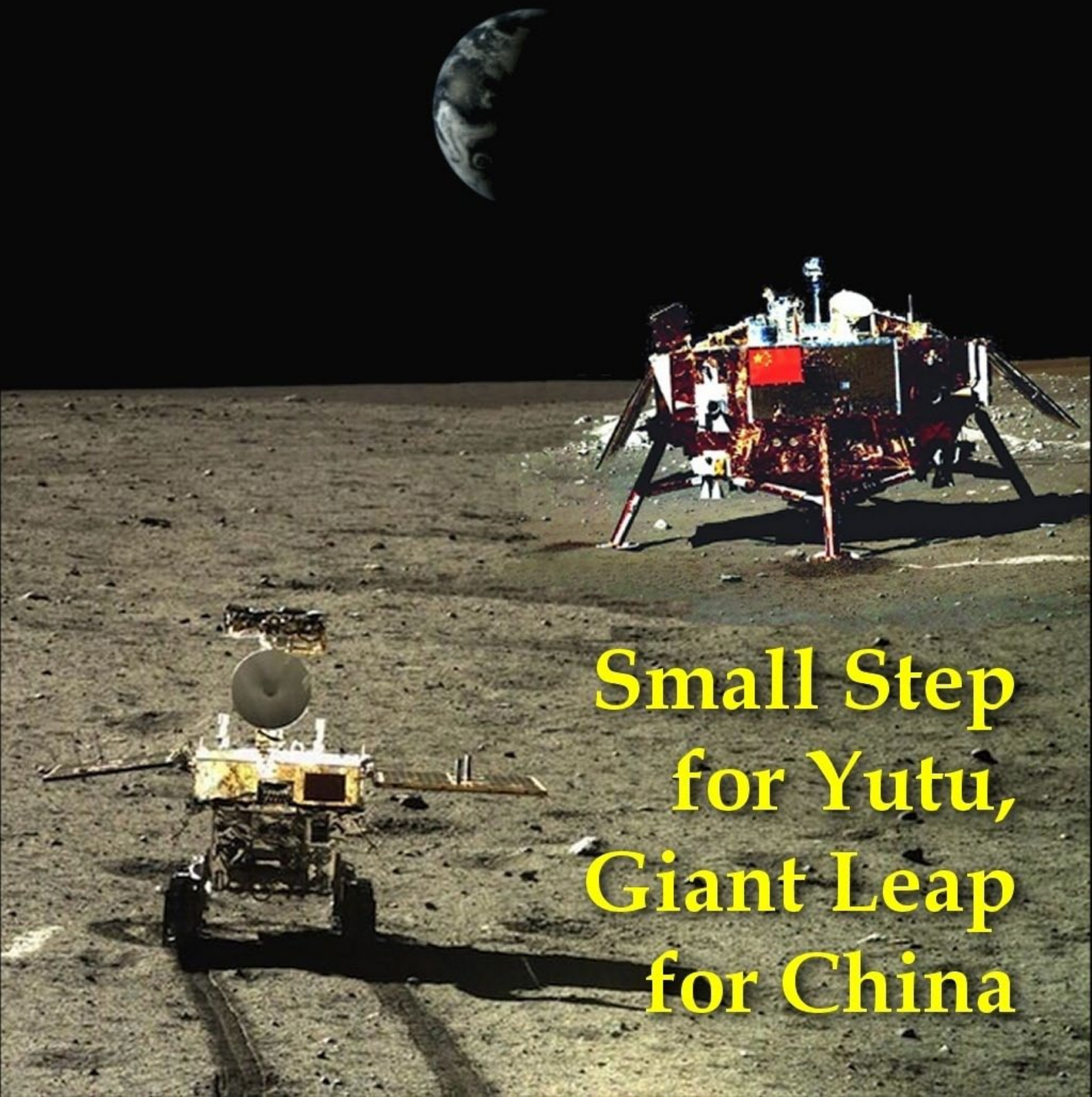
All About The Chinese Space Programme

Go Taikonauts!

龙腾太空

Issue 11 | February 2014



Small Step for Yutu, Giant Leap for China

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Small Step for Yutu, Giant Leap for China

Chang'e 3's Historic Lunar Landing

The 14 December is bound to be written into history of China. On that day, Chang'e 3, China's third lunar probe and the first lunar lander, made a successful soft-landing on the Moon. China becomes the third country after the U.S. and the former Soviet Union, to soft-land a man-made object on the Moon. "Made in China" appeared on a celestial body for the first time. So did the wheel marks of a Chinese vehicle. ...
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On the Spot

Competition has reached its limit! Space is for all - Marsward ho!

Heads of Agencies Summit 2014 in Washington

Welcome to Washington DC! For two days in January 2014 the capital of the United States put on its spacy hat. The 9 and 10 January saw the probably biggest ever get-together of leaders of national and international space agencies, but in contrast to the importance of the event it went with little public notice and limited media attention. ...
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The Go Taikonauts! Team
William Carey - Dave Chen Qing - Chen Lan - Jacqueline Myrrhe

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

Editor's Note

As you may have expected, the cover story of this issue of Go Taikonauts! is about the Chang'e 3 lunar mission. Chang'e 3 and Yutu, a small rover carried by the spacecraft, did not disappoint the world. On 14 December 2014, the main engine of Chang'e 3 fired and started a breath-taking 11-minute descent sequence. It made it, with a gentle and safe touching down on the lunar surface. It was another historic moment - the first soft-landing of an Earth departure vehicle on the Moon since 1976, and also the first Chinese presence on the Moon. A few hours later, Yutu drove down from its mother ship and set its foot (wheel, more exactly) on the Moon. There is no more appropriate words to describe that moment: a small step for Yutu, but a giant leap for China. Chang'e 3 was actually one of the most difficult missions and one of the most complicated spacecraft ever developed by China. The cover story has accounts of Chang'e 3's development history, the spacecraft design and payloads, as well as mission activities in the first month. The gallery in this issue also has some stunning images taken by the Chang'e 3 lander and Yutu on the Moon.

The 9 and 10 January saw probably the biggest ever get-together of leaders of national and international space agencies, but in contrast to the importance of the event it went with little public notice and limited media attention. GoTaikonauts! tries to give the highlights of the different conferences and panel discussions in Washington. We do not know what really happened behind closed doors, but already now, only a few weeks after the event, it turns out that Washington might have laid the foundation for solid global space endeavours in the future. In this issue, we have a report on the Heads of Agencies Summit in Washington, as well as the International Space Exploration Forum and Conference, and an analysis on US-China space cooperation. In these two articles, you will find a lot of detailed information, including a comprehensive timeline on US-China space relationship, and good analysis by the authors. We believe what happened in Washington may decide the future of the US-China relationship in space, and even the future of space cooperation of the whole world. We do not give a clear answer. You can judge by yourself.

This issue also includes the second part of our reports from the IAC 2013 and the UN-China workshop one week before it: Two articles, one with an interview of Leon Chiang, the Vice President of HEAD Aerospace, a Chinese space trading company, and another article with the impressions of a European, Jack van Loon, and an African participant, Proven Emmanuel Adzri, of the UN-China workshop. The latter article is quite interesting in that although coming with a very different motivation and from a different background, both participants are of the same opinion that the role of the UN is highly useful in supporting space capacity-building not only in less-developed, but also in developed countries.

Another interesting piece is the extract from the annual press briefing by Thomas Reiter, ESA's Director of Human Spaceflight and Operations. He brought the latest news on the efforts between ESA and China in the consolidation of space cooperation. Reiter's explanations are completed by an interview with Frank De Winne, Head of ESA's Astronaut Centre Department, on the current status of the work in the European Astronaut Centre and particularly with respect to cooperation with China. For details, go ahead and read!

(Chen Lan, Jacqueline Myrrhe)

Chinese Space Quarterly Report

October - December 2013

by Chen Lan

Highlights

- China experienced another launch failure
- Long March 6 launch vehicle rehearsed
- New Methane engine test-fired
- China's first space telescope, HXMT, entered flight model development phase
- Naming of the Chinese Space Station (CSS) and the cargo vehicle announced
- Chang'e 3 made an historic lunar landing, Yutu drives on the Moon
- China studies nuclear-powered space electric propulsion system
- Larger electric engine developed
- Pakistan astronaut might visit Tiangong 2
- China to build the largest thermal vacuum test chamber

Launch Event

On 9 December, China experienced its second total launch failure in 28 months. This time it was one of the Long March 4 models that have never failed since its maiden flight in 1988. Carrying the Sino-Brazilian resource satellite CBERS-3 (or ZY-1-03 as it is called by the Chinese side). The CZ-4B rocket lifted-off at 11:26 from the Taiyuan Satellite Launch Centre, and initially worked normally and almost sent the satellite into its planned polar orbit. But at the final moment, the YF-40 engine on the third stage, shut down prematurely, about 11 seconds ahead of time, according to the National Institute for Space Research (INPE), in Brazil. The satellite performed programmed separation and deployed its solar panel, but only achieved a sub-orbital trajectory with a negative perigee. It was tracked, and it communicated with the ground station in Brazil for about 15 minutes before re-entering the atmosphere.

China Great Wall Industry announced in a statement on 16 December, that the failure was caused by the premature shutdown of the second of two third-stage engines because of reduced fuel flow. The root cause of the failure is still unclear. The investigation will continue. However, China and Brazil both expressed that they will continue the cooperation and will launch the replacement, the CBERS-4 satellite, in December 2014.

Long March 6 (CZ-6) in rehearsal (credit: Chinese internet)

In the last three months of 2013, China also made six successful space launches, including the highly-anticipated Chang'e 3 launch of China's first lunar landing and rover mission. The six launches were:

- 11:50, 25 October: the SJ-16 launch by a CZ-4C from JSLC.
- 10:50, 29 October: the YG-18 launch by a CZ-2C from TSLC.
- 11:31, 20 November: the YG-19 launch by a CZ-4C from TSLC.
- 10:12, 25 November: the SY-5 launch by a CZ-2D from JSLC. SY-5 uses the CAST's third generation smallsat bus CAST300, that was developed for high-resolution optical and radar Earth observation.
- 1:30, 2 December: the Chang 'e 3 launch by a CZ-3B from XSLC.
- 0:42, 21 December: the Bolivian comsat Túpac Katari 1 launch by a CZ-3B from XSLC.

The number of successful space launches in China in 2013 is 14, a decline from 18 and 19 in the previous two years, and it was back to the third position behind Russia and the U.S. This was partially due to completion of the regional system of the Beidou Navigation System. However, the recent CBERS-3 failure had no significant impact on China's launch schedule and launch rate, which was shown by the immediate Túpac Katari 1 launch after the failure.

Long March 7 (CZ-7) ready for testing (credit: Chinese internet)

Space Transportation

On 10 December, the Long March 6 new generation small launch vehicle completed its first ever pad rehearsal lasting about two months in the Taiyuan Satellite Launch Centre, paving the way for its debut in 2015. During the rehearsal, launcher testing, interface coordination, fueling and simulated launch sequence were drilled at a temperature as low as minus 30 degrees Celsius. A photo of the launcher in rehearsal was posted on the Chinese internet. It was the first time a real CZ-6 launcher was seen in public.

Long March 5 development continued to make progress. In December, CALT completed the low-temperature static load test of the combination of the first stage hydrogen tank and the inter-tank structure. With a load of 300 tonnes and temperature of minus 196 degrees Celsius, it was the largest test on such a scale in Chinese space history. And also in December, the CZ-5's first stage was moved into the vibration tower, and a joining of the boosters using a new type of strapping mechanism was achieved. The Oxygen tank and other components of CZ-5 will be moved into the vibration tower later to make the modal test. In early December, the 6th Academy of CASC reported that its YF-75D expander cycle cryogenic engine for use on the CZ-5 second stage, made a successful test-firing, creating a working duration record.

It seemed that Long March 7 development was behind its big and little brothers. But in this quarter, it made a breakthrough. In early October, the first strap-on booster assembly of the Long March 7 launcher was completed. The 27 m long booster is the longest rocket stage ever built in China, and is the first rocket product totally designed and manufactured with digital technology. It was built to test the booster's propulsion system. On 11 November, a successful test-firing lasting 170 seconds, was made. It was the first whole-rocket test-firing for CALT since 1993. On 17 December, the second test-firing, lasting 167 seconds, was also successful. In the two test-firings, all rocket and ground systems worked well and large amount of data was obtained. In parallel, assembly of the CZ-7's core-stage was also started. It is built purposely for propulsion system testing.

It was reported in October that China's new generation liquid Oxygen/Methane engine recently made its first successful full-system test-firing. It was developed by the Institute 11 of CALT. But there was no mention of the new engine's specification in the report. It was China's second Methane engine. In February 2011, China's first liquid Oxygen/Methane engine with a thrust of 60 tonnes, developed by the Institute 11 based on its experience of cryogenic engines, made its first test-firing successfully. Another report in December indicated that the Institute 11 has three models of cryogenic engines in its development plan of 2014. Apart from YF-77 and YF-75D, the 200 tonne thrust class large cryogenic engine prepared for a future Moon launcher, was suspected of being among the three.

Satellites

China's civil high-definition Earth observation satellite, the Gaofen 1 (GF-1), has been formally put into service, the State Administration of Science, Technology and Industry for National Defence (SASTIND) announced on 30 December. The satellite has undergone eight months of in-orbit tests since it blasted-off on 26 April. It has met the requirements and even performed better than expected, by sending back high-quality photos according to SASTIND. GF-1's onboard camera is able to capture images with ground resolution of 2 metres.

The Gaofen Programme is planned for a constellation of 7 satellites to establish a comprehensive all-time, all-weather and global civil-use Earth observation system. The 7 satellites are:

- GF-1 & 6: optical imaging satellite with 2 m resolution for panchromatic images, 8 m for multispectral images and 16 m for wide-width (800 km) multispectral images.
- GF-2: similar to GF-1 & 6, but the resolution will be 2 times better.
- GF-3: one-metre resolution C-band SAR satellite.
- GF-4: GEO optical imaging satellite with a ground resolution of 50 m.
- GF-5: hyperspectral imaging satellite, also equipped with atmospheric component detectors.
- GF-7: high-resolution spatial cartographic satellite.

The GF-2 launch was planned for the end of 2013. But in the wake of the CBERS-3 launch failure, it has been postponed to early 2014.

On 22 November, the National Remote Sensing Centre of China (NRSCC) hosted a seminar in Beijing on Kuaizhou-1 satellite's application. It also opened a website for domestic users to request and download image data acquired by Kuaizhou-1, that was launched by the Kuaizhou solid-fuelled mobile small launcher in September.

In mid-November, development of the FY-4 geostationary meteorological satellite moved one step forward. Its bi-propellant unified propulsion system made a successful hot test-firing. This test set a foundation for the optimised design of the FY-4 flight model.

On 27 December, the anniversary of the Beidou Navigation System's official service launch to the Asia-Pacific region, China released the second version of the Signal in Space Interface Control Document (ICD) on the official Beidou web site, which provides more information than the previous version and will enable third-party developers to develop better Beidou-based navigation products. In fact, Beidou-based products have reached the market already. On 22 November, Qualcomm announced its solution to enhance location precision in mobile devices initially in China with support for the Beidou System. The first such device is the Samsung Galaxy Note 3 that uses Qualcomm's integrated tri-band location platform to provide more accurate and responsive location data.

Within the framework of the Space Science Pioneer Programme, China's science satellites made substantial progress in recent years. HXMT (Hard X-Ray Modulation Telescope) will become the first pure science satellite developed by China, not counting the Sino-European DoubleStar satellites. On 16 December, a review meeting approved the HXMT flight-model development. The spacecraft is expected to be shipped for launch in March 2015. HXMT is just a beginning. The first four projects in the Space Science Pioneer Programme (HXMT, SJ-10, QUESS

– QUantum Experiments at Space Scale, and DAMPE – DArk Matter Particle Explorer) were either in prototype or flight-model development. From 15-19 December, conducted in Sanya by CAS, the satellite-ground data link test for the QUESS and DAMPE were completed successfully. In addition, two batches of the background projects (each has four), have been reviewed and selected (First batch: SPORT, XTP, MIT, Space VLBI; second batch: Einstein Probe, STEP – Search for Terrestrial Exo-Planets, ASO-S – Space-borne Solar Observatory, WCOM - Water Cycle Observation Mission).

Manned Space Flight

On 31 October, the China Manned Space Agency released the official logo of the China Manned Space Programme and the names of CSS, its modules and the cargo vehicle:

- The CSS as a whole is named “Tiangong” (abbr. TG) meaning “heavenly palace”.
- The core module is named “Tianhe” (abbr. TH) meaning “peace in space/sky”.
- Experimental Module-1 is named “Wentian” (abbr. WT) meaning “ask or greet the space/sky”.
- Experimental Module-2 is named “Xuntian” (abbr. XT) meaning “cruise or survey in space/sky”.
- The cargo vehicle is named “Tianzhou” (abbr. TZ) meaning “space vessel”.

The China Manned Space Agency initiated a solicitation for proposals of names from the general public in April 2011. In total, over 100,000 names and 9,000 logos were collected.

According to USSTRATCOM, Tiangong 1 raised its orbit twice in late October and entered an orbit of 367 x 374 km. It was reported in late December that the mini-station was in an extension mission when it tested its battery pack and the lock on the docking mechanism.

Huang Chunping, a consultant of the Chinese Manned Space Programme, revealed to Chinese media at the end of November that the Tiangong 2 will be launched in 2015, followed by the Shenzhou 11 mission in May 2016 for a manned mission that will last no longer than 7 days. This excluded speculation of a longer duration mission, and hinted that the Tiangong 2 will be focused on cargo vehicle docking and a refueling test.

On 1 December, China completed a 30-day isolated habitation test in ACC (Astronaut Centre of China). Two test subjects spent 30 days in a 300 square metre cabin simulating future bases on the Moon and Mars. It was said that it was supported by the third generation ECLSS (Environmental Control and Life Support System) based on a mini farm that is able to supply food and Oxygen in a self-sufficient way. China is also developing the second generation ECLSS for use on the CSS with water recycling and Oxygen electrolysis from water.

Lunar and Deep-Space Exploration

The most anticipated Chinese space mission in 2013 was undoubtedly the Chang’e 3 robotic lunar landing mission. Six days before the planned launch date, on 26 November, China announced the result of the naming campaign for the lunar rover that would be carried on Chang’e 3. The name China had chosen was “Yutu” (Jade Rabbit) after a worldwide online poll.

From midnight of 1 December, CCTV covered the historic launch. The CZ-3B performed flawlessly, sending the 3.7-tonne Chang’e 3, the most complicated robotic spacecraft China has ever made, directly into a trans-lunar trajectory. At 1:48, the camera on the third stage sent back stunning live video showing the spacecraft separating from the upper stage and being eclipsed by the sun. At 2:14, Chang’e 3 deployed its four landing gears. Four minutes later, it deployed its solar panels, marking the successful completion of the launch. During the next 2 days, Chang’e 3 made two mid-course corrections, with the first at 15:50, 2 December and the second at 16:20 the next day. The third correction planned at 17:50 on 5 December was cancelled thanks to the high orbit insertion precision. At 17:41, 6 December, the 7,500 N engine on Chang’e 3 fired for about 360 seconds and the probe entered a 100 km circular orbit around the Moon. The Chang’e 3 mission was supported by China’s newly-built two deep-space tracking stations in Jiamusi and Kashi, and a VLBI tracking network with stations in Shanghai, Urumqi, Beijing and Kuming. ESA’s Estrack network also supported the mission.

On 10 December at 21:20, Chang’e 3’s engine fired again while travelling behind the Moon and lowered itself to a 15 x 100 km orbit. On 14 December, at 21:00, at 15 km above the lunar surface, Chang’e 3’s 7,500 N engine ignited, starting the complicated 11-minute landing sequence. It went well, exactly according to plan. At about 100 m above the Moon, the

Drop-test of the Chang’e 5 re-entry capsule (credit: Spacechina.com)

Yuanwang 21, carrying the mobile launch platform, arriving at Qinlan Port. (credit: Chinese internet)

lander made an automatic hazard avoidance correction and then continued to lower its altitude. At 21:11, the lander gently touched lunar surface, marking mankind's return to the Moon's surface after 36 years. In 1976, the Soviet Luna 24 made the last soft lunar-landing. Chang'e 3 landed at 19.5 W, 44.1 N, East of Sinus Iridum, the planned landing area. The actual landing site was actually in the northwestern portion of Mare Imbrium. The landing was seemingly one orbit earlier than originally planned that would have been after 23:00 Beijing Time. It was speculated that such a change was to make it broadcast live during prime-time television.

Immediately after the landing, Chang'e 3 deployed its solar panel that was retracted before landing. It then started its onboard equipment check-out and preparation for rover deployment. At about 23:45, all required conditions were satisfied and the first command was sent by the ground control. Yutu deployed its solar panel and the mast on top, and then its wheels were unlocked from the lander. At 3:10, it started to slowly move towards the so-called rover transfer mechanism. At 4:06, it was wholly on the track on top of the mechanism, and then the mechanism lowered itself until its track (or ramp) touched the lunar surface. At 4:35, Yutu finally drove down to the surface, leaving fresh tracks in the lunar dust. It was an historic moment. CCTV covered the whole event with near real-time video captured by the descent camera and monitor cameras mounted on top of the lander, at a rate of about 10 images per second.

The rover stayed at 10 metres north of the lander, the so-called Point A, for about 13 hours before the first photo-opportunity moment came. After a U-turn, the cameras on the lander and the rover took pictures of each other. CCTV released the pictures at around midnight of 15 December. After picture taking, because of concerns about the high temperature at the Moon's noontime, the rover moved to the Point B and entered sleep mode. 5 days later, Yutu woke up and made a 21 m journey from the Point B to C and then to D and the lunar vehicles took more pictures of each other. The rover also tested its robotic arm on 23 December. Some payloads on the lander, for example the spectrometer, were powered on and tested. But all activities ceased before the lunar night beginning on 26 December. The lander and the rover entered hibernation mode on the morning of 25 December and dawn 26 December respectively. They will rely on the radioisotope heater units (RHU) to survive the 14-day lunar night.

On 24 December, NASA's Lunar Reconnaissance Orbiter (LRO) approached the Chang'e 3 landing site, and LRO's onboard camera (LROC) was able to capture an image clearly showing the existence of the Chang'e 3 lander and the rover with the help of a long shadow, though LRO was at an altitude of 150 km-orbit, in which it can only obtain images with a resolution of 1.5 m.

When the Chang'e 3 news hit the media, there was sporadic information on the Chang'e 2 and Chang'e 5, its predecessor and successor. On 16 December, Chang'e 2, now in a planetary orbit, reached a position of 65 million kilometers away from the Earth. On the same day, the State Administration of Science, Technology and Industry for National Defense (SASTIND) announced that the sample return mission, Chang'e 5, will be launched in 2017. Another report revealed that Chang'e 5 is expected to bring back 2 kg of lunar soil. It is widely speculated that the Chang'e 5 lander will be similar to that of Chang'e 3. While its orbiter (reportedly in development by SAST) will be totally new. In mid-November, the re-entry capsule of Chang'e 5 completed a successful air-drop test, the first of 5 planned such tests. On 2 December, a key component of Chang'e 5, the 3,000 N engine to be used on the orbiter and the ascent stage, set a new duration record in a test-firing.

