from the first manned missions up to the set-up of the Chinese space stations is presented on the fast track. Cool details like the reporting of Tiancong's crew straight in the beginning are setting the scene for what will come in the next almost 2 hours. Tiancong does look like a taikonaut. The viewer is tempted to assume he is one of the real ones. Impressive and highly interesting are the shots in the space locations. For Westerners who have never been to those places, the movie gives a glimpse of what is available in China. From the film it seems that the training in the Chinese



space programme is very rigorous and taikonauts have to undergo tough tests, like the hypobaric chamber and the stay in the silent room. Considering that Yang Liwei, Fei Junlong, Sun Jinyun and Wu Jie have been the adviser for this movie, I would assume, that the training was reflected in the realistic way.

What makes the movie likeable is that the filming was done with a lot of attention to little features, such as the moment when PC screens come out of the table top to click into a tilted position with an audible sound what gives the movie a fancy flavour. Also, how the camera is catching the scenes is pleasant for the viewer's eye.

Yes, there is propaganda involved. Certainly, the film could have done without it and would not have detracted from the plot. But would it have been the same, would it still have been typically Chinese or a just a Hollywood copy with Chinese actors? I found it interesting to see how I would take these portions of propaganda. And to be honest, having grown up in the GDR, I did feel at home without embarrassment. Without being malicious, I did enjoy the scenes in Star City. On the one side the movie-maker decided to let old friendship win over business when Tiancong got a good deal on the number of parabolas for the parabolic flight, he and the youngster were supposed to

undergo. On the other side the Russians remained very firm with the treatment of the English-speaking flight participants and did not deviate from the Russian-language-only approach. Bravo!

The biggest plus the movie got from me was its focus on the human side of space flight and on the relationship between humans. There is a lot about real - deep and sincere - friendship in it. To me it was striking to see Tiancong's friend taking over his role when Tiancong's mother is about to die. While on training with the six young aspirants in Moscow, Tiancong's duty prevents him from being with his family when badly needed. Also, it was admirable to see Tiancong's wife remaining strong and taking over responsibility for not calling him home to China to spend the last minutes with his dying mother. The movie-makers did very well to incorporate much of a human touch into a technical story. Most likely, even the coolest among us, have to shed a tear when seeing Tiancong's brother running with the laptop to the mother's grave showing her the TV broadcast of Tiancong's space mission.

So be prepared and get the pack of tissues ready beforehand! There is nothing wrong with that!



credit: Huaxia Film Distribution Co. Ltd, China Film. Co. Ltd., August 1 Film Studio.

Gallery

Wenchang Space Launch Centre



Full view of the Wenchang Space Launch Centre looking from the northeast. At the far left, near the sea coast, there are two launch towers - the front one is for CZ-7 while the back one is for CZ-5. At the far right are two vertical assembly buildings (VAB). (credit: Chinese internet)



Two launch towers as seen from the sea (from the east). From left to right are the CZ-5 and the CZ-7 launch towers. Lightning towers are also visible in this picture. (credit: Chinese internet)



View from the top of the CZ-5 tower. At the left of the picture, there are two vertical assembly buildings (VAB) in the distance. At the right of the picture is the launch tower for CZ-7. The two VABs and two launch towers are linked with tracks. (credit: Chinese internet)



Two vertical assembly buildings (VAB). This picture was taken from the northeast side so that only the backside of the buildings are seen. (credit: Chinese internet)



Close-up view of one of the vertical assembly buildings as seen from the south. The building, topped up in October 2012, has a height of 101 m, and is 8 m taller than the VAB in Jiuquan Satellite Launch Center. (credit: Chinese internet)



Interior view of the vertical assembly building. (credit: Chinese internet)



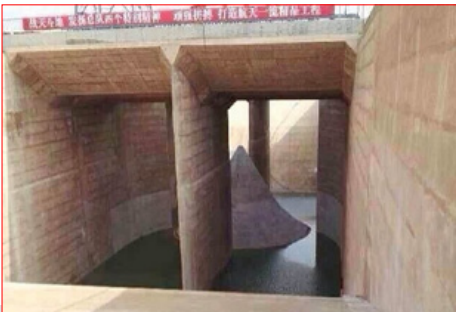
The tracks from the vertical assembly building to the launch pads under construction. The picture shows that the bed for one of two tracks has been almost completed. The vertical assembly building and another track are visible in the background at the left of the picture. (credit: Chinese internet)



Full view of the CZ-5 launch tower, taken in early 2014. The tower had almost been completed when the photo was taken. Note, that there is no crane at its top, which is the first time for a Chinese launch tower. (credit: Chinese internet)



Close-up view of the bottom-most platform when closed, looking from the ground. The space for the 5 m diameter core stage and four strap-on boosters are seen at the centre of the platform. (credit: Chinese internet)



Flame diversion trough of the CZ-5 launch pad. (credit: Chinese internet)



Two mobile transportation and launch platforms, one for CZ-5 and another for CZ-7, in assembly. Note the two "short sticks" near the platforms, which are the 58 m tall umbilical towers to be installed on the platforms. (credit: Chinese Space News/weibo)



One of the umbilical towers still on the ground. Once installed on the launch platform, they will provide support of fueling, gas, air conditioning and power supply to the launcher. The VAB and the launch platform are seen in the background. (credit: Guangzhou Transportation Co. Ltd.)