During the China International Industry Fair (CIIF) held in November in Shanghai, SAST displayed a scale model of a future Mars probe. The 2,350 kg probe consists of a lander carrying a 300 kg rover, an orbiter and a propulsion stage. It would be launched by a CZ-3B in December 2015 and reach the Red Planet in September 2016. It is unclear if it is the same mission reported earlier that combines the orbiting and landing mission in 2018, or it was only a "dropped" proposal from SAST.

The research publication, Scientific Reports, from the Nature Publishing Group, published a paper on 12 December by Chinese scientists Xiaoduan Zou and five co-authors, with more details of the Chang'e 2 Toutatis fly-by one year before. It revealed new and more accurate nearest fly-by points from the asteroid: 770 ± 120 m from the surface and 1.32 km ± 120 m from the geometric center. Toutatis measures 4.75 x 1.95 km (±10%).

Advanced Technology

In late December, it was reported that CAST has completed the design and optimisation of a "high-power nuclear space electric propulsion system". The system is specially designed for future human Mars exploration. It will make a relatively short round trip to Mars possible. However, the report did not mention what type of nuclear electricity generation system it is and what type of electric propulsion will be used.

CAST also made progress on the development of a new type of electric engine – the magnetic focusing Hall-Effect thruster. The thruster, developed by the Institute 502 of CAST, completed a full-system test in November. It was turned on and off for more than 30 times and accumulated 20 hours of firing time. It will be tested on a new technology demonstration satellite later on.

International Cooperation

On 2 December, on the day of the Chang'e 3 launch, witnessed by Premier Li Keqiang and Prime Minister David Cameron, China and the UK signed a Memorandum of Understanding on space cooperation. Both sides will explore possibilities on cooperation in the fields of space science, space applications and education. David Willetts, the Science Minister of the UK, said after returning from Beijing, that Britain's deepening relationship with China and its role as the "trusted partner" of the US, puts the UK in a strong position to co-ordinate a manned mission to Mars by the world's great powers within 30 years. The UK trade delegation to China also witnessed the signing of an agreement by Surrey Satellite Technology Ltd (SSTL) and DMCii, with their Chinese partners 21AT, for the launch of a high-resolution Earth observation service (Beijing 2 smallsat), following on from a £110 M contract signed in 2011. SSTL also signed an agreement with

the China Academy of Space Technology (CAST) for potential collaboration on satellite applications and training.

In the last quarter of the year, news media reported on a series of activities related to space cooperation between China and other countries:

- It was reported in early October that SAST and NPO Lavochkin had discussed further cooperation in the field of deep-space exploration. The two sides had cooperated in the ill-fated Yinghuo 1 / Phobos-Grunt project.
- In early November, CALT signed an agreement with MC2, an Italian company, for cooperation on terra-hertz communication technology.
- On 6 November, China and Brazil signed an agreement that extends bilateral space cooperation for another 10 years.
- In late November, the Institute 802 of SAST and Pennsylvania State University (PSU) of the U.S. signed an agreement to establish a joint R&D centre for High Intensity Radio Field (HIRF) - Thunderbolt Effect study. The centre was formed by The Electromagnetic Communication laboratory (EMC lab), at PSU, and the Key Laboratory of Aerospace Electromagnetic Environment Effect, at SAST.
- During 24-25 November, ISSI-BJ (International Space Science Institute – Beijing) hosted a forum on the Solar Polar Orbit Telescope (SPORT) project in Beijing. 28 experts from the U.S., UK, France, Italy, Russia and China attended the forum and discussed scientific objectives and payloads of the mission, and the plan for international cooperation on solar studies. More forums on other projects within China's Space Science Pioneer Programme will be held.

China's announcement of opening the CSS for international cooperation sparked dreams in developing countries. In November, Major General Ahmad Bilal, chairman of Pakistan's Space and Upper Atmosphere Research Commission, told China's Global Times that his country would like to become the first in the world to send its astronauts to China's Tiangong 2 space station.

In early October, NASA rejected applications from Chinese nationals who hoped to attend the space agency's Kepler Science Conference in November, at its Ames Research Center in California, citing a law which prohibits anyone from China setting-foot in a NASA building. After intentions of boycotting the conference by some prominent US-American astronomers and wide media reporting, NASA lifted the ban and explained it as a misinterpretation of its policy on foreign nationals. Among those leading the boycott warning were Debra Fischer, an astronomy professor at Yale University, and Geoff Marcy, an astronomy professor at the University of California, Berkeley.

Commercial Space

Prior to the Túpac Katari 1 launch on 21 December, Bolivian media reported that the country will purchase another satellite from China. This satellite will be an Earth observation satellite, and has been named Bartolina Sisa, wife of Túpac Katari. Túpac Katari was a Bolivian hero in the fight against the colonialism of the Spanish Empire.

On 22 November, China Great Wall Industry signed the in-orbit delivery contract with APT Satellite Holdings Limited for the ApStar 9 comsat. ApStar 9 is a DFH-4 based comsat that will be launched in October 2015. The satellite completed its preliminary design review in October.

On 27 December, Dexo Travel, a Chinese travel agency focusing on high-end travellers and the Netherlands-based space tourism firm, Space Expedition Corporation (SXC), signed an agreement to open the door for Chinese citizens to experience sub-orbital space flight. Travellers will pay a minimum of 580,000 yuan (about 95,000 U.S. dollars) to board the Lynx Mark I spacecraft produced by the U.S. private aerospace company XCOR. Participants will receive one week of physical training at Royal Dutch Airlines or Air France before their space trip, and the spaceship will arrive in outer-space 60 minutes after its take-off, and will fly in space for 20 minutes while the tourists enjoy a view of the Earth and space, Zhang, CEO of the company, said, "The Lynx Mark I spacecraft is expected to begin flights in the fourth quarter of 2014."

Miscellaneous

Ground Facility

In early November, CAST started construction of the KM8 thermal-vacuum chamber in its new AIT (Assembly, Integration and Test) site in Tianjin. The KM8 has a height of 32 m and an inner diameter of 22 m. It will become the third largest of its kind in the world. Once completed in later 2014, it will be used to test the space station modules, DFH-5 based communication satellites and larger remote sensing satellites.

One month later, the foundation for CAST's other large-scale ground facility, the assembly and test building for ultra-large optics was laid in Tangjialing, Beijing.

On 4 December, a large-scale sun simulator, the largest one in China and developed by CASIC, was put into use.

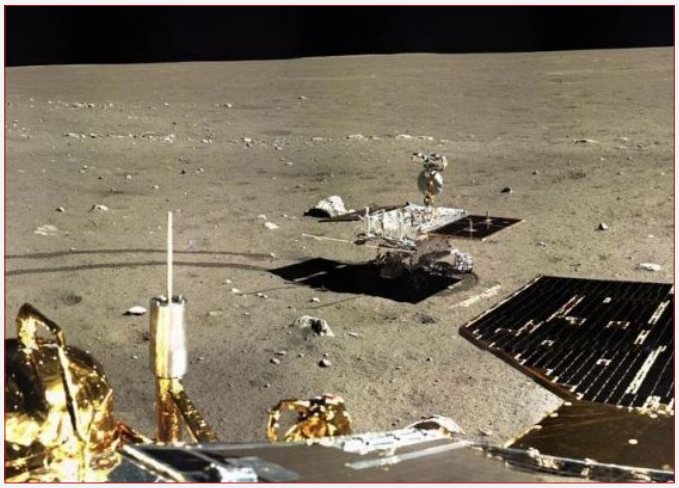
On 17 November, two rocket transportation ships, Yuanwang 21 and 22, arrived at Qinglan Port, near the Wenchang Satellite Launch Centre. They carried components of the mobile launch platform of CZ-5, weighing about 2,000 tonnes. During the next 5 days, all the cargo was unloaded by cranes on the ships and then transported to the launch centre by highway. On 23 November, the two final and largest components of the platform were conveyed to the centre by two flat trucks in a 10-hour journey.

(Chen Lan)

Small Step for Yutu, Giant Leap for China

Chang'e 3's Historic Lunar Landing

by Chen Lan



The Rabbit Has Landed

The 14 December is bound to be written into history of China. On that day, Chang'e 3, China's third lunar probe and the first lunar lander, made a successful soft-landing on the Moon. China becomes the third country after the U.S. and the former Soviet Union, to soft-land a man-made object on the Moon. "Made in China" appeared on a celestial body for the first time. So did the wheel marks of a Chinese vehicle.

Chang'e 3 was launched at 1:30 Beijing Time on 2 December 2013. On top of the Long March 3B rocket is the 3,780 kg combination of a lander, and a rover called Yutu (Jade Rabbit) whose naming was announced just a few days before. After a journey of 380 thousand kilometres over 4 days, at 17:41, 6 December, the 7,500 N throttleable engine on Chang'e 3 fired for about 360 seconds, and it entered a circular orbit with an altitude of 100 km. On 10 December at 21:20, Chang'e 3's engine fired again when the probe was flying around the Moon and lowered itself to a 15 x 100 km orbit, the planned final orbit for landing on the lunar surface.

Prior to the landing date on 14 December, it was reported that the landing would take place at about 23:30 Beijing Time. However, on the landing day, CCTV announced that it will begin live coverage from 20:00 and the landing was expected to be around 21:40. It happened to be the prime time for television. So there was speculation that the landing was tentatively made one orbit earlier to attract a larger TV audience.

At 20:30, the ground sent out the first commands for landing. The spacecraft adjusted its attitude and retracted its solar panel to avoid structural damage during decent and landing. At 21:00 sharp, at 15 km above the lunar surface and with a velocity of 1.7 km/s, Chang'e 3's 7,500 N engine ignited and started the complicated six-phase landing sequence consisting of:

- Major deceleration phase: lowering its altitude and velocity to 3 km and 57 m/s respectively.
- Fast adjustment phase: keeping a smaller thrust and further lowering its altitude to 600 m.
- Approaching phase: keeping a smaller thrust and finding a safe landing area using optical devices.
- Hover phase: hovering at zero velocity and precisely measuring the surface using the 3D laser scanning imager and finding a safe landing site.
- Hazard avoidance phase: descent to 30 m above the selected safe landing site.
- Slow descent phase: further slowly descending to 3 m above the surface and then a shutting-down of the engine. The lander then falling by gravity, lands on the surface.

At 21:04, the descent camera at the bottom of the lander turned on and sent back the first image 8 seconds later. It continued at a rate of 10 images per second, making it possible to provide near real-time video. During the whole landing, lasting a total of 11 minutes, both descent camera images (in total 4,673 images) and simulated animations representing the real status, were displayed on the large screen in the Flight Control Centre in Beijing, which was also relayed by CCTV. All went well, exactly according to plan. At 21:09, the lunar probe was hovering at an altitude of 30 m. At 21:11:18.695, the lander gently touched lunar surface, marking mankind's return to the Moon's surface after 37 years. The last occasion was in 1976, when the Soviet Luna 24 made the last lunar soft-landing. It reminded us of a voice many years ago, "the eagle has landed". But this time, we heard the echo, "the rabbit has landed."

The Legend of the Jade Rabbit (Yutu)

There are different versions of the legend. The following is the most popular one:

Three fairy sages transformed themselves into very poor old men. They decided to test the character of a fox, a monkey and a rabbit. The men turned themselves into desperate old beggars and asked the fox, the monkey and the rabbit for food. The fox and the monkey gave some food they had spare. But the rabbit had nothing to give. So he jumped into a burning campfire to roast himself as food to the three old men. The men, who were not actually hungry, were very touched by the rabbit's self-sacrifice and generosity. They decided to grant him immortal life, sending him to live in a palace on the Moon as Jade Rabbit.

The Jade Rabbit then became the companion of Chang'e who had already been living alone on the Moon for many years.

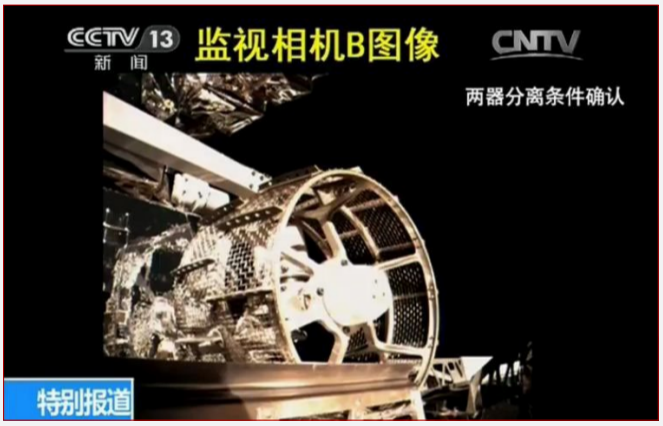
Chang'e 3 landed on the lunar surface at 19.51º W, 44.12º N, in the northwestern portion of Mare Imbrium, instead of the earlier-reported Sinus Iridum, to the west of the actual landing site. In fact, the actual landing site was still inside the planned landing area of 356 x 91 km, though very close to its eastern-most border. The so-called Sinus Iridum landing site is probably not strictly correct, and could just be for a simpler naming of the landing strip, because more than half of it is inside Sinus Iridum.

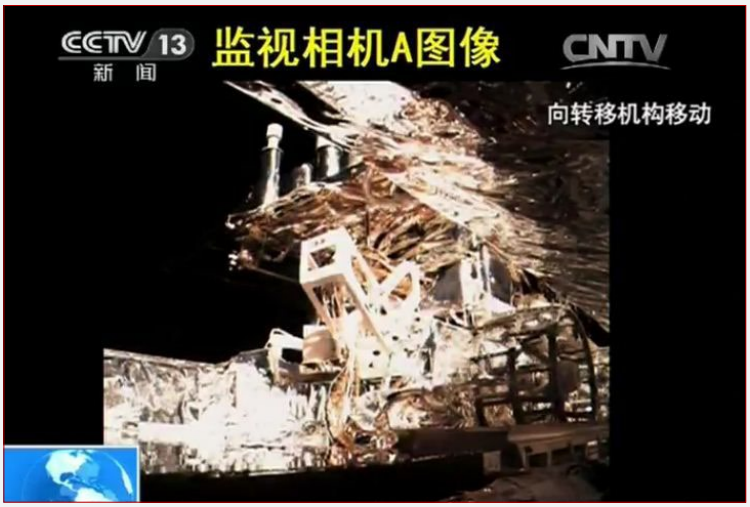
Immediately after the landing, Chang'e 3 deployed its solar panel that was retracted before landing. It then started onboard equipment check-out and preparation for rover deployment. At about 23:45, all required conditions were satisfied and the first command was sent by ground control. Yutu deployed its solar panel and the mast and then its wheels were unlocked from the lander. At 3:10, it started to slowly move towards the so-called rover transfer mechanism. At 4:06, it was fully at the track on top of the mechanism, and then the mechanism lowered itself until its track (or ramp) touched the lunar surface. At 4:35, Yutu finally drove down to the surface towards the north, leaving fresh tacks in the lunar dust. It was an historic moment. We seemed to hear another echo from many years ago - "it's a small step for Yutu, but a giant leap for China". CCTV covered the whole event with near real-time images captured by three monitor cameras mounted on top of the lander, and two navigation cameras and two hazard avoidance cameras on Yutu.

After a short stop following touchdown, Yutu continued driving north and reached the so-called Point A, about 10 metres north of the lander. It stayed there for about 13 hours before the first photo opportunity moment came. It first made a U-turn, facing its camera towards the lander. Then, the cameras on the lander and the rover took pictures of each other. CCTV released the pictures at around midnight of 15 December. More than 40 years after the end of the Apollo programme, people in the world see again clear, stunning and beautiful colour pictures from the lunar surface. After the picture-taking, because of the high temperature at the Moon's noontime, the rover moved to the Point B and entered sleep mode on 16 December. 5 days later, Yutu woke up and made a 21 m journey from the Point B to C and D and the rover and lander took more pictures of each other. The path from Points A to D is almost a semi-circle that allowed Yutu to take pictures of the lander at different angles with different lighting conditions. At Point C and D, Yutu sent back portraits of the lander with China's national flag on the side of the lander. Besides the different types of cameras,

Chang'e 3 separated from the launcher. Jet flows from its thrusters were clearly seen. The sun was behind the spacecraft. (credit: CCTV)

Yutu's front wheel. The image was captured by the monitor camera B on the lander, just before the rover was commanded to move forward. (credit: CCTV)





Yutu's rear wheel. The image was captured by the monitor camera A on the lander, shortly after the rover had started to move forward. (credit: CCTV)

Yutu touched down on lunar soil. The image was captured by the monitor camera C on the lander. (credit: CCTV)

other payloads on the lander and the rover were turned on and tested one-by-one. The Ground-Penetrating Radar (GPR) was turned on later, on 15 December. The Lunar-based Ultraviolet Telescope (LUT) was turned on at about 9:30 on 16 December and obtained the first sky image. After the "noon nap", the rest of the payloads were all tested. The rover also tested its robotic arm on 23 December. But all activities ceased before the beginning of the lunar night on 26 December. The lander and the rover then entered hibernation mode on the morning of 25 December and the dawn of 26 December respectively. They would rely on the radioisotope heater units (RHUs) to survive the 14-day long lunar night.

On the first day of 2014, China Post issued two stamps for the historic lunar landing. It was the third time in 10 years that China has issued stamps for a space mission. The first one was in October 2003 for China's first manned space flight, the Shenzhou 5 mission. And the second was in November 2007 for the first lunar orbiter Chang'e 1.

Challenges

China considered sending a probe to the Moon as early as the 1990s. But serious planning was only done in the 2001-2003 time-period, in the wake of India's and Japan's lunar missions. In 2003, China laid down an ambitious three-phase long-term lunar plan in which the first phase is robotic lunar exploration, and the second phase is to send people to the Moon, while the last phase is to set-up a permanent lunar base. It was more correctly, just a vision. Only its first phase, the robotic exploration phase, was seriously planned with three steps as well. The first step was to orbit the Moon in 2007, the second step was a soft-landing on the Moon in 2015, and the last step was to return a sample to the Earth by 2020. Chang'e 1 and 2 have completed the first step, and Chang'e 3 was given the duty to accomplish the second step.

After the Chang'e 1 mission in October 2007, CAST established two parallel teams for two follow-on lunar missions. One team developed Chang'e 2, originally a backup for Chang'e 1. As the Chang'e 1 mission completed successfully, it became Chang'e 2, which the Chinese decided to use as a pathfinder for Chang'e 3. The most important task of Chang'e 2 was to map and select the landing site for Chang'e 3. It did it. By late May 2011, it had obtained the 7 m resolution full-Moon map and 1-1.5 m resolution images at Sinus Iridum, the primary site for the later landing mission. In addition, the Chang'e 2 spacecraft tested the direct trans-lunar trajectory, a descent camera designed for lunar landing, and the newly-built deep-space tracking network. All these worked well and set a solid foundation for the success of the Chang'e 3.

Another team, led by Shun Zezhou, was focused on the Chang'e 3 landing mission. In February 2008, the Chang'e 3 project was approved by the government. It took 21 months for proposal and design, 26 months to develop the prototype and 20 months to develop the flight model. From the project's approval to launch, it had been nearly six years, much longer than its brothers, the first two Chang'e probes, showing the challenges and difficulties China encountered. China has never built a spacecraft that had to work on the surface of a celestial body. Too many technologies had to be developed from the beginning: soft-landing, rover, tracking, communication and remote control to the lunar surface, lunar night survival, surface scientific tasks, etc. Chang'e 3 was undoubtedly the most complex robotic spacecraft China has ever developed to date.

The 7,500 N throttleable engine is one of the major elements developed from scratch. Prior to Chang'e 3, China's largest engine on a spacecraft was the 2,500 N engine on the Shenzhou manned vehicle. Besides its much larger thrust, it has to work for 1,200 seconds and to be throttled to as small as 1,500 N during final descent. AALPT (6th Academy of CASC) was responsible for the engine development. During the development, more than 100 test-firings were conducted, and more than 60,000 seconds of firing time accumulated. To guarantee a safe and precise landing, a throttleable engine is not enough. Microwave ranging radar, high accuracy laser range finder, 3D laser scanning imager, gamma ray altimeter and software for GNC, terrain recognition and hazard-avoidance, all needed to be developed. Many of these technologies have been used and tested in the Chang'e 1 and 2 missions, and in Shenzhou-Tiangong dockings.

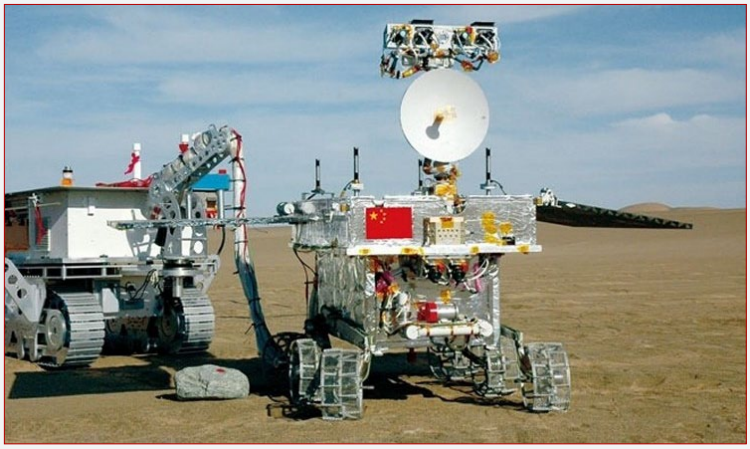
It was another challenge for a spacecraft to survive in the long lunar night without sunlight. China has learned from the experiences of the U.S. and the former Soviet Union, who used nuclear energy to keep the spacecraft warm and provide electric power to it when they are in the shadow of the Sun or the sunshine is too weak. Radioisotope thermoelectric generators (RTGs) and radioisotope heater units (RHUs), have been used on spacecraft for many years. But China has never used them before, though R&D work has been underway for many years. China's first RTG was born in 1971. In 2006, the first 100 mW class Pu-238 based RTG was completed. However, both the Chang'e 3 lander and the rover carried only the RHU. Its purpose is to keep the temperature inside the equipment bays between -20 to +55 degrees Centigrade. No specification of the RHU has been reported.

Landing gears (legs) and the rover transfer mechanism are also a first for China. The legs are similar to those of Apollo, but there has been no other rover in history that has had to move down from such a tall platform, as in the case of Chang'e 3. The Institute of Solid State Physics of CAS, Hefei, Anhui Province, was responsible for the development of the stretchable shock-absorbing buffer rod, a key component of the legs. The Harbin Institute of Technology (HIT) and CAST jointly developed the transfer mechanism with various creative designs. According to the design, the lander is able to safely touch down at a velocity of 4 m/s on a slope with an angle of up to 15 degrees, and the rover can also move down to the surface with such an angle. The landing and transfer mechanism has proven very successful in the actual landing and rover deployment on 14 and 15 December 2013.

The rover is also a very important, complicated and challenging part of the project. In fact, initial rover development started very early in 1998 at Tsinghua University. Later on, more than 20 Chinese organisations joined the game with more than 40 proposals and prototypes. They were mostly universities and institutes of CAS. Of course, CAST and SAST were not absent. There were even reports that the Polytechnic University of Milan (PUM), Italy, would join a team with a Chinese university for developing a rover. In July 2007, CNSA released the technical

The drop-tower designed to test lunar descent and landing. (credit: Chinese internet)

Chang'e 3 was in preparation for an engine firing. (credit: Chinese internet)



Yutu was in outdoor field-testing in Kumtag Desert, Qinghai Province. (credit: Chinese internet)

The newly built 64 m antenna in the Jiamusi deep-space tracking station. (credit: Chinese internet)

requirements for the rover competition. However, there were rumours later, that a formal bidding or competition had been cancelled. The CAST rover design was finally selected and other organisations with the best technologies in specific fields were to develop the various parts of the rover. HIT was responsible for the suspension system and wheels. While the Camera Pointing System was developed by the Hong Kong Polytechnic University (PolyU), which previously developed the Mars Rock Corer for the UK's Beagle 2 Mars lander, and the Soil Preparation System for Russia's Phobos-Grunt probe - both were ill-fated. It is worth to note that Yutu's rocker-bogie suspension system is very similar to that used on NASA's MER, Spirit and Opportunity, as well as Curiosity, rovers.

Development of Chang'e 3 also pushed the set-up of new ground test facilities. A simulated indoor lunar surface test field was built in CAST, Beijing. It was covered with dust finer than flour, collected from Changbai Mountain, a dead volcano at the Korean border, to simulate the lunar surface. An outdoor test field was also set-up in a remote site near Lop Nur in the Kumtag Desert, Qinghai Province. An 80 m tall drop-tower with simulated lunar gravity was built to test the lander's final descent and touchdown. A deep-space tracking network was also planned during the early stages of the programme. In late 2012, China completed two new tracking stations in Jiamusi (64 m antenna) and Kashi (35 m antenna), forming China's initial deep-space tracking network. A large 65 m radio telescope in Shanghai was also completed during the same period, further enhancing the existing VLBI tracking network. They were successful tested during the Chang'e 2's Toutatis fly-by in December 2012.

All the above is only a small part of the total effort required to fulfill the mission. Numerous organisations from Chinese space industry, CAS institutes and universities were involved in the Chang'e 3 development. New technologies developed were not only used in this mission, but will also benefit more advanced missions in the future. Since Chang'e 3, China's space technology has come up to a high level and China has taken over a leading role in deep-space exploration. It is indeed "a giant leap for China".

Chang'e and Yutu

Chinese planners have set three engineering objectives and four scientific objectives for Chang'e 3. The engineering objectives are:

- To breakthrough key technologies of lunar soft-landing and

lunar rover;
- To establish basic capabilities of robotic lunar landing, surface survey and deep-space TT&C;
- To establish a fundamental engineering system for lunar exploration.

And the scientific objectives are:
- To investigate lunar topography and geological structure of the Moon;
- To investigate the material composition of the lunar surface and distribution of lunar resources;
- To survey the space environment between the Moon, the Earth and the Sun;
- To carry out astronomical observations from the lunar surface.

Chang'e 3 has a launch mass of 3,780 kg, including the 1,220 kg lander and the 140 kg Yutu rover as well as propellant. At the top of the octagon-shaped body of the lander is a pair of refoldable solar panels and the rover. The rover transfer mechanism was folded on the side of the lander. The lander has four legs, an 7,500 N throttleable engine on the underneath, and twenty-eight 150 N and 10 N thrusters on eight sides for attitude control, as well as sensors, antennas and three engineering monitoring cameras on the top. The lander is expected to work on the Moon for one year. There are four major scientific payloads on the lander:

Topographic camera

Installed on the top of the mast of the lander. The topographic camera is able to capture a 360 degree panoramic image around the lander, for rover monitoring and lunar topographic studies. It was developed by the Institutes of Optics and Electronics, CAS.

Descent camera

The lander is equipped with a single descent camera that was tested on the Chang'e 2 spacecraft. It was developed by the Institute 508 of CAST.

Lunar-based Ultraviolet Telescope (LUT)

The lander is equipped with a 150 mm Ritchey–Chrétien telescope in the near-UV band (245-340 nm). The LUT will be the first long-term lunar-based astronomical observatory. More than 41 years ago, a far-UV telescope carried by Apollo 16 to the Moon, had made some short-term observations. The LUT was developed by the National Observatory, CAS.

Extreme Ultraviolet (EUV) Camera

The lander also carries an extreme ultraviolet (30.4 nm) camera to observe the Earth's plasmasphere. It was developed by the Chuangchun Institute of Optics and Electronics, CAS.

The rover weighs about 140 kg including 20 kg of payloads. It has a length of 1.5 m, width of 1 m and a height of 1.1 m. It is able to climb slopes of up to 20 degrees, cross obstacles with a height of up to 20 cm, drive at maximum speed of 200 m/hour, and drive continuously for 10 km. It has a pair of solar panels on top, and a mast mounted with cameras that will be folded during lunar night to protect them from the extreme cold temperature. Two navigation cameras and two hazard avoidance cameras are installed on the front of the rover. The rover has the capability to automatically plan its route using its camera and software and to drive itself to the target. It is designed to explore an area of 3 square kilometres during its 3-month mission.

The rover carried four scientific payloads:

Panoramic Cameras

As one of the most important payloads on the rover that are able to obtain 3D images of the lunar topography, they are mounted on the rover's mast. These were developed by the Xi'an Institutes of Optics and Electronics, CAS.

Ground-Penetrating Radar (GPR)

A ground-penetrating radar (GPR) is at its underside. Its purpose is to measure the structure and depth of the lunar soil to as deep as 30 m. This radar was developed by the Xi'an Institutes of Electronics, CAS.

Infrared Imaging Spectrometer

The purpose of the infrared imaging spectrometer is to detect the composition of lunar material, in order to carry out a resource survey of the Moon. This spectrometer was developed by the Shanghai Institute of Technical Physics, CAS.

Robotic Arm and Particle Excitation X-ray Spectrometers

There is a small robotic arm on the front of the rover. On its top is mounted the alpha particle excitation X-ray spectrometer, which is intended for analysing the chemical element composition of lunar samples. The spectrometer was developed by the Institutes of High Energy Physics, CAS.

Chang'e 3 development was sped up in 2011. Here are the major milestones.

- 20 January 2011: the propulsion system of the lander made a successful whole-system hot-firing test in the Institute 101, Beijing. The system was developed by the Institute 801, Shanghai.
- Late August, 2011: the rover started intensive indoor field-testing.
- 5 October to early November 2011: the rover completed the outdoor field-testing in the test field near Lop Nur.
- By 29 December 2011: Chang'e 3 had completed hovering and hazard avoidance testing, indoor and outdoor field testing, and the lander's integrated testing.
- 13 March 2012: flight model development formally started after completion of reviews of five major sub-systems and breakthroughs of a series of key technologies.
- Late September 2012: a launch site rehearsal had been made to prepare for the launch in 2013.
- In December 2012, an Electromagnetic Compatibility (EMC) test of the lander and the rover was completed.
- In mid-May 2013, Chang'e 3 started its final major testing, the thermal vacuum test, in the KM-6 chamber. The testing lasted about 40 days.

- July 2013: one of the final tests, the soft-landing cushion test was completed successfully.
- On 24 August, a review for shipping the spacecraft to the launch centre was completed.

On 11 September 2013: at 3:19, the Chang'e 3 lunar probe departed from CAST in seven vehicles. It arrived at the Capital Airport of Beijing at 5:51, and was then loaded into an Ilyushin IL-76 cargo aircraft. At about 6:00, 12 September, the cargo aircraft took-off and arrived in Xichang three hours later.

On 2 December, at 1:30, witnessed by hundreds of millions of TV audience

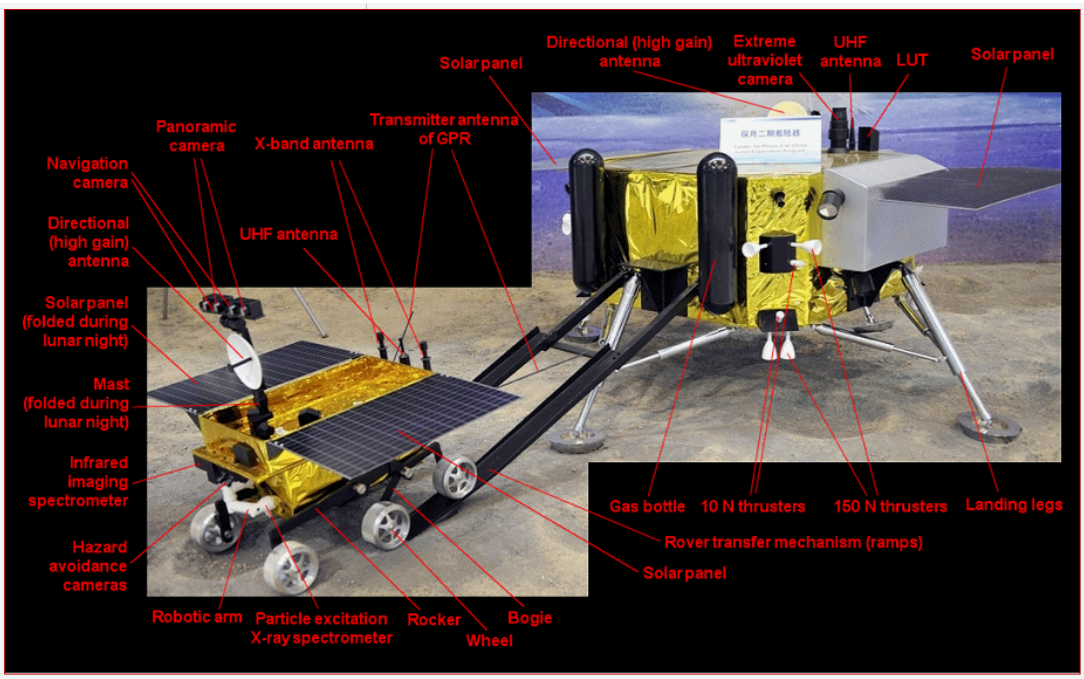
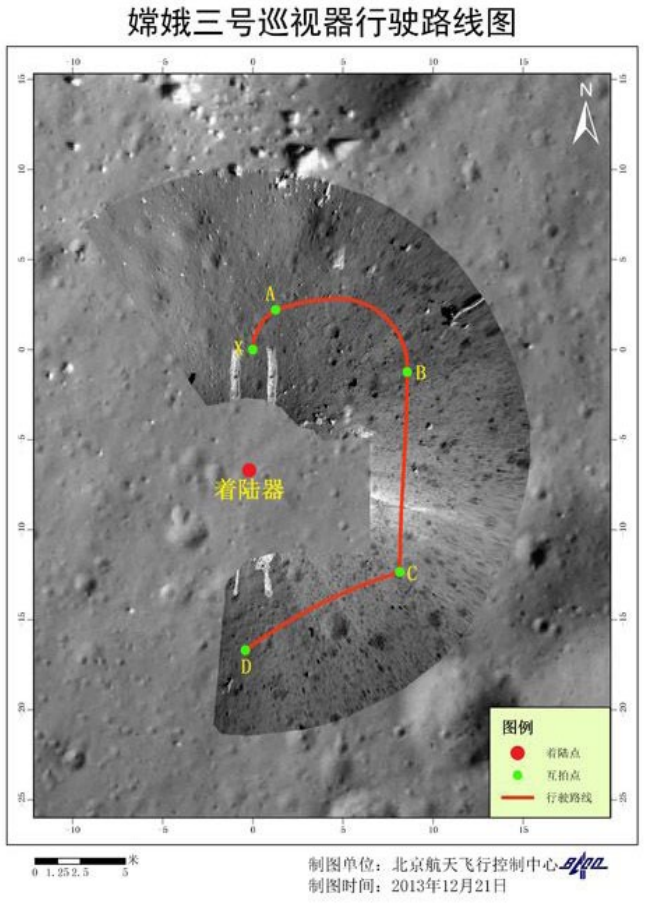
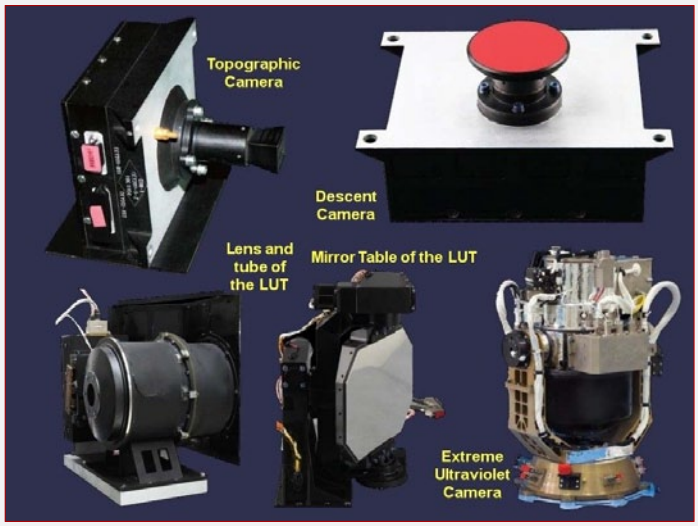


Diagram of Chang'e 3 lander and rover, with indication of major components and payloads. (credit: Go Taikonauts!/Chinese internet)

Yutu's traverse map from 16 to 22 December 2014. (credit: BACC)





Payloads on the Chang'e 3 lander (credit: Go Taikonauts!/CAS)

Payloads on the Chang'e 3 rover (credit: Go Taikonauts!/CAS)

and web surfers, a CZ-3B launch vehicle blasted-off from Pad 2 at the Xichang Satellite Launch Center. The launch went smoothly and looked quite routine. Only the longer cruise time made it a little different. Instead of a low Earth orbit insertion, it sent the Chang'e 3 straight into a direct trans-lunar trajectory. The most surprising thing came last: at 1:48, the camera on the third stage sent back a long stunning live video showing the spacecraft separating from the upper stage and then entering the eclipse of the Sun. What a Hollywood style long shot!

Shadow of Apollo

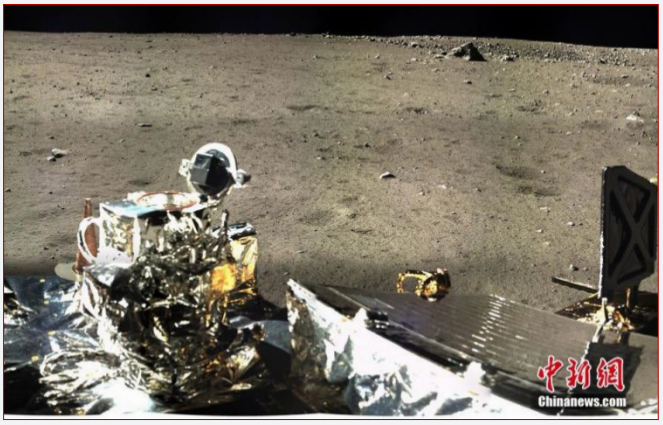
As an important link between the Chang'e 1 orbiter and the Chang'e 5 sample return vehicle, Chang'e 3 is more of a pilot and validating vehicle with a focus on its engineering objectives. Its scientific objectives can be considered as a bonus. In such a sense, the mission can be considered 90% accomplished when it entered its hibernation mode on 25 December.

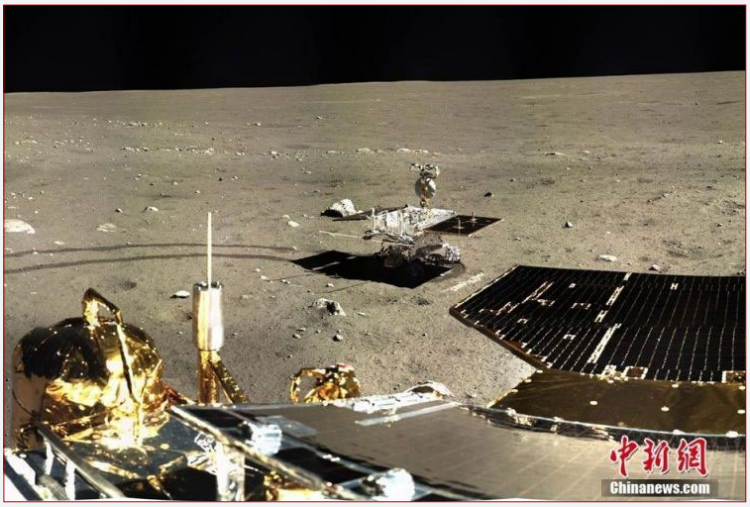
If you compare Chang'e 3 with other lunar landers in history, you will find that it has the closest appearance with the Apollo lander. If it is understandable that the four-leg design shares common principles for manned and un-manned landers, one may question why the rover is unnecessarily placed at the top of the lander, which is so high that it needs a complex mechanism to deploy it. Weight and size of the lander, and thrust of the engine also look more than what is required by its scientific payloads. All these aspects point to a speculation that it is a shared design with the Chang'e 5 sample return vehicle and will in future, become a basis of a manned lunar lander by just simply scaling it up.

It is a reasonable speculation that is consistent with China's lunar plan and practice of the Chinese space programme. In fact, from released pictures and animations of Chang'e 5, we can see that the Chang'e 5 lander is almost identical to that of Chang'e 3. There has been also a lot of official information about the sample return mission. Looking at the Chang'e 5 lander, you will find that the rover on the top, is replaced by an ascent stage carrying a container of lunar soil. Also new is a robotic arm and a drill on the lander. The Chang'e 5 lander (with an ascent stage) will be launched with an orbiter, carrying a small re-entry capsule. Once it has reached lunar orbit, the lander-ascent stage combination will separate and land on the Moon. Then, its

Earth seen from the Chang'e 3 landing site, taken by the topographic camera on the lander at 2:15 on 25 December 2014. (credit: CLEP/CAS)

Part of a panorama picture taken by the topographic camera on the lander showing a pyramid-shaped rock southwest of the landing site. It was planned as an object to be studied by Yutu. (credit: ChinaNews/CAS)





Part of a panorama picture taken by the topographic camera on the lander showing the rover, Yutu, near Point B (credit: ChinaNews/CAS)

Model of the Chang'e 5 lunar sample return vehicle. Note its lander is almost identical to that of Chang'e 3. (credit: Chinese internet)

robotic arm, with a soil grabbing device on its tip, will collect soil samples and move them into the container on the ascent stage. The drill will also obtain samples from 2 m below the surface and transfer them into the container. After that, the ascent stage takes-off from the lunar surface and enters an orbit around the Moon for the orbiter to chase and dock with. After a successful docking, the sample container, with 2 kg of samples, will be transferred to the re-entry capsule. Then, the ascent stage is jettisoned and the orbiter's engine will be ignited, putting itself into a direct atmospheric re-entry trajectory, and finally returning to a landing site within China.

Sounds familiar? Yes, it is exactly a scaled-down Apollo mission. If Chang'e 5 becomes a success, many of the technologies for a manned mission would have been proven. It is happening now - the successful Chang'e 3 mission may have already solved many of the problems for a round-trip robotic mission to the Moon - at least the lander could be directly used in future without many changes. We have to say that Chinese planners are very wise and visionary, and this approach is very reasonable, cost efficient and sustainable. As a result, it is very easy to understand why the Chang'e 3 lander so much resembles the Apollo lander.

Chang'e 5 development is already underway. It has been announced that the launch will take place in 2017, three years ahead of the original plan. According to reports, SAST will be responsible for the lunar orbiter, while CAST is believed to be developing the other modules. A key component of Chang'e 5, the 3,000 N engine to be used on the orbiter and the ascent stage has been in testing for some time. Two docking radars - the microwave radar and the laser ranging radar, based on Shenzhou models but lighter and smaller - are also in development. The parachute recovery system of the small capsule has also been tested successfully using a rocket sled. And the re-entry capsule has also completed a successful air-drop test in late 2013.

It was reported that China will launch a pilot spacecraft before 2015 to conduct the crucial re-entry test. This spacecraft is expected to use the Chang'e 2 bus (presumingly DFH-3) carrying a small capsule to make a circumlunar mission and simulate the high-speed re-entry expected for Chang'e 5.

An interesting topic is Chang'e 4, the backup of Chang'e 3. It is unlikely that this will be the above-mentioned pilot vehicle. What will it be used for then? People on the Chinese internet have speculated polar landing, landing near a hole, landing near Apollo, and landing on a planet. So, let's wait and see!

On 11 January 2014, CAS released some high-resolution images and scientific data obtained during Chang'e 3's first lunar day (See Gallery in this issue). 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 continues to drive towards the south, and all payloads on the two spacecraft have started formal scientific work. It is reported that a pyramid-shaped rock to the southeast of the landing site had been identified as the first object to be closely investigated by the rover. Although there is unofficial information indicating that the topographic camera had a malfunction, all other equipment appears normal. On 23 January at 4:00, Yutu successfully tested UFH communication with the lander from 24 metres away. It was the first "talk" between two Chinese space vehicles on a celestial body. In early morning of 24 and 25 January, the lander and the rover entered hibernation mode respectively, again. To many people's surprise, the official announcement for the second lunar night operation, came with some bad news - Yutu had encountered an abnormality on a "mechanism" just before the second lunar night. Then, for as long as two and half weeks, there had been no news from the two lunar vehicles. Even two days past the planned waking-up date, there was still no news. Many people thought that the rover had died, as its equipment was exposed to deep-freezing for so long as a result of the "mechanism malfunction". A suspected "mechanism malfunction" was that the solar panel at one side, that was to be folded over the payloads to protect them, had not done so.

A miracle came on 13 February when China announced that Yutu had woken up and resumed its full status before hibernation except for the malfunction at the mechanism. Will the miracles continue? Will Yutu be able to drive forward again? How long will the mission last and how much scientific data can be acquired? Many people are eagerly waiting. So are we. Go Taikonauts! will closely follow the mission and will report further progress in future issues.

A Heads-up for HEAD

by Jacqueline Myrrhe

Commercial space activities are not new to China. While in the past the focus was on launch service provision, China's increasing capabilities and demands allow a broader and more attractive range of projects. Also, the many young and talented Chinese space experts are coming up with very creative ideas, which cover more than cheap labour or hardware production.

During the International Astronautical Congress in September 2013 in Beijing, GoTaikonauts! became aware of the exhibition stand of the China HEAD Aerospace Technology Co. Upon approaching the booth, the GoTaikonauts! team did not need to ask twice to get the opportunity for an interview. The Vice President of HEAD, Leon Chiang, was happy to get involved in a pleasant talk and to answer the many questions.

GT: GoTaikonauts! is an English language space magazine. We only publish on Chinese space activities.

Leon Chiang: I saw your magazine here in Beijing and I read your article about Liu Yang, the female taikonaut. It is interesting. Which organisation is running this?

GT: We are independent, there is no organisation behind us. We have certain expertise in space publishing, but so far it was in German language only. So we decided that if we want to reach out to the world, we have to publish in English. In our day-time job we are working in the space sector. But GoTaikonauts! is our hobby project - our dedication and our passion. And as you know, if you are a real space professional you can never switch off, so we do space all around the clock, every day. We see ourselves in a pathfinder function, because we want to show that there is a big potential in China. GoTaikonauts! is an iPad application, a PDF newsletter, and only for the IAC2013, we have published this printed version.

Leon Chiang: Yes, I see that. This is a special version.

GT: Actually, we are here to learn more about your company. So please, tell us: What is the scope of your company, what are your objectives? What are your ideas about cooperation with either Europe, the US or even worldwide?

Leon Chiang: I don't know if you have seen that HEAD is a company and not an organisation or administration. We are the only company here in the IAC exhibition which is not state-owned, it is a fully private company. We are a member of the IAF. All the other exhibitors are state-owned. We are a small company. We are doing trading and cooperation. We have engineers, but we do not do engineering work. Our job, vision, and mission is to promote collaboration between Europe and China. For example, I was invited to give a presentation about my company on Tuesday afternoon in a German-China round-table for space cooperation. It was very well perceived. The HEAD company has been established in 2007, and we have now successfully established several contacts and successful contracts, and even more intermediate relations between European space companies and Chinese space companies – like an intermediate private company that can promote this kind of cooperation.

GT: Which projects are you involved in, and to which organisations or companies are you talking?

Leon Chiang: We have many contacts, several contacts in

Leon Chiang, The Vice President of HEAD. (credit: GoTaikonauts!)

Leon Chiang (left) and Go Taikonauts! team member William Carey (right). (credit: GoTaikonauts!)

Europe and many contacts in China. Currently, most of our customers are located in China. Our customers are Chinese entities and institutes. Therefore, you see that this booth is a joint exhibition stand and you see joint staff. You see China HEAD Aerospace written on our booth, but you see as well the logos of the Institute of Space Power, the Institute for Attitude Control, from institutes for communications, electronics, space environment, and also of the institutes from Beijing. We came together on our own initiative and manage and organise ourselves. The most part of our business is buying European products, to promote the application of European space technology in our Chinese space missions. And at the same time, we are trying now, to promote the Chinese space technology and space products, to sell them outside of China to the rest of the world, but also to seek opportunities to serve space missions outside China. So in short, this is what we are doing.

GT: You are buying European technology?

Leon Chiang: Yes, we are buying mainly European products.

GT: You re-sell it here in China?

Leon Chiang: Yes.

GT: This works?

Leon Chiang: It works, yes. Maybe I can give you some examples. I'm not sure if I can tell you of many examples, but I can give you an example of a well-known product, for instance for ExoMars. We have also scheduled a Chinese lunar rover. ExoMars and the Chang'e lunar rover are both planetary rovers. So it is a rover. And we found the opportunity, the interest in China and at the same time our partner in Switzerland, RUAG, was interested in cooperation in a lunar rover test facility. The contact started in May 2008, and we spent half a year working together with RUAG and succeeded in getting an export license, a commitment, which is signed and formally confirmed, to adapt the ExoMars locomotion sub-system test-bed to a lunar rover locomotion sub-system test-bed. We did some technical work together with our Chinese customer and European partner to define the specifications. We changed the simulant Mars soil to lunar soil, because they are different. The British made the lunar soil. And we adapted the wheel performance into the software, and we asked from the Chinese side a further function, which was more advanced than the function required by ESA. I think the delivery took about 11 months, and the cooperation works very well. From Europe, they adapted their ExoMars test-bed to the Chinese lunar test-bed, which works now in the Shanghai laboratory. The story before we started, is that our partner in Europe identified the interest in China, and they also recommended that to China. Beneficial also, is that this kind of lunar test-bed or Mars test-bed is a fully civilian and scientific application.

GT: You said that you took the technology from Europe. You advanced that technology, the mechanism in this case. But did you also transfer it back to Europe and sell the advanced solution back to Europe, or do you have an example where you transfer back technologies or products from Chinese companies to Europe.

Leon Chiang: I think I cannot say it is technology transfer, it's only that we offer a solution to Chinese customers. And this solution is usually customised and tailor-made. It can be hardware and software. We have our similar Chinese technology, which might be suitable. So we would buy that, and we may compare the different approaches. We also analyse how it works in Europe and in China. We look also into the purpose of the exchange. For example in this deep-space exploration project the Chinese wanted to establish a relationship with Europe, because you have a product, then you have contact, and during that procedure you can build trust to each other. And that works perfectly.

GT: Are you supported by the government? You said that you are commercial and independent, but do you get support from the government?

Leon Chiang: Yes exactly, we get some sort of support from the government. Because our customer may ask for a budget or financial support from the government, and the government approves that. Our customer for this lunar test-bed project is also state-owned. So in some way they are representing the government.

GT: Maybe one can understand your company more like an interface: you are not doing your own scientific research or have your own laboratories for technology development, or your own production facilities, you are more a commercial business. You are on the level where you bring partners together, aren't you?

Leon Chiang: I think you are right, we are not doing the research for the dedicated technology. We are not doing the hardware. We do some software for our domestic customers, but without European involvement. However, we did support the technical contact. There are different cultures, different systems of how to do space programmes. That's how our project is organised. It's our job to understand very well how the European space companies operate or how ECSS (European Cooperation for Space Standardisation) standards operate.

We also need to convince domestic customers to trust ECSS standards. Sometimes we have in China higher requirements, which are outside of ECSS standards, then we also need to convince our European partner to accept that. For that we work closely together with our Chinese and European customer. The tasks involved in such a project are to draft the technical specifications, the statement of work, what is a technical kind of job, but it is not research. Most of our business development people have a technical background. You must know that Chinese start to talk in a different way, they talk about potentials. Europeans start with a proposal or with a request for quotation. In China, we get two pages, two pages full with specifications which are just defining the major things. But in Europe, I think you have 2,000 pages to start with. Our job now is to work together to convert these two pages into a relevant input acceptable for both sides. We start talking with our partner in Europe and at the same time, we keep talking with our customer in China to get to 30-50 pages, then it's more precise. After that is done, our supplier in Europe can make a proposal based on a more precise theme.

Anyway, I think it's not bad to do it like this, because the

Chinese way of compiling these two pages as a starting point, is also efficient, as it focuses on the main critical technical specifications. Once you see that the requirements noted down on the two pages work, we can come to the more complex things. Sometimes, our domestic Chinese customers even try to directly contact the European counterpart to explain the limits, the many signatures needed for approval and that this is the reason which allows them to draft only one or two pages. It happens a lot that the European companies are reluctant. They don't want to respond to that. They think this is not serious.

GT: Are you also planning to extend your business to the US?

Leon Chiang: No.

GT: Do you have problems with ITAR regulations? You said you try to stay in the field where there are scientific applications mainly and civilian applications. Is ITAR an issue for you, or do you stay completely out of it?

Leon Chiang: We never touch ITAR. It's difficult. I was asked by one of my customers to offer a proposal of a mechanism and electronics together. But after we checked and after our European customer checked, we realised by doing the project in that way we would need an ITAR approval. And this means that only President Obama could approve that. So we did not do this. We try to avoid ITAR-related things. We do not have any contact with any US entity.

GT: But by listening to you, is this possible? Can you still have a good business, while complying to ITAR?

Leon Chiang: Yes, exactly. I think in Europe ITAR is also a problem. I see a lot of European companies want to get rid of ITAR. So for some products one has to navigate around ITAR and this is maybe not so efficient in performance but it works as a business.

GT: Are you also involved in the atomic clock from Switzerland or the POLAR telescope on the next Tiangong spacelab?

Leon Chiang: No.

GT: What are your ideas about the future? After this conference, how will you go on? Do you have new ideas, did you get new inputs from the situation here or from your own ideas?

Leon Chiang: During this IAC we signed three intention agreements, and established a joint laboratory between our Chinese customer, our HEAD company, and our European company partner. We signed the agreement for a Sino-Italy Joint Laboratory on Electric Propulsion with the Italian company Alta and the Lanzhou Institute of Physics. The institute in China has worked in the area for 40 years they have had a successful launch and application of electrical propulsion. With our Italian partner we can offer some knowledge, service test facility, and new concepts of very far advanced electrical thruster. However, I must say that my domestic customer, Lanzhou Institute of Physics, is more competitive because we have our whole system flying in orbit. They have an open mind and they want to collaborate with the Italian counterpart.

We also signed an intention to establish a joint laboratory in the field of mechanisms with a domestic customer and those joint laboratories are expected to support the space programme in China and also worldwide. Within that joint laboratory there will be some work share, joint development, and both parties will define that precisely so that IP is protected. It's not only selling things, not only trading, but we also bring the customers together to do something interesting.

And what concerns the vision? Now, we are just a trading company and our target is that we want to get more involved and we want to contribute more based on our knowledge and experience in international cooperation. One vision is to extend significantly on what we are already doing: to promote the application of very advanced European technology in China. So we introduce our domestic customer to what is happening in the world and to what is the most advanced technology available in China. Sometimes we get these products applied to our system, but sometimes it's not acceptable because of regulations. And we will tell other customers: we have this technology, there are these kinds of technologies, there are those kinds of application products, this is very efficient, this concept is good. Maybe you can also consider to make some development to make sure we are not let's say "keep going behind". And at the same time, by trying, we promote a kind of export, but I have to say we must obey the law. We have also Chinese export controls and it is not easy to do. But I see a lot of interest in Asia, in Europe, in other countries – they come to us and want more details. They want to see if we in China can support their space missions.

GT: What is your professional background?

Leon Chiang: My expertise is in spacecraft system design. We also have in our team a Ph.D. who worked for two years in the area of space docking. He was making the rhythm, the dynamic of the space docking. He trained the female taikonaut in manual docking. One of our other employees we have in our team is now doing business development, but in the past he worked as an engineer in the Chinese Academy of Science. He joined the programme of the accompanying satellite of Shenzhou. I don't know if you heard about the fact that during the Shenzhou 7 flight, one of the taikonauts released a small satellite by hand. And our engineer participated and contributed to that mission in his previous job.

GT: So all these people are working for you now?

Leon Chiang: No. We work for us. They are not working for me. We work both for China space and for the space community. I think it's not a good choice if you want to make money, like in the economy sector where it is only important to grow and to get rich. This is not the space business. Its dedication, passion, and you have to be interested in the subject. So, we work for our interest.

GT: Thank you very much for this highly interesting talk! Much success!

Competition has reached its limit! Space is for all - Marsward-ho!

Report from the IAA Space Exploration Conference, Heads of Space Agencies Summit, and the International Space Exploration Forum – ISEF

by William Carey and Jacqueline Myrrhe

Welcome to Washington DC! For two days in January 2014 the capital of the United States put on its spacy hat. The 9 and 10 January saw the probably biggest ever get-together of leaders of national and international space agencies, but in contrast to the importance of the event it went with little public notice and limited media attention.

Following its long tradition of promoting international exchange among space experts and space cooperation on a global scale, the International Academy of Astronautics IAA initiated for the first time, a dialogue among 25 Heads of Space Agencies on 17 November 2010 in Washington. Originally, the occasion of the event in 2010 was to celebrate the 50th anniversary of the IAA. Because of the big success, soon a second summit was planned to follow-up on the fruitful discussions from four years ago.

Two days – three events

A record breaking 33 Heads of Space Agencies followed the invitation of the IAA for a Heads of Space Agencies Summit, taking place in the Ronald Reagan Building and International Trade Center in Washington on the 10 January 2014. During four panel discussions, centred around four different topics, the Heads of Space Agencies contributed to moderated discussions.

The IAA Heads of Space Agencies Summit, was preceded by the International Space Exploration Forum ISEF on Ministerial level on the 9 January. The ISEF is a meeting for discussing space exploration policy matters with Ministers and members of national governments. For that, the more than 35 Heads of Space Agencies plus the representative for space of the European Commission were accompanied by their delegations, some smaller some bigger, comprising government representatives, space and policy experts. For the first time the US Department of State hosted that event.

Also in conjunction with the Heads of Space Agencies Summit, the IAA Space Exploration Conference on planetary robotic and human spaceflight exploration took place on the 9 January in the same building as the next day's summit, the Ronald Reagan Building and International Trade Center, in Washington DC.

International Space Exploration Forum ISEF

The 9 January-meeting in Washington was the consequent continuation of a process initiated by the European Commission in cooperation with ESA. ISEF 2014 marked the fourth meeting of the high-level platform for space exploration at ministerial level, after three precursor conferences in Prague, Czech Republic in 2009, in Brussels, Belgium in 2010, and in Lucca, Italy in 2011.

During the Washington forum, access for journalists and the public broadcasting of the forum was only granted for the Opening Session, during which representatives of the governments of the U.S., Italy, Japan and the European Union took the floor.

Enrico Saggese, by the time of the conference, the Head of the Italian Space Agency ASI, was speaking on behalf of the Italian Minister of Education, Universities and Research, Maria Chiara Carrozza. He took the opportunity to go into the history of the ISEF. By pointing out that the roots of ISEF go even further back as 2009, he explained the events which led to the ISEF meeting 2014: "All this started two years ago when in collaboration with the European Commission and ESA, Italy hosted the first meeting of the high-level international platform for space exploration in Luca. There, space leaders, heads of space agencies and government representatives adopted the Luca Declaration, starting a high-level dialogue on space exploration aiming at creating a flexible protocol to increase knowledge and mutual confidence as a basis for ambitious space exploration projects. Italy, in cooperation with ESA organised and hosted in the years 2005, 2006 and 2007 in Tuscany, in the Abbey of Spineto, three workshops on international cooperation for sustainable space exploration, where representatives of 14 space agencies defined the first framework for the coordination of individual plans for space exploration. They discussed the elements underpinning the first global exploration strategy implementation. The first international process then merged into the international space exploration strategy, and the international space exploration coordination group. This work produced the final global space exploration roadmap document, issued in August last year."

Also giving a short speech during the open part of ISEF was William J. Burns, Deputy Secretary of State of the U.S. He gave some very inspirational insights, but also focused largely on the importance of an international approach to space exploration. "The achievements of last year and the triumphs of the past century are not the product of a single country or a single space agency. They are the product of shared endeavours and shared sacrifices." … "As the number of space faring nations increases, as states' monopoly on knowledge and technology erodes, and as commercial interest in space exploration grows, international cooperation will prove more important than ever."

Further in his speech he came up with some substantial proposals for how to go on after the conference: "The question facing us today is whether we can muster the courage and political will to advance space exploration and ensure that cooperation continues to trump competition.

If we do that – if we choose to put our collective strength behind cooperative efforts rather than competing efforts – the opportunities are as vast as the Solar System itself. Let me highlight three particular areas where we can enhance our collaboration.

View into the Loy Henderson Conference Room of the U.S. State Department during the public part of the ISEF. (credit: U.S. State Department)

Paul Weissenberg, Deputy Director General of the European Commission (credit: U.S. State Department)

William J. Burns, Deputy Secretary of State of the U.S. (credit: U.S. State Department)

First, we should encourage more countries to participate in the activities of the International Space Station. ...

Second, we should explore ways to encourage entrepreneurial ventures and support the kind of robust and competitive commercial space sector that is vital to the next era of space exploration. ...

Finally, we can do much more to defend the planet from near-Earth objects and space debris."

He finished by saying: "… space exploration is not just the pre-occupation of scientists and astronauts, but a vital undertaking for all those who wish to advance the cause of global peace and prosperity.

Now is the time to come together to make space exploration a shared global priority, to unlock the mysteries of the universe, and to accelerate human progress here on Earth. I am confident that we will advance further, faster, if we work collectively."

Competition has reached its limits

Another remarkable and well-worded talk during the open session of ISEF was presented by Paul Weissenberg, Deputy Director General of the European Commission. He stated:

"Prague, Brussels, Luca, now Washington, and in two years from now Tokyo - this is the roadmap for the international framework of space exploration." … "Exploration continues to happen. Fortunately! But let's face it! The strategic and geopolitical environment in which we operate has changed. The world has become smaller – not just financially. Less and less nations are exploring space for national pride reasons." …

"Competition yes, but competition has reached its limits. Ambitious space exploration programmes are beyond individual capabilities of most countries. That's why the Europeans, the European Space Agency and the European Commission, kicked-off this process of sharing our vision for future space exploration."

Weissenberg's recognition that "competition has reached its limits" must be considered as a brave and strong, but also future-oriented exclamation. To make a statement like that, in a societal environment, where competition is considered to be the saviour for everything and anything, such a call for cooperation within a new model changes all paradigms the Western world has propagated and promoted. In particular if one takes into account that space exploration will feed back not only technological and scientific inspiration to the global societies but also cultural, philosophical and humanistic influence. Like all the other speakers during the morning of the 9 January, Weissenberg also came well prepared to Washington and made some well thought-through proposals: "Everybody in this room has assets which can serve as elements of a global political partnership. And this conference will contribute to the emergence of convergence, in a very pragmatic way, step-by-step, building partnerships around technological projects including demonstrators. A lot of meetings on space exploration took place. This one is different. It is the political level allowing for an intensified dialogue linking space exploration to our bilateral or multi-lateral relations, which we have successfully established. Nothing in the universe can resist the converging strength of a large enough number of intelligences working together in an organised way."

And indeed, already in December 2013, the European Commission released a call for proposals under its Horizon 2020, the Framework Programme for Research and Innovation from 2014 to 2020, to "allow implementing the 'technology demonstrator projects' to be initiated after the ISEF meeting. These demonstrator projects would target underpinning enabling technologies for space exploration, notably robotics, novel energy production and storage, propulsion or life support, as well as atmospheric entry, return/re-entry vehicles or communication and data handling systems."

After so much inspiration, there was not much opportunity left for John P. Holdren, Assistant to the U.S. President for Science and Technology and Director of the White House Office of Science and Technology Policy, to carry away the international audience of the crème-de-la-crème of space. But he also joined the previous speakers and kept the spark of optimism for a future of joint space exploration on a global scale, and the crackling atmosphere of anticipation of something big and alive: "We may have different flags patched to our space suits, and different cultures, traditions, and political systems. But as the success of the ISS has shown, we can transcend these differences in space."

The rest of the day took place behind closed doors. Until today is very little known about the content of the discussions which followed. The Chinese delegation, led by Xu Dazhe, Administrator of China National Space Administration, and Wang Zhaoyao, Director General of China Manned Space Agency (CMSA), attended the forum and summit. From the programme it may be seen that the day was structured around three main sessions, each lasting one hour and 20 minutes. Xu Dazhe, was scheduled to talk in all of them.

Session I: National Policies and Public Support for Space Exploration.

Session II: Space Exploration and Utilisation: Strategies and Shared Goals.

Session III: International Cooperation in Exploration and Peaceful Uses of Outer Space.

News published on the CMSE website after the forum, reads: "The Chinese delegation voiced China's attitude and policies on international space cooperation. Throughout the conference, delegations from many countries extended congratulations on China's success in Shenzhou 10 and Chang'e-3 missions and expressed willingness to cooperate with China.

Xu Dazhe, on behalf of China, took part in the three keynote symposiums of ISEF and made keynote speeches. Xu Dazhe talked about China's latest accomplishments in manned space and lunar exploration projects, emphasised China's standpoint in developing space industry peacefully, scientifically, innovatively and openly, and expressed China's principles in participation in the implementation of a global exploration plan and fostering international space cooperation."

There are contradicting accounts on the number of ISEF participants. Some press releases talk about 35, some of more than 30 participants, on the CMSE website it was reported that 37 countries were present. However, when counting the flags, put in place for the meeting in the Loy Henderson Conference Room of the U.S. State Department, one could come up with 43 forum participating delegations. Maybe the exact number is not the most important criteria for the meeting, as long as there are many of them, and as long as we can keep counting.

For a short summary of the event please, consult:
http://iipdigital.usembassy.gov/st/english/texttrans/2014/01/20140110290302.html#ixzz2t8gmXVWa

The IAA Space Exploration Conference - A global overview on space

While the ISEF discussed space exploration behind closed doors in the Department of State, just a stone's throw away to the East, space experts from all over the world were busy presenting their work to a professional audience of approximately 400.

The activities began with a Plenary Session, with opening remarks given by the IAA President, Madhavan Nair and IAA Secretary General, Jean Michel Contant.

This introduction was then followed by two talks summarising the IAA activities on Planetary Robotic Exploration, presented by Marcello Coradini (ESA/JPL) and Catherine Conley (NASA HQ), and Human Spaceflight, given by Giuseppe Reibaldi (IAA) and Sundaram Ramakrishnan (ISRO, India).

The rest of the day was reserved for the following sessions, held in parallel:

1. Human Aspects in Spaceflight.
2. Scientific Goals in Robotics Missions.
3. Technical Factors: Enabling Technologies Common Requirements.
4. Private Industry's Role in Space Exploration and Exploitation: Technical, Policy and Legal Considerations.
5. Space Exploration: The Imperative of Global Cooperation.
6. Space Stations Utilization for Robotics and Human Spaceflight Exploration.

Many of the 15-min talks were on the proposals the IAA made for international cooperation projects in robotic exploration and human spaceflight, such as planetary protection, space exploration outreach activities, international protocol to handle crisis situations of astronauts in LEO, standardised career-dose limits for astronauts, or a human spaceflight life science virtual institute. These set of proposals are outlined in the IAA study: "Future Human Spaceflight: The Need For International Cooperation." The respective IAA Study Group leaders released the results of ground-breaking studies. But as many presentations were given by representatives from national space agencies to provide an overview on the current status of their work with respect to space exploration.

There were only two presentations given by Chinese experts: one presentation on Tiangong and one presentation on the DFH-4 based communication satellites. The Tiangong talk entitled "The Technical Characteristics of China 'Tiangong-1' Target Spacecraft" was made by Yang Hong from the Institute of

Manned Space System Engineering, China Academy of Space Technology (CAST) and took place in the Session 6-A, on "Space Stations Utilization for Robotics and Human Spaceflight Exploration".

Yang began by providing an overview of his talk, beginning with a brief introduction of the spacecraft, then a look at the functions of the spacecraft, followed by the characteristics of the mission, the "innovation practice" adopted by China for Tiangong-1, and ending with a short conclusion. After reviewing the three major phases of the manned space programme, and summarising Tiangong-1's high-level specifications, he described the four major functions: Basic platform; Combined vehicle management; RVD support and science and experiment support. He then described how this mission was very different from China's previous human spaceflight missions, as it involved multiple launches and rendezvous and docking in low Earth orbit.

Under the term "innovation practice" he described the elements that had been addressed: the integrated design of Tiangong-1 as an RVD target spacecraft and experimental space laboratory; the design and evaluation of technologies involved in long-lifetime manned spacecraft in low Earth orbit; the cooperative operation of two spacecraft; and astronaut support.

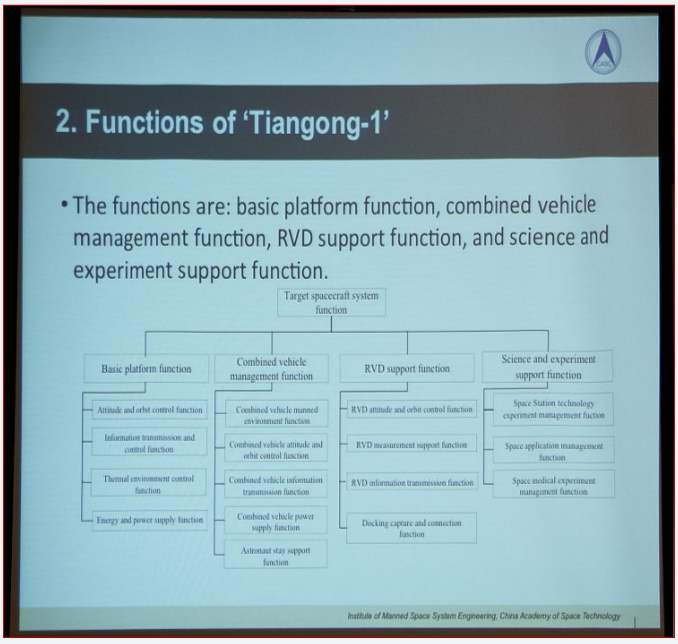
He concluded by noting that the successful RVD missions of Tiangong-1 and Shenzhou indicate that China has mastered RVD technology, control of combined vehicles, and the design technologies involved in long-lifetime manned spacecraft. And noted that the successful applications of "innovation practice" provide China with reliable references for future space station and other spacecraft development missions. Re-iterating again, that China welcomes cooperation with all countries in their space station programme.

Although an interesting presentation, for Go Taikonauts! it did not provide us with any additional information that we were not aware of prior to the conference.

In the evening of 9 January, the International Academy of Astronautics had the privilege to commemorate this unique and historic event with a reception and gala dinner that brought together both communities, Ministers and their delegations, Heads of Space Agencies and their delegations, as well as government officials, distinguished scientists, summit participants and special guests.

It was rather impressive to see almost all of the participating Heads of Agencies standing on the stage. During the evening, the Theodore von Kármán award, the highest appreciation of the IAA was handed over to Chinese space expert Wu Meirong. The award was given to Wu 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, which was founded in 1982. It is often referred to as the "Nobel Prize of Aerospace Science", and is awarded annually in recognition of outstanding achievements in the fields of space science and technology. Originally from Changzhou, Jiangsu province, Wu graduated from the Moscow Power Engineering Institute, and is Chief Expert and Honorary Director General of China Centre for Resources Satellite and Data (CRESDA).

Yang Hong presenting his paper (co-authored by Wei Chuanfeng, also of CAST) (credit: Go Taikonauts!)



Functions of Tiangong 1. (credit: CAST/Go Taikonauts!)

Design and technology evaluation using Tiangong 1. (credit: CAST/Go Taikonauts!)

Group photo of the Heads of Space Agencies Ceremony during the Gala Dinner in the Atrium of the Ronald Reagan Building and International Trade Center, on 9 January 2014, in the Washington. (credit: IAA)

Professor Wu Meirong, former Director of the China Resources Satellite Application Centre, became the second woman to win the prize but was the first women engineer-scientist and the second Chinese national. (credit: IAA/CRESDA)

The IAA Heads of Space Agencies Summit - Not so round roundtables

The second day in Washington was another early morning to late evening conference marathon. Each Head of Space Agency appeared once on the stage to contribute his insights on the subject topic, and most likely also reflected the essence of the discussion from the day before in the U.S. State Department. In five cases, the Heads of Agency were substituted by a deputy. This was for good reason, since it is likely that the delegations, used the second day of their stay for behind-the-scenes bilateral talks with their international counterparts.

Overall, the roundtables were informative and depending on the panellists, even entertaining, like roundtable four "The Benefits of Space Exploration". It must have been an enormous effort by the IAA to get those high-level persons organised and lined up for their appearance at the right time at the stage. The moderation – in general - could have been a little bit more controversial. Often, the moderators were too much focused on having a polite reporting by ticking-off the list of questions instead of requesting some more and less known detail. But the format worked very well.

We have structured the roundtable reports so that readers can make their own interpretation of the discussions in panels 1, 2 and 4. Whereas for panel 3, in which Xu Dazhe and Charles Bolden participated, there is more of an analysis. The words of Angelino Garzón in panel 1 had quite an effect on the audience.

Roundtable 1: "The Importance of International Cooperation"

Moderator: Daniel Goldin, Chairman, President and CEO, The Intellisis Corporation and 9th NASA Administrator.

Panel members:

- Angelino Garzón, Vice-President of the Republic of Colombia and President, Comision Colombiana del Espacio, Colombia.
- Harald Posch, Head, Aeronautics and Space Agency, Austria.
- Bo Andersen, Director General, Norwegian Space Centre, Norway.
- Ger Nieuwpoort, Director, Netherlands Space Office, The Netherlands.
- Prince Turki Saud Mohammed Al-Saud, Vice President for Research Institutes, King Abdulaziz City for Science and Technology, Saudi Arabia.
- Thomas Reiter, Director of Human Spaceflight and Operations (for Jean-Jacques Dordain, Director General, European Space Agency).
- Gorm Kofoed Petersen, Chief Advisor, Danish Agency for Science, Technology & Innovation, Denmark.

Panel members for “The Importance of International Cooperation” roundtable. From the left: Moderator: The Honorable Dan Goldin, Chairman, President and CEO, The Intellisis Corporation and 9th NASA Administrator; Mr. Angelino Garzon, Vice-President of the Republic of Colombia and President, Comision Colombiana del Espacio, Colombia; Mr. Harald Posch, Head, Aeronautics and Space Agency, Austria; Dr. Bo Andersen, Director General, Norwegian Space Centre, Norway; Dr. Ger Nieuwpoort, Director, Netherlands Space Office, The Netherlands; His Highness Prince Dr. Turki Saud Mohammed Al-Saud, Vice President for Research Institutes, King Abdulaziz City for Science and Technology, Saudi Arabia; Mr. Thomas Reiter, Director of Human Spaceflight and Operations (for Prof. Jean-Jacques Dordain, Director General, European Space Agency); Mr. Gorm Kofoed Petersen, Chief Advisor, Danish Agency for Science, Technology & Innovation, Denmark; Dr. Francisco Javier Mendieta-Jimenez, Director General, Agencia Espatial Mexicana, Mexico; Dr. Olle Norberg, Director General, Swedish National Space Board, Sweden. (credit: Go Taikonauts!)

- Francisco Javier Mendieta-Jiménez, Director General, Agencia Espatial Mexicana, Mexico.
- Olle Norberg, Director General, Swedish National Space Board, Sweden.

As Daniel Goldin was kicking-off the first of the roundtable discussions, he commented that of the 32 Heads of Agency (HoA) at the previous evenings Gala Dinner, there was not one woman among them, and at the next HoA meeting, it would be nice to see some women on the stage. As one woman sitting near me commented, “It would be so easy, so easy”, and indeed it would – Mr. Goldin take note!

Moderator Dan Goldin: What are the key principles for international cooperation and exploration?

ESA as a Role Model

Thomas Reiter (ESA) responded by saying that ESA could not exist without cooperation, consisting as it does of 20 Member States, and went on to explain the flexibility and competitive advantages of having both mandatory and optional programmes, and that international cooperation should be global.

Bo Andersen (Norway) observed correctly that space agencies are paid by their tax-payers, and that in space, all countries are small! He confirmed that ESA was a good model of how to cooperate and compete, as going beyond low Earth orbit in particular, will be extremely expensive, it will be necessary to cooperate and compete.

Harald Posch (Austria) supported the view that ESA is a good role model, noting that if ESA did not exist, they would have to invent it! In a cooperation between large and small space nations however, the small nations must have a voice, and the relationship must be a reliable framework, with a common understanding where everyone can contribute in a coordinated manner.

Ger Nieupoort (Netherlands) stated that the first question that needs to be answered is “why” a country wants to cooperate, as if this is not clear, then there is a risk that one gets quickly into the “how” question, which could end in a situation where the cooperation is done just for the sake of cooperating. So the clear goal is to first define the “why”, and then find the ways and means of how we can come together, to find suitable models, which include a balance of cooperation and competition, to do exploration as a human race.

Not Only Buy and Sell, but Open, Genuine and Fair

Francisco Javier Mendieta-Jiménez (Mexico) said that regarding cooperation between developed and developing countries (in the space sense), the developed countries should not only use a “buy and sell” approach.

Turki Saud Mohammed Al-Saud (Saudi Arabia) commented that to be successful, cooperation has to be open, genuine and fair. It should not be, yes, I will cooperate with you, but I am not going to transfer technologies to you. For example ITAR is an issue, some nations can meet this and some not. Nations should also participate at an early stage, from the design, through to manufacturing and the use of data. It should not be, just use of data, but I’m not going to let you work on the design, and the manufacturing. So cooperation has to be open, genuine and fair in order for it to work.

Time and Patience

The Moderator, Daniel Goldin, then recounted that from his


Thomas Reiter - ESA.
(credit: Go Taikonauts!)

Angelino Garzón - Colombia.
credit: Go Taikonauts!)


A passionate Francisco Javier Mendieta-Jiménez - Mexico. (credit: Go Taikonauts!)

experience on cooperating with the Russians on the ISS, it took 2-3 years to get to know each other and establish a basis for good communication. So time and patience are a necessary ingredient.

Moderator Daniel Goldin: Does space exploration encourage international cooperation? If so, what are the most relevant and encouraging examples of international cooperation in exploration?

A Student Learning from Professors

Angelino Garzón (Colombia) began his answer with, "… at this meeting I do not feel like the Vice President of Colombia, nor do I feel like the Director of the Programme for Space Exploration, I feel like a student who is here learning from Professors." He then went on to say that Colombia could not pursue any activities in the space domain without seeking cooperation. He also noted however, that in order to learn, Colombia could not look to cooperation with countries less-developed (in space) than themselves, they must look to the more developed nations. International cooperation however, must have a peaceful purpose, and should not be for military use – "… space has a terminology that is peaceful … those that control space for peaceful means have the knowledge and the power to resolve the great problems of humanity, such as hunger and extreme poverty…"

Olle Norberg (Sweden) observed that the ISS is a great example of international cooperation, and that he looked forward to seeing the ISS used for the development of exploration technologies. Another example would be robotic exploration (Sweden has cooperation in this area with ESA, US, Japan and Russia), as this is a field where scientists can get involved in a step-wise manner, and so would be a good starting point for countries to become involved.

Gorm Kofoed Petersen (Denmark) observed that the global science community at its heart is international.

Francisco Javier Mendieta-Jiménez (Mexico) argued that a structured approach is required, where the role of each party is well-defined – this would be a good starting point for developing cooperation.

Moderator Daniel Goldin: How important is international space cooperation for your agency? If you are small or emerging country, what are your agencies plans to cooperate with larger countries? If you are a large country, what are your plans to cooperate with smaller countries? There are responsibilities and aspirations involved here, so how do we balance these?

A Niche Strategy

Harald Posch (Austria) stated that they follow a niche strategy, by supporting their scientists and by their industry specialising in certain areas. He also noted that their involvement in the Cassini-Huygens mission would not have been feasible without international cooperation.

Turki Saud Mohammed Al-Saud (Saudi Arabia) responded that as a developing-country in the space field, they must follow the leading entities like the US, Russia, ESA and China, but for them, projects that cannot be realised in under ten years are not attractive, they are more interested in projects that can be realised in 2-3 years, and concurrently builds their capacity. They are cooperating in the ISS, but are also looking to China's space station, where they could also have a human participation as well.

Moderator Daniel Goldin: Do you believe that human and robotic exploration should broaden from a few countries to a larger and more diverse number of countries?

We Must Go Together

Bo Andersen (Norway) noted that presently there are two habitats in low Earth orbit, the Chinese Tiangong, and the ISS, but the collaboration between them is not as good as it could be. He went on to say that emerging countries might get the most out of their involvement in space by looking at the Earth, observing that the dreams that we had in the 1980's and before of landing on Mars, and the fact that we have not returned to the Moon during the last 40 years, is because it is difficult, and the necessary funds have not been made available. To achieve our dream of going to Mars, we must have strong leaders, e.g. Russia, US, China, but we should not go there unless we go there together.

Turki Saud Mohammed Al-Saud (Saudi Arabia) concurred with this view stating that "space exploration is a fantastic adventure … something that should be shared with everyone."

Always the Horse and Never the Jockey

Moderator Daniel Goldin: Government and political support is important for justifying major space development programmes. How do you see the larger and smaller nations partnering in future exploration programmes?

Angelino Garzón (Colombia): "Small countries such as Colombia, all need to learn from larger countries, but the larger countries need to stop seeing smaller countries as nothing but a business opportunity. For example, we are making steps to acquire an observation satellite for peaceful uses on Earth. But we have always said that we wish to purchase this satellite from a country that will then transfer to us the knowledge for technology and research. We would gain nothing from simply purchasing the satellite, because what we would like, would be, is when we need another satellite, we would like to be able to build that one ourselves, and all of you here know, my friends, what we mean to say is more needs to be invested in space.

Some leaders only want to look at the Earth, and they do not want to look at space. Space is the present and the future. We cannot resolve problems here on Earth without looking towards space. And when it comes to the relationship between smaller and larger countries, I'm going to tell you what we need to avoid is for the bigger countries to always to be the jockey, while the smaller countries are always the horse! It is the right international cooperation among equals.

And it's cooperation for peace. Space is for peace not war. Space is not for the creation of rivalries, it is for cooperation, and that is why my friends, we wish to have a relationship with all of you, with all of your countries when it comes to cooperation.

I invite all of you to help Colombia to become stronger and to look at space as a mechanism for international cooperation. We are currently looking towards peace when it comes to armed groups here on Earth, and of course we are dialoguing with them. But as we seek peace here on Earth, space is an essential factor for that peace here on Earth, and we must continue to use this information to help for example in the case of natural disasters, so that Colombia may be a better country. Thank you."

Francisco Javier Mendieta-Jiménez (Mexico) felt that robotics would be a very suitable starting point for developing nations to get involved in space, as terrestrial robotic technology may be easily scaled up and adapted to space. For smaller countries to become involved in human spaceflight, they must invest heavily. He also noted that those countries that have already invested significantly, would not like someone who has not invested heavily to be a part of this. Mexico's successes in space have been isolated success stories, and not linked. Although Mexico has a large aerospace industry, building capacity from planes to space is a political problem and the risk factors involved must be taken into account. Mexico, like Colombia, must make the transition from a purchaser, to making strategic alliances with the larger space nations. The big question for developing countries that remains however, is what will developing countries win from these alliances?

Roundtable 2: "Space Stations"

Moderator: Dr. John Elbon, Vice President and General Manager, Space Exploration Division, The Boeing Company.

Panel members:

- Enrico Saggese, President, Agenzia Spaziale Italiana, Italy.
- Pham Anh Tuan, Director, Vietnam National Satellite Center, Vietnam.
- Seidu Oneilo Mohammed, Director General, National Space Research and Development Agency, Nigeria.
- Alexey Krasnov, Director of Human Spaceflight, Roscosmos, Russia.

Go Taikonauts! found this panel a little disappointing, as despite

Panel members for "Space Stations" roundtable. From the left: moderator Dr. John Elbon, Vice President and General Manager, Space Exploration Division, The Boeing Company; Enrico Saggese, President, Agenzia Spaziale Italiana, Italy; Pham Anh Tuan, Director, Vietnam National Satellite Center, Vietnam; Seidu Oneilo Mohammed, Director General, National Space Research and Development Agency, Nigeria; Alexey Krasnov, Director of Human Spaceflight, Roscosmos, Russia. (credit: Go Taikonauts!)

Pham Anh Tuan - Vietnam.
(credit: Go Taikonauts!)


Seidu Oneilo Mohammed - Nigeria.
(credit: Go Taikonauts!)


Alexey Krasnov – Russia.
(credit: Go Taikonauts!)

the moderator emphasising at the beginning that the title of the panel was “Space Stations”, i.e. in the plural, discussion of the future Chinese Space Station was quite limited. One also has to admit, that it must have been quite a challenge for the moderator to combine the topic with only four guests, of whom only two contributors from within the ISS framework.

Moderator John Elbon: The ISS is a concrete step towards deep-space exploration….how has it helped your countries with deep-space exploration planning?

Applications that Benefit Our People

Enrico Saggese (Italy) noted that there was an Italian astronaut, Luca Parmitano, on the ISS last year, and that it was interesting to see that he had not lost any bone or muscle mass, he was stronger than when he had left! So we are getting better at understanding how to cope with microgravity. Luca also used the robotic arm on the Station to dock a visiting vehicle. So, survival in space, and the ability to assemble things, are two important things needed to go beyond low Earth orbit.

Pham Anh Tuan (Vietnam) stated that Vietnam are newcomers to space, but that they already use the ISS, from which they released a cubesat last year.

Seidu Oneilo Mohammed (Nigeria) emphasised that Nigeria is involved in space for the benefit of its people, and are looking for a niche area in which they can contribute, but as a developing country have limited resources. They have developed a roadmap of space science and technology, which includes having astronauts with international partners in 2015. However, the main emphasis is on applications that benefit their people – creating jobs and addressing certain diseases, such as sickle-cell. Nigeria sees the ISS as a platform that can support Nigeria in her development.

Moderator John Elbon: What impact of being involved in space had on the youth of your countries?

Something Special – Like a Movie Star

Pham Anh Tuan (Vietnam) noted that their first astronaut was the first from an Asian country, and was a great motivation for many Vietnamese. Vietnam would like to send an astronaut to the ISS, but this is costly for such a small country.

Enrico Saggese (Italy) said that although astronauts are the best ambassadors for involving the youth, before, during and after a mission, a major problem is that they are seen as something special, like a movie star. But the real purpose of an astronaut is to perform experiments, to perform science. To convey this message is much more difficult, to move beyond the symbol to see the effort involved before and after the flight itself. We need to work harder to catch the enthusiasm of young people.

Moderator John Elbon: Much has been written this week about the announcement of the US extending the ISS, what is the reaction to that in your countries governments?

A Positive Message

Enrico Saggese (Italy) commented that ISS beyond 2020 sends a major positive message.

Alexey Krasnov (Russia) said that those who were planning but not able to deliver equipment by 2020, will now deliver and use the space station for another 4 years at least…and technically there are no issues, it can be used until 2028. However, policy wise, it will take some effort to adjust the necessary resources associated with space station operations for another decade.

Moderator John Elbon: What are your thoughts on other stations?

The Two Communities Will Become One Community

Alexey Krasnov (Russia) stated that he had no doubt that China would build its station, as the initial steps will begin already next year. This is the future – another space station is coming – and it will likely be China.

Enrico Saggese (Italy) said that Italy are helping China in the connection of their ground stations for the Chinese modules (Italy has a ground station in Malindi, Kenya). Italy is also providing some biological experiment containers, and would be willing to help China build their station, for example, if they wanted a Cupola! The Chinese station will be ready in 2020, at

The roundtable on “Low Earth Orbit and Beyond”. 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!)

which time the ISS will be more than 20 years old, so information should pass between these two communities (the Chinese are presently cooperating with 28 countries), and in time these two communities will become one community, with advantages for both of them.

Moderator John Elbon: As emerging countries what are the barriers to participating in the ISS? What could be changed to make that easier, more attractive?

Public Support

Pham Anh Tuan (Vietnam) remarked that Vietnam does not want to experiment on the ISS for fun, they want to achieve something, and for them it was important in the future to use the ISS.

Seidu Oneilo Mohammed (Nigeria) stated that for Nigeria, it is necessary to have public support, and then to form a space programme.

Roundtable 3: “Low Earth Orbit and Beyond”

The third roundtable of the day was moderated by Clayton Mowry, President Arianespace Inc. His guests on stage were:

- Charles Bolden, NASA Administrator.
- Jean-Yves Le Gall, Director General CNES - French Space Agency.
- Seung Jo Kim, President Korea Aerospace Research Institute.
- Marius-Ioan Piso, President Romanian Space Agency.
- José Raimundo Braga Coelho, President Brazilian Space Agency.
- Kiran Kumar, Director Space Applications Centre on behalf of Koppillil Radhakrishnan, Chairman of ISRO - Indian Space Research Organisation.
- Xu Dazhe, Administrator China National Space Administration.
- Luis Valero Artola, Secretary General of Industry and Small and Medium Enterprises, Ministry of Industry, Energy and Tourism in Spain.

Mowry tried hard to keep the panel as a polite reporting rather

The Head of the Chinese Delegation, Xu Dazhe. (credit: Go Taikonauts!)

Jean-Yves Le Gall is a tall person but he is also a person with wide international experience. However, lifting ones feet higher than the table is also in Europe bad behavior. But pointing with the shoe’s sole to a person is taken as an offence in most parts of the world. (credit: Go Taikonauts!)

than a discussion. He paid a lot of attention to get through his prepared list of questions and was not showing much flexibility to divert from it.

When some exciting and strong statements came up, Mowry too often let it go instead of jumping on it. He missed some really good opportunities of taking over the lead for getting more details, or another aspect of the just stated fact and support a dialogue or even multilogue. This was the case when Bolden spoke about the inspirational aspect of space exploration, or when the 60 million students where mentioned who followed the space lecture by Wang Yaping from the Tiangong 1 space station, or when the talk was about 3D printing and the advancement of that technology in China. “Somebody like to comment?” was his reaction, which sounded sometimes a bit helpless. In an attempt to give each panellist a fair share of time the roundtable did not really ignite a lively talk. This was a particular pity, since Mowry had with NASA Administrator Bolden and CNSA Administrator Xu the most unique configuration of the day on stage.

When work becomes quite enjoyable

The first question, which moderator Clayton Mowry brought up was about the importance of cooperation in space exploration and which approach for that is taken in each of the panellist’s countries. Everybody agreed, that cooperation is important and that bilateral as well as multilateral projects are suitable. Also, everybody gave good examples of current partnerships. Korean’s Seung Jo Kim, made clear that cooperation has pros and cons, while Spain’s Luis Valero Artola, stressed that cooperation needs clear ideas and long-term commitment. Brazilian’s José Raimundo Braga Coelho, explained that cooperation is best done in a defined programme and for Brazil cooperation in space projects is a necessity, but at the same time an opportunity, a view which all the space experts on stage shared.

Xu Dazhe said: “I believe that because of the need of high amount of investment and the nature of challenges, space exploration is the area that requires international cooperation the most. Because China’s space programmes have been developing very rapidly, we have conducted cooperation with many countries. We have signed 78 contracts and project agreements with 28 countries. We have been benefitting from cooperation.” Then he mentioned the cooperation with Russia on the development of a space suit and for astronaut training. China also had a good cooperation with ESA in the very successful Double Star - Cluster programme, with Brazil on the joint satellite development, and with developing countries for the launch of remote-sensing satellites. He continued by giving an interesting little detail: “This morning when I met with the Director General of ESA, he mentioned to me that ESA by providing assistance to China’s Chang’e 3 project, the ESA scientists considered the work so interesting that it was not work rather something very enjoyable. We also enjoy the pleasure of cooperation.”

Next, the moderator asked for some opinions on the issue of robotic versus human exploration. NASA-Administrator Bolden made a start by saying that man and machine have to work together because they are depending on each other. While robots can take over the precursor exploration and lay the foundation for future human missions, space exploration does require the human flexibility and ability to collect selected data and take decisions. Each destination has its special requirements, he said, and based on those requirements it needs to be decided which approach to take is best. For example, Bolden does not think that it will be possible to send a human mission to Europa, although there is a huge interest into that Jupiter Moon. But for Mars exploration, humans will play an indispensable role.

Likewise, the Indian representative, Kiran Kumar, and most of the other experts agreed that a mix of both approaches is needed and important. Only Romania’s Marius-Ioan Piso thought that technological progress makes robots more efficient than humans. “Human are not made for the universe.”, he stressed. They are too expensive and therefore he is sure that the future exploration might be largely robotic. Brazil’s José Raimundo Braga Coelho put emphasis on the fact that robotic technologies are not only for space exploration but even more so for risky, dangerous terrestrial applications.

China’s Xu Dazhe explained that human space flight is challenging, risky and expensive. But robotic missions can be used for preliminary exploration and can be assigned with bolder and cutting-edge goals. He continued by saying that human missions are different from robotic exploration, and that needs to be taken into account.

Space technology has benefitted the common man

The next topic which was addressed was the question about the return of investment from space exploration and how the benefits can be best explained to the taxpayers. Many convincing facts came out of the answers of the panellists.

India’s representative, Kiran Kumar, was convinced that in his country there is no doubt that space technology has benefitted the common man. People can see and use applications like communication and navigation. But the question of return of investment is asked for any programme, and for deep-space exploration it is more difficult to find a conclusive argumentation. What is done in India, is to explain to the public that before you can get the benefits from applications one has to push the technology capabilities and this can be achieved by scientific exploration. Romania’s Marius-Ioan Piso had the same positive experience about the acceptance of benefits through space activities. He said, that the benefit factor can vary between 2 and 20, depending on the resulting application.

France’s Jean-Yves Le Gall, having just left as CEO of Arianespace to become the Head of CNES, knew that for each Euro invested in commercial space activities the return of investment is 20 Euros. He admitted it is difficult to determine this factor for scientific missions.

Xu Dazhe had a detailed answer on that subject: “I have been working in the space sector for more than 40 years and I always come across people, friends, and in particular young people who keep asking me that question: Why do you want to spend so much money on space? I have come up with the following answer including five motivations:

1. To inspire people,

2. To learn more about the unknown and the mystery,
3. To foster innovation,
4. To bring benefits to mankind,
5. To provide opportunities for countries to work with each other.

In China we have the beautiful legend of Chang'e, a fairy flying to the Moon.

In our modern era we are able to use technology to make the dream possible by sending Chang'e 3 to the Moon.

We have enjoyed a lot of support from the general public in China. The people are very passionate about these projects including manned space flight. Last year after we have achieved successfully the rendezvous and docking of Shenzhou 10 with Tiangong 1, we have conducted a teaching session from space which lasted about 45 minutes. Over 60 million basic school and middle school students participated in this teaching lesson. This was a great kind of return of benefit. The effect of teaching the concept of microgravity is different when it is done from space.

The technological advancement achieved through these projects and having applications in Earth observations, telecommunications, satellite navigation etc., provide direct benefit for the people. We have been in a very good job to make that clear to the public."

South Korea's representative Seung Jo Kim pointed out that space cooperation also has unexpected returns. Initial difficulties, rooted in cultural differences can be overcome and people form diverse backgrounds can become friends. That statement gave way for Bolden's explanations about the inspirational benefits coming from space exploration. And those benefits cannot be calculated, they are simply there. Brazil's José Raimundo Braga Coelho mentioned that applications are important but at the same time, in particular for a country like his, getting technology development on the way is as important. Finally, he made a very interesting observation when he asked what is the right subject for space cooperation? It is the one which is good for all who participate in the cooperation, when all involved parties can gain from it. So, for developing countries like Brazil, joint technology developments are desirable and wanted.

Later during the roundtable talk, he used the comparison of two people contributing one orange to a project. If both end up with one orange each, this has not been very beneficial but if both end up with two oranges, the cooperation was highly successful.

Next, when the moderator asked his guest to tell about any exciting exploration mission they are involved in, Bolden used this opportunity to advertise NASA's human asteroid return mission.

Kiran Kumar, from India clarified that an Indian manned space programme is still awaiting political clearance. As long as that is not given, the space experts on the sub-continent are working on critical technologies. At this moment in time there are studies for further deep-space exploration missions.

China's Xu Dazhe briefly said: "Right now we are working on our Tiangong space station project and in our lunar programme we are looking into a lunar sample-return mission. As for further projects, we are conducting concept studies for a possible Mars exploration. Personally speaking, I am also very curious to learn about possible life in the universe."

Return the ability to children to dream

When the moderator asked: "Are we doing enough to promote our space activities?", Charles Bolden answered: "Communications is the greatest challenge that we all have. I found it fascinating because every once in a while when dialing, I'll end up on CCTV so, having an opportunity to watch the first Chinese woman astronaut teaching a class from space, that was awesome. As I said yesterday, we have to remember what brought us to that business. We all were dreamers, that is what brought us here. There is one thing that we have an obligation to do, is to return the ability to children to dream. That is a kind of hokey-pokey. But that is what we do. We represent here eight different organisations. Whether we think about it every day or not, what we want to do is give children the ability to dream again as we did when we decided to take up this kind of work." Bolden's enthusiasm made the moderator turn to Xu Dazhe for asking: "How many children watched that space lesson?" Although that was already mentioned by Xu short before, he answered: "60 million." But instead of asking, how this was achieved, the moderator rushed on by saying: "Let's turn to another topic." Pity, although the next question was interesting too: How can new technologies such as nano-satellite technology, virtual reality or 3D printing contribute to the advancement of space exploration?

All panellists agreed that new technologies are essential for progressing in space exploration, to bring the costs down, improve propulsion systems to move on a much faster speed, as the Indian representative pointed out. Brazil, on the other hand, is highly interested in nano-sat technology, because this is an area, possible for a country like Brazil and suitable for enlarging international cooperation. Also, very advantageous is the fact, that nano-sats are within the reach of universities, which is supportive for the education of the next generation of engineers.

France's Jean-Yves Le Gall, stressed that 3D printing might have the biggest potential for the advancement of space exploration and might possibly even revolutionise that area. He mentioned the case that a few weeks ago a UK fighter-jet flew with parts made directly on the runway before take-off. The moderator turned to Charles Bolden to ask him, whether he would fly on an airplane made by 3D printing. The Administrator replied: "Probably, I would. We are getting there. We are already testing an engine made by 3D printing." He extended his answer by telling about the terrestrial applications for water purification or nano-encapsulation as a substitute for chemotherapy.

Xu Dazhe then gave a small insight in the advancement of China in 3D printing:

"I believe that it is not only necessary but also beneficial to utilise those cutting-edge technologies in space. For example in 3D printing, in China we have already started to use 3D printing technology on some of the components and parts in our space industry. It will still take a long time before an entire aircraft might

be printed by a 3D printer, but right now I think it is reasonable to expect some key parts or some special parts of an aircraft to be printed by a 3D printer. I believe that the 3D printing technology is beneficial for space as well as for maintenance."

A companion for the Chinese Space Station

At the end of the roundtable, the moderator gave way to NASA Administrator Bolden to elaborate on the announcement of the ISS extension until 2024. Bolden concluded his explanations by ensuring the ISS is the best available platform for advancing space exploration: "The future is only limited by our imagination."

Romania's Marius-Ioan Piso contributed an interesting detail: "I am looking into the culture of my country. My country has a very old culture which includes stars, which includes the sky, includes the universe. I cannot see that space exploration is an act of culture by itself. By looking into this act of culture, … we can claim that space exploration is still in its early stage. We should push this process." Brazil's José Raimundo Braga Coelho joined that last round of statements when admitting: "Brazil has missed a very nice opportunity to be part of the ISS. For many reasons we were not able to make it." This was completed by the Indian perspective, which reflects the daily reality of a highly-populated sub-continent: "Can we sustain life on Earth? Will we be forced to find a new home? These are also things we should start to address."

The comment by Xu Dazhe was given with a little smile: "We are very happy to hear the news about the extension of the International Space Station till 2024. This means by the time when our station, the Chinese Space Station Tiangong to be built between 2018 and 2022, is in low Earth orbit, it will have a companion up there. And I hope that more countries should be participating in those space stations, whether it is the International Space Station or Chinese Tiangong space station."

The very last question, thrown into the round during the last few minutes was: "Human mission to Mars – can we do it together? Can we go to Mars together?"

Bolden without hesitation, replied to that like a shot: "We have to! When you look at the global exploration roadmap, that was signed by 12 nations but cooperatively in the production by even more than signed it. We, all of us sitting here on this panel, believe that we can do it, we will do it, we must do it, we can't let it go." There was nobody on stage who could not agree to that!

Roundtable 4: "The Benefits of Space Exploration"

Moderator: Dr. Ray Johnson, Senior Vice-President and Chief Technology Officer, Lockheed Martin Corporation. Johnson was lucky to have been in charge of a pretty outspoken round of panellists. Each of his guests had some lively ideas and was not shy of putting the thoughts on the table. Like all other moderators of the day, Johnson also had some difficulties to bring all those inputs together and create a sparkling debate out of it.

Panel members:

- David Parker, Chief Executive, UK Space Agency, United Kingdom.
- Johann-Dietrich Wörner, Chairman of the Executive Board, DLR, Germany.
- Asanda Sangoni, Space and Stakeholder Director (for Dr. Sandile Malinga, South Africa, Chief executive, South African National Space Agency).
- Walter Natynczyk, President, Canadian Space Agency, Canada.
- Naoki Okumura, Japan Aerospace Exploration Agency, Japan.
- Alexander Degtyarev (for Yuri Alekseyev, Chairman State Space Agency of Ukraine, Ukraine).
- Jan Kolar, Director Czech Space Office, Czech Republic.

It is interesting to note that Asanda Sangoni and Jan Kolar from the Czech Republic were the only panel members to immediately

Panel members for "The Benefits of Space Exploration" roundtable. From the left: moderator Dr. Ray Johnson, Senior Vice-President and Chief Technology Officer, Lockheed Martin Corporation; David Parker, Chief Executive, UK Space Agency, United Kingdom; Johann-Dietrich Wörner, Chairman of the Executive Board, DLR, Germany; Asanda Sangoni, Space and Stakeholder Director (for Dr. Sandile Malinga, South Africa, Chief executive, South African National Space Agency; Walter Natynczyk, President, Canadian Space Agency, Canada; Naoki Okumura, Japan Aerospace Exploration Agency, Japan; Alexander Degtyarev (for Yuri Alekseyev, Chairman State Space Agency of Ukraine, Ukraine; Jan Kolar, Director Czech Space Office, Czech Republic. (credit: Go Taikonauts!)

Asanda Sangoni - South Africa. (credit: Go Taikonauts!)

Jan Kolar - Czech Republic. (credit: Go Taikonauts!)

David Parker - UK (left) and Johann-Dietrich Wörner - Germany (right). (credit: Go Taikonauts!)

catch the point that the first question was specifically related to "emerging countries"!

Moderator Ray Johnson: What are the benefits for an emerging space country to join a space exploration programme?

A Need for Story Tellers

Johann-Dietrich Wörner remarked that the question should be put to the people, and if the right questions are asked, we would get more disruptive answers than we would like.

David Parker (UK) recounted that ESA performed a so-called "Citizen's Jury" several years ago which was very successful in getting input from the general public.

Naoki Okumura (Japan) reminded everyone that he worked in the non-space industry most of his life, and he never asked himself what benefits his work would bring. Japan started their involvement in space in the context of the Cold War, but since the US-Russia space race has ended they now question themselves. He also noted that space brings different kinds of benefits, for example, exploration needs technology development, which in turn brings commercial benefit, and so on.

Asanda Sangoni (South Africa) said that her country established its space agency on the existing capabilities within South Africa, although this did not include space. South Africa is present at this conference because it wants to explore, and cooperation would allow it to be part of a bigger programme, part of a global effort, as without this their individual contribution would be small. Emerging space countries need to understand the value-chain, and where they can play a role in the "big picture". A developing country like South Africa needs to motivate its people more than a developed country does, so there is a need for assistance in motivation. She also said that although she tries to tell the benefit story, this would be done much better by inviting "story-tellers" to explain the benefits to the people.

Jan Kolar (Czech Republic) began by stating that the question referred to emerging countries, so he would answer that, although he did not fully understand what the term "emerging country" meant. Noting that all the people at the meeting were agreed that space is needed, he believed that every country would like to participate, so the question becomes how to make this participation possible? How to make participation efficient and useable for everyone who wants to play a part in the space endeavour? He then stressed that space exploration is specific and distinct from space applications, although in addressing the benefits of space, most people use examples from space applications, and not space exploration. Knowledge is the reason we do space exploration. The basic motivation is the curiosity we have inside us. For humanity, this is our nature – if we would not be curious, we would not be human.

Johann-Dietrich Wörner (Germany) replied that he could not get funding for "curiosity" in Germany, but agreed that stories could be given, and then gave some examples where fundamental scientific research led eventually to developments that were unpredictable.

David Parker (UK) stated that although the UK were the third country in the world to put hardware into space in 1962, they only formed a space agency three years ago. This agency was established because it has been recognised that space is important to the economy. Space fits into an overall strategy – societal benefit and knowledge. He went on to say that for the UK, it is about the longer-term return. The UK is investing in telecommunications satellites that will bring a return to the tax-payer in a few years' time. There will also be a longer-term benefit, it is not known now what this will be, but there will be some.

Alexander Degtyarev (Ukraine) said that for Ukraine, space exploration is not just about knowledge, but colonisation.

Walter Natynczyk (Canada) referring back to Jan Kolar's point, noted that there are accountants, acting on behalf of the government, who want to know the return on investment, and how to minimise the risks involved. To make this case well, strong leadership and willingness to take risks is required.

Johann-Dietrich Wörner (Germany) interjected that the timescale associated with space exploration is maybe too big for private investors, and that agencies have some responsibility to "boldly go where no one has gone before".

David Parker (UK) mentioned that the finance minister in the

UK has accepted the metric that for every one pound invested, there is a return over time. So small countries should invest, yes, but cautiously, in different areas such as, hardware, technology transfer, and training the next generation, and they should certainly engage with their population.

Naoki Okumura (Japan) noted that in Japan they have to discuss about benefits extensively. Large investments are needed in both space exploration and fundamental research – science is focused, but exploration is broad and not so well focused. So if one could take a more focused approach, and put financial resources in focused areas, it is more likely to bring significant results, and hence a greater understanding of the benefits by people "in the street".

Moderator Ray Johnson: What could we do to better integrate the smaller countries…space programmes, into the activities of the larger nations…so that everyone can achieve their goals? How can we extract the best innovative ideas from the smaller nations?

Knowledge Transfer and Trust

David Parker (UK) highlighted the work of the International Space Exploration Coordination Group (ISECG) in bringing countries together, and to show where individual nations can find their role. He also mentioned that in the International Space Exploration Forum (held on the previous day) the need for a political view that there needs to be an overall clear goal, e.g. sending humans to Mars. Not all participants necessarily would buy into this goal, but could agree to as an end objective, and so enable the addressing of the elements along the way, that would be needed to achieve this goal, whenever that end objective might be reached. He also noted that there is now a great opportunity for democratisation in space, citing what the commercial sector is doing and what can be achieved through the use of nano-satellites.

Jan Kolar (Czech Republic) reiterated that involvement in space should not just be about purchasing a satellite, but knowledge transfer, otherwise it is not so beneficial for the receiving country.

David Parker (UK) concurred, stating that for the UK working with emerging space nations, that it should be about education, capacity-building, training the next generation, and engagement – a REAL partnership.

Johann-Dietrich Wörner (Germany) related that when he first approached the US about cooperation, he received a positive answer, but with the proviso that it would not be on the critical path. But now, many years later we are on the critical path through our work on Orion – so we must learn to trust the other partner.

Moderator Ray Johnson: How does space affect societal evolution?

Get Back to Basics

Walter Natynczyk (Canada) recalled that Chris Hadfield singing on the ISS, and the space lecture by taikonaut Wang Yaping, helped support the idea that space is the "norm", a normal evolution. Also, it is key, that as agencies push the envelope out towards Mars, they know when to recognise when it is time to hand-off to industry and others, at an acceptable risk threshold, so that the agencies can focus on the next big step.

Asanda Sangoni (South Africa) thought that everyone needed to be reminded that Earth was part of a greater universe. There is a need to get back to basics, to what people can really understand and identify with.

David Parker (UK) wondered what would happen when, in relation to space tourism, not just a few hundered people would be able to see the Earth from space, but thousands. What cultural change will come about when the appreciation of the fragility of this little planet increases, and what this will do to our understanding of working together to solve problems.

Moderator Ray Johnson: Space is expensive how can this be changed?

Space is not Expensive!

Jan Kolar (Czech Republic) received considerable applause from the audience and the only time during the day when he strongly stated "Everyone is saying space is expensive – I don't think space is expensive. If we think it is expensive, it will be difficult to get. Why is everyone repeating that space is expensive? Sorry its not! Its not! How much do you spend of your total governmental budget? NASA is begging for 1%. I don't know how much in Canada, but in our country it is 0.1% - is it expensive?".

Alexander Degtaryev (Ukraine) while agreeing with Jan Kolar, said that it is impossible when speaking about space programmes, not to speak about money, and that space is not yet a business case, it would be later, but not now. He went on to say that only the big countries can afford to invest in new technology to access space, propulsion for example, and would they then give that knowledge to everyone? No! It is necessary to change something. He ended by saying "People would only join together in one case – if Martians attacked Earth – but lets not wait for this".

Walter Natynczyk (Canada) added that "…countries need to afford tanks and planes because of national interest…the challenge for all of us here in the room, is how do you convert space exploration into the national interest?".

When then asked by the moderator for one short final comment, the panel members responded:

David Parker (UK) "Think global act global."

Johann-Dietrich Wörner (Germany) "Competition and cooperation must be combined – competition as a driver and cooperation as an enabler."

Asanda Sangoni (South Africa) "I think respect for one another – respect for each nation."

Walter Natynczyk (Canada) "There is no place like space to

build trust in common."

Naoki Okumura (Japan) "When we talk to people about space, we look at Earth from space we should think of what issues we face, what challenges we have, that should be the starting point."

Jan Kolar (Czech Republic) "Everything has been said, and it's quite important to be encouraged to go to space, and I wish all countries and all people around the world to keep thinking how to be part of that endeavour."

Press Conference concludes the Washington space days

Friday late afternoon ended with a one hour press conference organised by the IAA.

Gopalan Madhavan Nair guided the press event and gave the concluding remarks after the 2 days of discussions and presentations: "The International Academy of Astronautics has proposed to Space Agencies specific activities enhancing global cooperation in Space Exploration, which have resulted from the Heads of Space Agencies Summit in 2010. The IAA welcomes participation in these activities by Space Agencies. These proposals are:

Planetary Robotic Exploration

- Terrestrial Analogues
- Virtual Exploration
- Comparative Climatology
- Planetary Protection

Human Spaceflight

- Public/Private Human Access to Space: LEO and Beyond
- International Protocol to handle crisis/emergency of astronauts in LEO
- Long-term Space Propellant Depot
- Space Mineral Resources: Challenges and Opportunities
- Global Human Mars System Mission Exploration
- Space Solar Power Systems
- Astronaut Standardized Career Dose Limits in LEO
- International Human Spaceflight Life Science Virtual Institute
- Space Exploration Outreach
- Foundations of the first 50 years of Human Space Exploration
- Human Space Technology with Developing Countries
- Integrated Coordination in Space Exploration"

Participating in the press conference were:

- Thomas Reiter, ESA's Director of Human Spaceflight and Operations for Jean-Jacques Dordain, Director General of European Space Agency;
- Naoki Okumura, President of Japan Aerospace Exploration Agency;
- Francisco Javier Mendieta-Jiménez, Director General of Agencia Espacial Mexicana;
- Charles Bolden, Administrator of NASA;
- Seidu Oneilo Mohammend, Director General of National Space Research and Development Agency Nigeria;
- Yuri Makarov, Russian Federal Space Agency Roscosmos.

The most questions during the press conference where centred around the order by U.S. President Obama to NASA to look for possibilities to extend the operations of the ISS to 2024.

Before journalists could ask about progress in the space relationship between the U.S. and China, the NASA Administrator made a clear announcement: "Before you ask it, I know someone will, we are continuing to work in a multi-lateral capacity with China. We are looking for ways in time to find different ways that we can be a partner for them. Human space flight is not something that is gonna happen with the US and China in the foreseeable future, because we are forbidden from doing it by law. Just to give that out there right away. No

From the left: Jean-Michel Contant, Secretary General IAA; Gopalan Madhavan Nair, President of the IAA; Thomas Reiter, ESA's Director of Human Spaceflight and Operations for Jean-Jacques Dordain, Director General of European Space Agency; Naoki Okumura, President of Japan Aerospace Exploration Agency; Francisco Javier Mendieta-Jiménez, Director General of Agencia Espacial Mexicana; Charles Bolden, Administrator of NASA; Seidu Oneilo Mohammend, Director General of National Space Research and Development Agency Nigeria; Yuri Makarov, Russian Federal Space Agency Roscosmos. (credit: Go Taikonauts!)

Bilateral meeting between the Chinese and the ESA delegation in Washington. (credit: CMSE)


The area in front of the European Astronaut Centre in Cologne got re-designed recently. The group of five flagpoles for the flags of the five ISS partner states got extended. Is there a deeper meaning in it? There would be now space for flags of possible additional ISS participating countries. (credit: Go Taikonauts!)

matter how many times you ask me that's not gonna change. Not today, anyway."

However, Bolden did go into certain detail when replying to Jeff Foust's (The Space Review) question about the possibility of expansion of the ISS partnership: "Let me summarise it very quick: it is hard. It is a treaty. The partners have talked about this for a number of years and a decision was made not to increase the number of partners. But each member organisation would be encouraged to reach out and involve other nations as participants. If you hear the term "participant" and here I get formal with you, it means, any other nation that is not a Member Nation in the ISS partnership is getting ready to do something, whether it is to fly an experiment or something like that. But it is highly unlikely that any of us is willing to go through the process of increasing the partnership by going back and opening up the treaty. For those of you who were around when the Space Station partnership was formed, I was not, but I was told it was painful. Nobody wants to do that again."

And later on he added: "Life has changed. We are doing things really, really differently than the way we have ever done. So there is no one entity that people have to go to. They can partner with any of the partner organisations. China, is already participating on the ISS as a Member of the Alpha Magnetic Spectrometer team."

Jean-Yves Le Gall, Head the French space agency CNES, did not participate in the press conference, but he commented about the event to French APF journalists: "There is a change in the Chinese attitude, with a call for cooperation in space. And Americans aren't reticent - on the contrary," said Jean-Yves Le Gall. "The big question for the next three years is whether China will join the International Space Station. That's the challenge."

One month after Washington, Thomas Reiter, ESA's Director of Human Spaceflight and Operations gave a press conference at the European Astronaut Centre EAC in Cologne, Germany. He left room for interpretation when replying to a question by a German journalist similar to that by Jeff Foust in Washington: "One can determine that there is a certain opening up of NASA. And this step … that we try to include Chinese scientists in our programme will also be done by Russia. In this respect there had been indeed an opening up on the US-American side. But the question, of whether the Intergovernmental Agreement, the legal basis for the ISS cooperation will be opened to let China participate, this is too early to answer. In this respect I cannot answer this question. … Important is, that we continue this way which we have started to walk and that we continue to walk with small steps in the right direction. … By doing so we can create the best preconditions to actually tackle the major challenges in the next decade."

Side events possibly the main events

Officially, in total three events took place. But like so often, the real decisions are taken in personal talks.

From the remark made by Xu Dazhe during the roundtable discussion and the presence of Wang Zhaoyao, Head of CMSA, one could conclude that the 33+ Heads did not only come to Washington for enjoying two nice days but also to debate, discuss and negotiate in bilateral or multi-lateral meetings.

A check on the CMSA website reveals: "On the sidelines of the conference, Xu Dazhe and Wang Zhaoyao held a bilateral talk with Jean-Jacques Dordain, Director General of ESA, exchanging opinions about the progress and follow-on work of China Space Cooperation Agreement."

We, the GoTaikonauts! team, believe that the ISEF meeting and the IAA Heads of Space Agencies Summit in Washington was a milestone achievement on the way to true global space exploration as propagated since years by the UN and the IAA. Based on those efforts, there were breakthroughs in highly important areas achieved:

- Acceptance of the involvement of developing countries as equal and respected partners in international space activities on a global scale. By doing so, the technological divide of the world can be narrowed and finally overcome. This will contribute to tremendous changes in the societies of the respective nations and will enable their further national development and prosperity and consequently of

the world.

- China was recognised as a major space nation and accepted on the same level of playing field.
- The U.S. is accepting the access to the ISS for partners of the other four main ISS partners: Canada, ESA, Japan, and Russia. This paves the way for incorporating China into the ISS project through bilateral agreements most likely with ESA and/or Russia.
- The most suitable space exploration on a global scale would be an international human Mars mission.

Looking at those results, one cannot help but thanking the IAA for their persistency and visionary approach in the past. Why can IAA unite all these important persons so easily? Maybe it is the power of a neutral facilitator, beyond political limitations, combined with a pool of immense expertise available through the IAA members. As Gopalan Madhavan Nair pointed out in the press conference: “The IAA is a global community.” Could this be the foundation for the IAA becoming the global space agency of the future?

The Summit Declaration

Space exploration is opening new frontiers allowing humanity to make tremendous advances in leveraging space and space-based services that were, until recently, unimaginable.

Access to space is a door to progress, cutting-edge science and new technologies that will lead not only to activities in space but also to help create a more secure and affluent society.

It also inspires the growing populations of young people in developing countries to pursue higher education and work toward a better future.

There are many reasons that drive humanity to explore but ultimately governments invest in exploration to pursue their national interests and to ensure that their countries benefit from the new opportunities created by expanding their sphere of activities to space.

Making the benefits of space accessible means making space exploration affordable; international collaboration is one key means to do so. Space exploration is a catalyst for international cooperation.

International collaboration makes it possible for countries with diverse capabilities and interests to pool their resources and work together, based on mutual interest, towards the improvement of life on Earth and the expansion of humanity beyond our home planet.

The International Space Station is an excellent example to the benefits of international collaboration.

Ambitious international projects on the exploration and exploitation of space are possible and will involve new and emerging space faring nations.

These projects should be supported by international frameworks for collaboration on future space exploration, drawing on the experience of bilateral and multilateral projects such as the ISS.

International coordination will be indispensable for future space exploration activities requiring Space Agencies to share their goals and strategies and identify commonalities.

There is a need for consensus on the long-term sustainable exploration and exploitation of space by all for peaceful socio-economic developmental purposes.

The Global Exploration Roadmap and Benefits for Humanity documents developed by the International Space Exploration Coordinating Group provide an excellent basis for this consensus. The peaceful exploration of space should be a common adventure for all of mankind.

ESA's space cooperation relationship with China gains momentum

Thomas Reiter and Frank De Winne Talk about Space Cooperation

by Jacqueline Myrrhe

"It is a process, which we have just nudged."

Since former ESA astronaut Thomas Reiter took office as ESA's Director of Human Spaceflight and Operations in 2011, he has followed the tradition established by the ESA's Director Generals, to invite media at the beginning of each year for a press conference to explain to them the highlights of the work lying ahead.

In addition to his Director's job, Reiter is also Head of Establishment at the European Space Operations Centre - ESOC in Darmstadt, Germany, where he has held that very special press conference in 2012 and 2013. This year, however, he came to the European Astronaut Centre (EAC) in Cologne, Germany. Not only did he explain ESA's 2014 aims in the area of human spaceflight, but he also took his time to reflect on the current status of ESA's relationship with China:

"In the past years you could follow that we have been entering into an intensive dialogue with China. China has, with respect to space flight, become more and more present, as demonstrated with the Chang'e lunar mission at the end of last year. We at ESOC have been given operations support to this Chinese Moon mission with our ground stations. Already last year, during a congress in Beijing we had the opportunity to talk to our Chinese colleagues about possibilities for intensifying our dialogue. Not only in my directorate, the Directorate of Human Spaceflight and Operations, but also within the Directorate of Science and Robotic Exploration, under Alvaro Giménez Cañete, and the Directorate of Earth Observation, under Volker Liebig, we are looking for options of more intensified cooperation.

Here at the EAC, the Head of Establishment, Frank De Winne with his team has already prepared steps last year, which will be turned into action this year. It is about the set-up of two working groups. The two groups will exchange their experiences about the topic 'astronaut operations' - how to prepare mission operations when astronauts are on board the ISS – and about the topic 'medical support' to astronauts – in the sense of what is required for that. The latter is not about the medical part of space medicine research, this is an area with my Department Head, Martin Zell. It is about the operational medicine. What needs to be done to keep the astronauts fit in space, to keep them exercising during their mission and to provide them with medical advice and doctors in case of need? It is exactly this operational aspect of medicine that we want to look closer at together with our Chinese colleagues. For these activities we have planned two weeks for each working group. Each group will spend one week at the Astronaut Centre of China, and one week here at EAC.

Additionally, there will be an exchange on the topic human behaviour and performance. We have to prepare our astronauts for the special situation of working under space-limited and constrained conditions. Ideally, the training before the mission, here on ground, such as the survival training, gives them such opportunity. During recent years, we have introduced another type of training in a cave on the Italian island of Sardinia. We

Thomas Reiter, ESA's Director of Human Spaceflight and Operations answers the question by German space journalist Robert Vogel on the perspectives of ESA-China space cooperation during a press conference at the European Astronaut Centre on 6 February 2014. Left: Jocelyne Landeau-Constantin, Head of ESOC & EAC Communications, was moderating the press conference. (credit: Go Taikonauts!)

During the press conference (credit: Go Taikonauts!)

are using a partly unexplored cave for human behaviour and performance training. During their cave training, the group of astronauts are self-reliant and conduct active cave exploration combined with scientific research. This serves not only the scientific area of cave research, but in the first instance, for testing our astronauts under extreme conditions. The cave training has raised big interest with our international ISS partners. Therefore, we have also invited our Chinese partner to take part in the next cave campaign.

And the last point with respect to cooperation with China: when ESA astronaut Alexander Gerst will return from his stay onboard the ISS in November, he will undergo his rehabilitation process here at EAC. For this time period we would like to involve a Chinese specialist from the ACC, the Astronaut Centre of China. You can imagine that after half a year-stay in microgravity, it takes a little time to get used again to the conditions here on Earth. This process is intensively watched and accompanied by our medical team and our training department. And for this we are going to invite a Chinese specialist.

On top of these activities, we are also preparing this year another future project. We would like to include our Chinese colleagues in experiments in the scientific area. Martin Zell, my Head of ISS Utilisation and Astronaut Support Department, has the task within the next weeks and months, to identify topics which could be of interest for Chinese scientists in order to assign them as co-PIs in such research topics. This could be possible in the area of human research or possibly in the area of physical research. In the end, we can see that within the next years, for the first time, that Chinese scientists are part of the science teams and actively conducting experiments.

Question by Robert Vogel (Perry Rhodan Magazin, Germany):

Mr. Reiter, you have been mentioning the cooperation with China. I can recall very well, that it is not so long ago, that China was looked upon with scepticism. What has broken the ice? And a second question: You have been talking about this exchange. Could this be a first step leading to welcoming a Chinese astronaut on the ISS?

Regarding your first question: I think that also in the past I have been emphasising, that the initiation of such a type of cooperation is a process, which we have just nudged. We are still in the middle of getting to know each other. Now we have initiated the next logical step. Of course we have to keep working on that. It is not like that we say suddenly from one day to another: all is brilliant and now we do some cool missions together.

In the meanwhile, we have also seen setbacks. You might remember the Ministerial Council in 2012. We had prepared a cooperation project proposal. It was about cooperation with China in the area of space situational awareness, or more precisely, in the area of space weather through the Kuafu mission. All of the space situational awareness community including the ESA Member States showed a big interest in the project. But because of the very difficult financial situation we had to prioritise the proposals with the consequence that the Kuafu proposal had to be withdrawn. This, of course, was a pity. But at the same time it was not the end of our cooperation. We have explained that very clearly to our Chinese colleagues. Fortunately, the scientist who is leading the project on the Chinese side has been working with ESA in the 1990s in ESTEC, our establishment in the Netherlands. This means, he knows how ESA works and that he is acquainted with ESA procedures and processes. For me it was important, that the Chinese colleagues understood that the decision was not driven by disinterest, but simply based on limited financial resources. And given the tasks and programmes, which were already running, we had to give those priority.

However, we are advancing by taking logical steps. Of course, we have to do that with prudence, but we do that. I have also mentioned the example of our cooperation with the US, where we are providing the service module for the Orion spacecraft to NASA. With this contribution we are delivering technology for the critical path. This project did not emerge overnight, but it developed continuously. When you are now asking what helped to make this breakthrough with China, then I can say, that last year at the sidelines of the International Astronautical Congress in Beijing, several meetings have taken place between the Directors and Director Generals of the different space agencies. These talks between Roscosmos, ESA, and the corresponding official representatives of CNSA and CMSA, have prepared the next step. This dialogue on the level of Director Generals will continue this summer. This is how we move on. During the International Space Exploration Forum which has taken place in January in Washington, with more than 30 representatives from space agencies from all over the world, including China, it was noticeable that China was very much interested in working in this international community. I think this is a very important fact. It was clearly stated by all participants of the Washington forum that international cooperation is wished and that a classic area for that is in particular, exploration.

The question however, and I am coming now to your second part, of when a Chinese astronaut will be on the ISS, that, today, I cannot yet answer. One can determine that there is a certain opening up of NASA. And this step which I introduced to you today, that we try to include Chinese scientists in our programme will also be done by Russia. In this respect there had been indeed an opening up on the US-American side.

But the question, of whether the Intergovernmental Agreement, the legal basis for the ISS cooperation will be opened to let China participate, this is too early to answer. In this respect I cannot answer this question. We know that China by the end of the decade intends to assemble a space station and certainly will do so. We will watch that. Important is, that we continue this way which we have started to walk and that we continue to walk with small steps in the right direction. That means that we get known to each other better and better. Then we will have a look at the things which are working and at the things which are maybe not working. By doing so we can create the best preconditions to actually tackle the major challenges in the next decade.

“A joint strategy will have an impact on the future of space exploration for all partners.”

52-year old Belgian Frank De Winne has a background as a military test pilot. In January 2000 he joined ESA’s Astronaut Corps. De Winne flew two space missions.

By the end of 2002 he served as a flight engineer on his OdISSea mission, a Soyuz support flight to the International Space Station ISS. Seven years later, he became the first European Commander of the ISS during his OasISS long-duration mission. Since 1 August 2012 he is Head of the European Astronaut Centre Department. In that function, he is not only responsible for the European astronauts but also for the further evolution of Europe’s Astronaut Centre in Cologne, Germany. In an interview with Belgian Space Author, Theo Pirard, he gave an insight into the tasks and challenges ahead.

Theo Pirard: How many ESA astronauts are currently prepared for operational services in space?

Frank De Winne: We have ten. In addition to ESA astronauts Jean-François Clervoy and Leopold Eyharts of French nationality, Hans Schlegel of German nationality, Paolo Nespoli of Italian nationality, there is the new selection of six astronauts. Italian Luca Parmitano made his first spaceflight – a six-month mission to the ISS – during 2013. German Alexander Gerst will fly in 2014, followed by Italian Samantha Cristoforetti. ESA astronaut Andreas Morgensen of Danish nationality will participate to a short-duration ISS-flight in 2015. British astronaut Timothy Peake is in training for a mission in 2015/16.

Theo Pirard: Will Frank De Winne fly again?

Frank De Winne: The desire to go to space is still existing. But my answer is: No. For me, a page has been definitively turned. I will not fly anymore. Clearly I decided to go ahead with a new step in my career, particularly busy with the preparation of up to four spaceflights during the coming years. This preparation represents an impressively great work performed by the EAC team and all our colleagues in the Directorate. I have to take into account, as elsewhere, the economic crisis that obliges us to find solutions in order to compress budgetary expenditures.

Theo Pirard: What about the future of the ISS? What will happen with the Station after 2020?

Frank De Winne: Nowadays, the space agencies involved within the ISS programme have indicated that the target to low Earth orbit remains the current priority, to conduct original research and to develop technologies for the future of space exploration. How to achieve the most efficient use of the low Earth orbit? In which manner will some new systems be developed and operated? Which planning is needed to continue the exploitation of the existing ISS infrastructure? Will it be an interesting way to cooperate with China, which is preparing its own space station for the 2020’s? Many options are on the table for evaluation. Clearly, from a technical viewpoint, the ISS utilisation can be extended until 2028. ISS is an option among others. Europe has not yet decided how to proceed… financially and technically.

Theo Pirard: Does ESA show any real interest for the use of the Chinese Space Station?

Frank De Winne: Jean-Jacques Dordain, Director General of ESA, has stated in many speeches that, in the future, the international partnership in space exploration should be an open one, also for the human missions. In this field, Beijing is developing capacities we have to take into account. It is

EAC - European Astronaut Centre (credit: Go Taikonauts!)

Frank De Winne (credit: ESA)

interesting for ESA and for its Member States to consider what China is currently preparing - its own systems for the human exploration of space. The question is: which evolution for any cooperation? ESA has developed a step-wise approach for such a cooperation with China in the area of human spaceflight. A joint strategy will have an impact on the future of space exploration for all partners. For this reason, the development of the partnership will take time and patience.

Theo Pirard: Did a Chinese delegation of taikonauts visit EAC?

Frank De Winne: We had the visit of Chinese managers responsible for the training of the taikonauts. In exchange, we had the opportunity to see how the Chinese managers, responsible for human spaceflight prepared their crews for orbital missions. These mutual visits are the first steps to evaluate a possible cooperation with China for joint human missions. If we refer to Agenda 2015 of ESA's Director General, the flights of astronauts in the future may go beyond the political borders. As you might have heard, we have set-up two working groups together with our colleagues from the Astronaut Centre of China. One on astronaut operations, and one on the aspects of space medicine. The working groups are about to start their work.

Theo Pirard: Does EAC, in the training programme of ESA astronauts, consider some Mandarin lessons?

Frank De Winne: We started to organise Mandarin lessons at a very small scale. This educational activity is not mandatory. It is just recommended to the new generation of astronauts.

Theo Pirard: Are ESA astronauts getting some preparation for future flights with the Orion spaceship of NASA?

Frank De Winne: This poses another question for the future of ESA in human missions. Our main partner is NASA. The Ministerial Conference of ESA 2012 in Naples took the decision about the participation of Europe's industry to the service module or the U.S. spaceship MPCV or Multi-Purpose Crew Vehicle, alias Orion. ESA will refer to the technological expertise of ATV, our Automated Transfer Vehicle. Europe's contribution to NASA MPCV represents an essential step to take part in human transportation systems beyond low Earth orbit, in a development phase. At this time, the ESA-NASA partnership is limited to the first flight of Orion in 2017, without people on-board. What will happen after this test? We would like to extend this cooperation, but it depends on the decision by the ESA Member States and consequently, the availability of financial resources to go ahead with a long-term strategy of Orion flights.

This interview is an abstract of an interview made in French, published in the bimonthly Espace & Exploration n°19 (January-February 2014), updated 12 February

IAC 2013 – But There Was Also Something Else

United Nations-China Workshop on Human Space Technology (Part II)

by William Carey, Jacqueline Myrrhe

In our previous issue we have given a detailed report on the United Nations-China Workshop on Human Space Technology, which took place from 16 to 20 September 2013, in Beijing. In order to get an all-around view on the workshop, we wanted to know from non-Chinese workshop participants why the four day-long get-together in the week before the IAC2013 was important to them. We asked Dutch scientist Jack van Loon and Ghanaian Proven-Adzri Emmanuel about their impressions of the workshop.

The two experts represent a European and an African view on the benefit of human space technology, and this guarantees quite different perspectives on the same topic. Although coming with a very different motivation, and from different backgrounds, both workshop participants are of the same opinion, that the role of the UN has great potential in supporting space capacity-building not only in less-developed countries, but also in developed ones.

Interview with Jack van Loon

Jacobus (Jack) van Loon (VU University Amsterdam, The Netherlands): Currently manages the 'Dutch Experiment Support Centre - DESC', a non-profit entity located at the VU Amsterdam, whose main goal is to increase the scientific output in the field of gravitational research in the Life and Physical Sciences, through knowledge, access to facilities and services/assistance for ground based and in-flight experiments. Jack received his PhD in mechano-sensitivity of bone cells/tissues at the ACTA (Dentistry Faculty) of the same university in 1995, the thesis involving experiments on the Space Shuttle and Russian Bion systems. He returned to VU Amsterdam in 1998 after a three-year period at Bradford Engineering responsible for microgravity research payloads on Space Shuttle, Mir, and the International Space Station. He is also currently Chairman of the Dutch Microgravity Platform and was President of the European Low Gravity Research Association, ELGRA, in the period 2007-2011. During his academic career, he has developed several centrifuges in order to perform hyper-gravity research.

Go Taikonauts!: What was the purpose of your participation in the UN/China Workshop on Human Space Technology in September in Beijing?

Jack van Loon: I was invited by the United Nations, (UNOOSA-HSTI), as an expert on gravity related research, so micro-gravity work. It was a week-long meeting, in which two or three workgroup sessions on micro-gravity related work were included, and two other workgroups; one on education and the other on human exploration and technology. I co-chaired the microgravity sessions together with Prof. Fengyuan Zhuang. Because of my previous involvement in the workshop in Malaysia two years ago I was asked again to chair those sessions.

Go Taikonauts!: Did you present some new ideas, new proposals?

Jack van Loon: As chairman I did not present anything, but in the general session, I presented the work we do with some 70 scientists and engineers, mostly from Europe, but also some from the US and Japan, to prepare a project with regarding a human centrifuge. This will be a really huge centrifuge with about a 150 m diameter for people to live in. The facility, the Artificial Gravity Platform (AGP) or also referred to as the Human Hypergravity Habitata (H3) will be installed here on Earth, so it is not an in-flight research platform. You can use that centrifuge, in preparation for human exploration, you can use it to see what gravity does to the human body in the long-term. These are studies where people will live in that centrifuge for days, weeks, or even months.

Go Taikonauts!: So it is hyper-gravity?

Jack van Loon: It is hyper-gravity, yes. Most people are focused on the microgravity region of the gravity spectrum, as I call it. But you can learn a lot by looking into what happens, what changes in your body with hyper-gravity as well. Most of these changes, if not all, are similar changes that one could see under reduced gravity, hypo-gravity or microgravity, but then in the opposite direction. So you can learn a lot on what happens to the body, how it adapts. It adapts one way as you go to hyper-gravity, and it adapts in the other way if you go to a lower gravity, while you are living there for weeks or months. But you can also see how the body adapts to lower gravity, and this is after you have been into hyper-gravity for weeks or months. So it's a bit funny paradigm, but you use the centrifuge then to look into reduced gravity effects.

Go Taikonauts!: The new idea about this is that people would stay in the centrifuge long-term, because there are existing centrifuges for pilots and so on – is this the main difference?

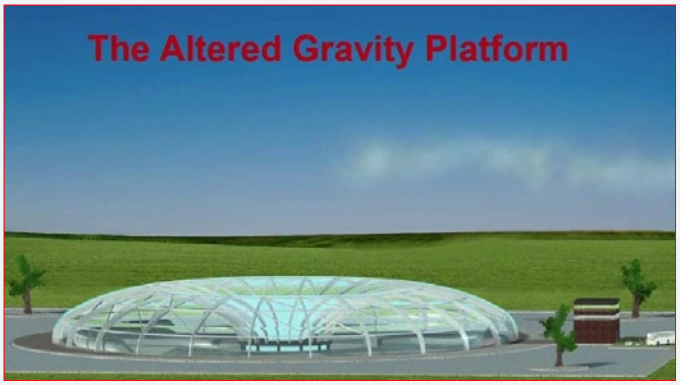
Jack van Loon: Yes, it would be long-term, so you could think about a centrifuge that could accommodate, let's say 12 people or so, living there for a long period of time. The exact number of persons is not yet decided, depending on specific science requirements. Or if you do short-duration experiments, you could maybe house some more people, but everything would happen inside the centrifuge facility. You live there, you have your leisure, your laboratories, your communication, you're whatever. Maybe you can compare it a little bit to Mars 500, but at a higher g-load.

Go Taikonauts!: So you are talking about weeks or months?

Jack van Loon: Yes. The idea is to also have a complete life-support system on there, so its also going to be a test-bed for new technologies in life support systems. Of course you have the effects of psychology and crew dynamics as well, which are of interest in such studies. Although the psychological effect of the harsh environment, such as you have it in Concordia, is different. Concordia is really more demanding in that respect,

Jack van Loon chairing one of the Microgravity Science Working Group sessions. (credit UNOOSA website)

Jack van Loon chairing one of the Microgravity Science Working Group sessions. (credit: UNOOSA website)



A schematic of the proposed Artificial Gravity Platform (AGP) facility. The diameter is approximately 175 m.
(credit: AGP team (J. Berte, K. Bok a.o.))

An existing centrifuge in operation in Star City, Russia.
(credit: ESA/Andre Kuipers)

than it would be in the large centrifuge. But it can be compared to Mars500. However, contrary to Mars500 we will be able to look at gravity effects, and the adaptation to gravity, and the re-adaptation to a lower gravity if you have been in a higher gravity. Another thing is, there are also some initiatives, which started off in the early 1900s with the Russian spaceflight pioneer Konstantin Tsiolkovsky, to have rotating space stations. There is actually very little known about what happens in the long-term with the human body and on the vestibular system when you are in a rotating system with a very large diameter. Of course, we all know the rotating chairs and all that kind of stuff, but this now is really living in a rotating environment for a long period of time, and we want to learn how you can adapt. You can also learn about it if you would go for a large diameter rotating system in flight, in space. Then you can learn something about the diameter, and how to construct and operate it, and how to behave while living in such an environment.

NASA recently released this Nautilus-X study, where I believe it was about a centrifuge of around 10 m diameter. This is not what we are thinking of, we are thinking larger than that, because the larger the better. But if you make it larger this also brings complications in terms of technology. We are currently exploring some patents for the unique technology you require for such a large centrifuge.

Go Taikonauts!: And what kind of g-levels are you talking about?

Jack van Loon: From the engineering point of view, I think you should not go higher than 2 g. There have been all kinds of animals under hyper-gravity conditions for weeks or months. We had experiments some time ago when we had rats in a centrifuge at 2 1/2 g for more than one year. They are happy, they walk around, they copulate, and produced offspring. And all these long duration studies have been done on animals such as rats, mice, dogs, chickens, and snails, fish, you name it. Especially in the 60s and 70s a lot of work was done on that subject, but also more recently. However, it's never been done with humans.

So scientifically it's very obvious why we need to do it, as why would you have otherwise done the animal studies? Most of it is for basic research on animals, and how their physiology adapts, but mainly to understand the human body better. So the questions are there, and I think the main reason why the large human centrifuge is not there yet is because it is a matter of scale, ergo budget, and to a certain extent also a matter of technology.

Go Taikonauts!: Have you discussed where this facility would be sited yet?

Jack van Loon: No. If we had it in Europe, I think three or four possible locations could be considered. One of them could be near an academic hospital, so you have physicians there, you have students there, you have human physiology research

infrastructure, also for safety and so on. Another possibility would be at ESA's Astronaut Centre in Cologne, because it is space-related, but also because it is close to the Envihab which opened last year. Envihab could be used as a 1g control for this facility.

Go Taikonauts!: So that makes sense?

Jack van Loon: Those places would be good locations. There are some other places where people do space related work where this would fit. But this is not only space related work. One of the particular things you see in all animal studies, is that in all these animals, you measure a reduced fat mass when they are under hyper-gravity conditions. All of them, in rats, in guinea pigs, in rabbits, in mice, whatever. So it would also be a very interesting research platform to look into things like obesity, which is the number one threat of the current Western society. Obesity and ageing, these sorts of effects, you could look into using hyper-gravity using such an Artificial Gravity Platform.

Go Taikonauts!: What was your general impression of the UN workshop?

Jack van Loon: My general impression was very good. I knew the structure from the Malaysia meeting in 2011. So I was familiar with it. What they try to do is to get non-space-faring countries involved in human spaceflight and in technology work and research. I think that's very good. Of course there were also a lot of space-faring countries participating. JAXA was there, China was there, ESA was there. But there were quite some non space-faring countries present, and I think it's very good to also have them involved. The United Nations is a facilitating agency, they bring people together. They don't have their own space programme, or grants, or rockets. But to bring people together and inform them, I think that's a very good function of the UN. Its high level, you are not discussing very particular things. If there are particular subjects to be discussed, they are not going to be reflected in the final declarations, because the result should be general recommendations and not specific items. But I think the UN-HSTI, managed by former Japanese astronaut Dr. Takao Doi, is a good platform to discuss between nations on what they could do together and how non-space faring countries can be introduced to human spaceflight and technology programs. It's a good initiative.

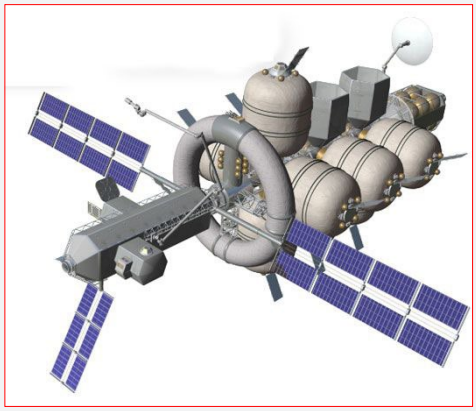
Go Taikonauts!: What did you personally gain from your participation in the workshop?

Jack van Loon: For the human centrifuge, the Chinese were very interested in the idea. And of course the good thing about China is that they have the capabilities and the willingness to advance. If you compare China with Europe, if China wants to do something, they can do it, quickly. If they make a decision, they can do it quickly, and this is a huge difference from Europe

The Concordia Station in Antarctica. Due to its extreme isolated location, is used as space analogue site for physiological/psychological research to gain knowledge for the future human exploration of Mars and beyond. (credit: ESA/IEV/PNRA – E. Kalmakamis)

The isolation facility in Moscow which was home for the 6 members of the Mars500 crew: 3 Russian, 2 European, and 1 Chinese, for a total of 520 days. (credit: ESA)

Konstantin Eduardovich Tsiolkovsky (1857-1935), The Russian 'father of rocketry', and one of the pioneers of astronautics. (credit: NASA)



Vehicle concept from NASA study 'Non-Atmospheric Universal Transport Intended for Lengthy United States Exploration – NAUTILUS-X'. (credit: NASA)

for example. This is also one of the comments we heard during one of the technical visits to CAST. We had a discussion with one of the people there, and some of them had worked with ESA on the Galileo systems a few years ago. So they learnt to a certain extent, on the technology part, but one of the main things they learned also, was, how slow it goes in Europe. And this is something I think we might consider, on our side, to speed up things. So the big advantage for China, is that once they make a decision to do something, they are going to do it, they are going to stick to it, and it's going to be fast.

Go Taikonauts!: They seem to be exactly the type of cooperation partner you would be looking for?

Jack van Loon: I think it's attractive, yes. I mean they did a lot of things in the meantime, especially in the area of human spaceflight. They had their launches, their manned missions, they had their docking activities, even twice already. And they are coming up with their space station in 2020 or 2022. It's happening. So probably we have to go from ISS to CSS!

Go Taikonauts!: What do you think will be the way forward for the UN?

Jack van Loon: I think the next step, and you saw that already in the Malaysia meeting, where my feeling was that ESA and NASA and CSA, were somewhat reluctant to get other nations involved in the ISS programme. On the one hand this is understandable, because Europe and NASA and CSA have spent a lot of money, so you want to use the ISS to a certain extent. There is not too much time available to do science, so to get others involved is difficult towards the science communities in their own countries. So it's understandable. But on the other hand, I think we also have to cooperate in a way. So it was obvious at the Malaysian meeting, that the Chinese were very interested to set-up collaborations and to open up their programme for foreigners, and this was also one of the main reasons that the meeting after Malaysia was in Beijing, where they again stressed, also with the attendance of various high-level people, to look for collaborations.

I think the United Nations can play a very significant role: Bring parties together, not on specific themes, but on general themes, discuss it. How can you do things? People can express their interest, their willingness to collaborate or to work together. That's how I see the role for the United Nations in this respect. It is another discussion level or discussion platform, not too specific, but to discuss the national intentions of what you want to do. And once that is sorted out, the experts can get together to do the rest of the work.

Further information may be found at the following URL's:
http://www.oosa.unvienna.org/oosa/en/SAP/hsti/index.html
http://www.oosa.unvienna.org/oosa/en/SAP/hsti/china2013.html

Free publication on Large Human Centrifuge:
http://www.zrs.upr.si/media/uploads/files/Annales%20Kinesiologiae_2012_2%281%29.pdf#page=89

The Warrior King Looks Towards Space

The Republic of Ghana is located in the Gulf of Guinea region, a few degrees north of the equator, on the west coast of Africa, and is bordered by the Ivory Coast, Burkina Faso and Togo. The word Ghana means "warrior king". Kofi Annan, a former Secretary-General of the United Nations (1997-2006) hails from this natural resource-rich country: rich in cocoa, gold, diamonds, industrial minerals, oil and gas. In July 2011 it was designated a "middle-income country".

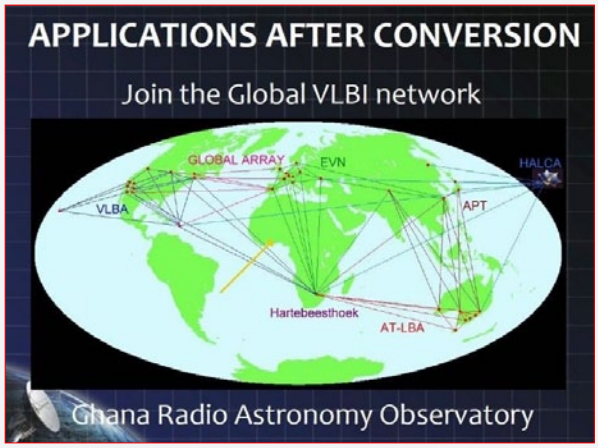
Although looking back on a long tradition of diplomatic relations with Ghana, in recent years, China established particular strong economic ties with this West-African country. The website of the Embassy of the PRC in Ghana gives a list of projects supported or financed by China in Ghana: http://gh.china-embassy.org/eng/zjgx/t177920.htm

Go Taikonauts! interviewed Proven Emmanuel Adzri from the Ghana Space Science and Technology Institute (GSSTI) and the Ghana Atomic Energy Commission in Accra, the country's capital, who also presented a paper at the UN-China Workshop in Beijing, entitled " Human Space Technology: A Case of Ghana". His paper summarised how the Institute is using the UN's Human Space Technology Initiative (HSTI) programme to address some key challenges that the country faces, such as illegal mining and logging, poor sanitation and flooding. The Institute's proposed future projects include the building of a cubesat, environmental monitoring, natural resource management, satellite communications (tele-education and tele-medicine), and coastal monitoring activities. Current projects include climate change studies such as the investigation of climate change impact on maize yield in Ghana or looking into issues how climate change impacts human health, biodiversity, and water resources. But also outreach (at senior high school level) initiatives or radio astronomy activities were explained during the presentation. There is a strong emphasis in all of these towards capacity-building, one of the three pillars on which HSTI is based.

The Ghana expert also described during the workshop in Beijing the highly interesting "Ghana Radio Astronomy Project". The 32 m dish, built in 1980 was used for more than 20 years for telecommunication until it was abandoned in the early 2000s. After an assessment of the structure in 2011 which revealed that the antenna was still worth 15 Mio USD, another 3,2 Mio USD were invested to convert the communication antenna into a radio telescope of astronomical observations. Most work for this conversion is done. The new "Ghana Radio Astronomy Observatory" will become part of the Global VLBI network. Already now it becomes obvious that the telescope project will yield far-reaching benefits, as impressively shown in the presentation by Proven Emmanuel Adzri.

GoTaikonauts!: What was the purpose of your participation in the UN-China Workshop on Human Space Technology in September in Beijing?

Proven Emmanuel Adzri: To showcase the achievements, challenges and gain knowledge and collaboration for our infant



Slides from the presentation. (credit: Proven Emmanuel Adzri, Nana Ama Browne Klutse; GSSTC/GAEC)

China-Ghana Political Relations in a nutshell
from "Ghana's Relations with China" by Isaac Idun-Arkhurst; 2008
(China in Africa Project Report no.3 - The South African Institute of International Affairs
http://www.africaportal.org/dspace/articles/ghanas-relations-china)

Ghana and the People's Republic of China (PRC) established official diplomatic ties in 1960. Since then, relations between the two countries have been deepened by strong personal relationships between the political elites of the two countries, especially during the era of Nkrumah and Premier Zhou Enlai, and by high-level official visits, including visits by Ghana's President John Kufuor to China in 2002 and China's President Hu to Ghana in 2003. On the second leg of Premier Wen Jiabao's seven-nation tour of Africa in June 2007, China and Ghana issued a joint communique on strengthening cooperation in trade, infrastructure, telecommunications, education, health and culture. The Chinese premier's visit resulted in the signing of six agreements, including an agreement to build a malaria centre and a primary school in Ghana, and a $66 million loan agreement to expand and upgrade Ghana's telecommunications network.

Over the decades, Ghana has provided critical diplomatic support to China, while China has reciprocated with material support for development. In the 1960s, Nkrumah campaigned for the reinstatement of the PRC in the United Nations and supported China in the border conflict with India in 1962. China rewarded Ghana with grants and continuous technical assistance for Nkrumah's development projects. After Nkrumah's overthrow, Peking withdrew from Ghana an estimated 200 Chinese aid workers and embassy officials. In spite of the frosty relations, Ghana joined other African states to cast the majority of votes to reinstate China in the UN in 1971. The man who cast Ghana's vote for China was John Kufuor, then Ghana's deputy minister for foreign affairs. Under President Kufuor, relations between China and Ghana have been given yet another personal touch, with China renewing its friendship with a grant of $2,4 million to renovate the National Theatre, which China built in the early 1990s to reward Ghana for the unflinching diplomatic support offered by the Rawlings-led government to Beijing during the controversial repression of the Tiananmen Square prodemocracy protestors in 1989.

Reflecting shifting focus from ideological considerations to all-round, but especially economic and cultural, cooperation, the last decade has seen rising bureaucratic, corporate and individual exchanges, including visits by high-profile economic bureaucrats such as Zhou Xiaochuan, governor of the People's Bank of China, who visited Ghana in 2005 accompanied by Chinese businessmen in search of new business opportunities. In the spirit of China's Africa policy, publicly launched in January 2006, there have also been political exchanges between members of Ghana's Parliament and officials of the Chinese People's Political Consultative Conference (CPPCC). In April 2007, Jia Qingling, the chairperson of the CPPCC, visited Ghana and signed agreements that included a $30 million concessional loan for the Dedicated Communications Project for the security agencies. The latter reflects China's growing military and security cooperation with Ghana, which has included the construction of an office complex for the Ministry of Defence with a $7.5 million Chinese grant.

Institution, the Ghana Space Science and Technology Institute (GSSTI) on Human Space Technology Initiative (HSTI).

GoTaikonauts!: How were your presentation and your ideas about space technology for Ghana perceived?

Proven Emmanuel Adzri: Well, the participants were enthused about the progress of our Institution, the GSSTI, on the HSTI in the short space of time of its existence.

GoTaikonauts!: What was your general impression of the workshop?

Proven Emmanuel Adzri: The workshop was organised well, and it's a great platform for the promotion of the UN's HSTI, a better platform for international collaboration.

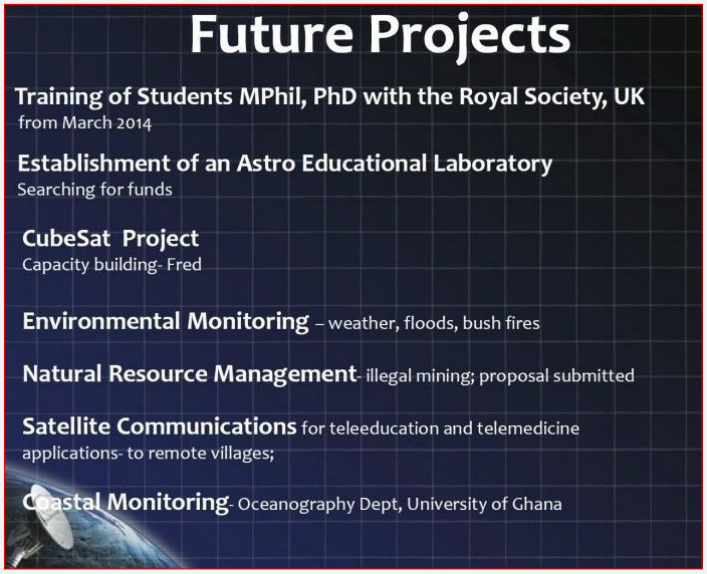
GoTaikonauts!: What did you gain from your participation in the workshop?

Proven Emmanuel Adzri: I gained insights on how to keep a space institution going in the midst of challenges. How useful it is for HSTI for all of humanity. I also learnt how it is to enlighten the public on space activities through HSTI, especially in my country, Ghana. I also gained some collaboration from organisations who are ready to help our GSSTI to make great impact in our country.

GoTaikonauts!: What do you think will be the way forward?

Proven Emmanuel Adzri: More of such workshops should be organised, where the big space-faring nations come to share ideas and collaborate with new/smaller space-faring nations.

The full presentation by Proven Emmanuel Adzri can be found under the link "18 September files (.ZIP, 70MB)" on this website: http://www.oosa.unvienna.org/oosa/en/SAP/hsti/china2013.html



Slides from the presentation. credit: Proven Emmanuel Adzri, Nana Ama Browne Klutse; GSSTC/GAEC

Hop-on and hop-off, … but where do you go?

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

by Jacqueline Myrrhe

China, the U.S.A., and space – is it a hopeless case or not? Looking at the developments of the last year, which were dominated by made-up spy accusations, rejected access for Chinese scientists to NASA's Kepler conference, Charles Bolden's modest and at the same time not-so-humble appearance during the IAC2013 in Beijing, one could get depressed and give up on any hope that the relations between the two biggest economies in the world would ever improve when it comes to space activities.

Surprisingly, U.S.-China space relations have always been marked by contrast, as it was the case also last year.

In June, Barbara Morgan, the first teacher in space during the STS-118 mission in August 2007, sent a letter with greetings and wishes to Wang Yaping, who gave a space lesson to 60 Mio Chinese students during her Shenzhou 10 mission on-board Tiangong 1. Former NASA astronaut, Sandra Magnus, together with first female taikonaut Liu Yang, had an astronaut appearance at Beihang University in Beijing in September. Sandra Magnus commented on that event one day later during a panel discussion at the IAC2013: "We had a wonderful time sharing our experiences. We spent a few hours talking with students and sharing our stories. It was a real delight and I know we look forward to interacting more in the future."

By the end of 2013, the first Chinese soft-landing on the Moon with Chang'e 3 gave way to the first U.S.-China lunar space cooperation. The International Lunar Observatory Association (ILOA) of Kamuela, Hawaii, and the Beijing-based National Astronomical Observatories of China (NAOC) of the Chinese Academy of Sciences, exchange observation time between China's Lunar near-Ultraviolet Telescope (LUT) aboard Chang'e-3, and the ILO-X Precursor and ILO-1 Moon South Pole missions currently under development for launch in 2015-2016.

So what is really in the way? Why is it so difficult for the two countries having the greatest potential in the world, to find a common goal for at least space cooperation, if not even more?

21 February of this year marked the 42nd anniversary of U.S. President Richard Nixon's visit to China in 1972 after 25 years of no official interaction between the two countries. The 1 January 2014 stands for the 35th anniversary of the establishment of

Visit of Chinese Vice Premier Deng Xiaoping to Johnson Space Center on 2 February 1979. Deng Xiaoping, Vice Premier of the People's Republic of China State Council, and his wife are briefed by Johnson Space Center Director, Dr. Christopher C. Kraft. A complete review of NASA's manned space programme was given, using exhibit scale models and flight simulators. (credit: NASA-JSC)

Visit of Chinese Vice Premier Deng Xiaoping to Johnson Space Center on 2 February 1979. Over the shoulder view of Deng Xiaoping, Vice Premier of the People's Republic of China State Council and party, seated in the visitor's viewing area for a briefing during their tour of the Mission Control Center, MCC. Visible through the glass are MCC consoles and orbit maps. (credit: NASA-JSC)

full diplomatic relations by issuing the "Joint Communiqué on the Establishment of Diplomatic Relations". At the end of the same month, the Vice Premier of the People's Republic of China State Council, Deng Xiaoping, and U.S. President Jimmy Carter, signed the "Agreement between the Governments of the People's Republic of China and the Government of the United States of America, on Cooperation in Science and Technology" on 31 January 1997. This document became known as the "umbrella agreement", and is the first formal cooperative agreement between the two governments establishing an institutional framework for promoting bilateral science and technology exchanges. It was agreed that a China-U.S. Joint Commission on Science and Technology Cooperation would be created and co-chaired by the U.S. President's Science Adviser, and the Chairman of the Chinese State Science and Technology Commission (SSTC). The joint commission would meet annually to survey the burgeoning official scientific exchanges. Deng clearly saw science and technology as an important force in China-U.S. relations. During his visit to the U.S., Deng made several stops at scientific institutions and technology corporations, and also at the NASA Johnson Space Flight Center in Houston. With the signing of the umbrella science and technology agreement, almost every U.S. technical agency began to develop constructive relations with its Chinese counterpart, both as a matter of national policy and popular inclination. [5]

In other words, shortly after the end of the dark decade of the Cultural Revolution - US-China cooperation in space science and technology made its jump start when the "Memorandum of Understanding on Cooperation in the Field of Space Technology" was even signed before the 1979 umbrella agreement, and was therefore one of the first documents included into the umbrella agreement.

Looking at the currently stormy days of U.S.-China space relations, one could easily forget that the roots of their bilateral connection go back even further than 1979. Already in the 1930s young talented Chinese academics went to the U.S., a country with the highest technological and scientific knowledge, to further their own studies or to get involved in state-of-the-art research. Qian Xuesen, Ren Xinmin, Wang Xiji, and Tu Shancheng are the best known such examples. The presence in China of a substantial number of Chinese scientists and engineers who had been educated in the U.S. prior to 1949, represented an important resource for building mutual understanding and trust during the initial phase of bilateral relations. [5]

But both - politics and economic interests - have been all too often interfering in scientific matters and have been shaping the ups-and-downs in the space cooperation relationship between the U.S. and China. Cooperation in space science and technology had a hard time to emancipate and to be simply just that: cooperation.

According to Jin Xiaoming [5], the development of the relationship between China and the U.S. in science and technology in general "has undergone three distinct phases, corresponding to the political relationship between the two countries. ... Non-governmental, sporadic visits characterised the first phase (1971-1978). During the second phase (1979-1989), rapid growth occurred following the signing of the umbrella science and technology agreement. Cooperation was curtailed following the June 1989 Tiananmen events, and later resumed its expansionist trend during the third phase (1990-2000). Since George W. Bush took office in 2001, we have been in a new phase, where the nature and future of the relationship is yet to be defined."

This evaluation can be complemented by Gregory Kulacki's assessment, who explains that in the late 70s and 80s, the U.S. uses space cooperation with China for political purposes against the Soviet Union.

Another driver has been economic interest, when U.S. satellite manufacturers became interested in launching their spacecraft on cheaper Chinese rockets. This interest was dropped again, once the U.S. launcher industry demanded back its share of the launcher market. In this situation, political restrictions were easier to introduce than sticking to the rules of a free market. However, all these regressive actions are remnants from the Cold War era, a world order now out of fashion and usefulness.

Deng Xiaoping shifts his focus to the high-tech field during his visit to Houston. He visited the Johnson Space Center in Houston, Texas, and tested a flight simulator on 2 February 1979, under the guidance of U.S.-American veteran astronaut, Fred Haise. (credit: Photo/QQ)

Deng's compact nine-day U.S. visit includes three days in Washington D.C. and six in Atlanta, Houston and Seattle. He observed local manufacturing industries and rode a lunar rover model at the Johnson Space Center on 2 February 1979. (credit: Photo/QQ)

The world has dramatically changed since then. Not only has China in the meanwhile, built up interesting and sustainable space capabilities, but there is also a demand for new models of setting up relationships between countries.

To draw the correct conclusions, GoTaikonauts! wanted to get a more detailed overview on the sequence of events in U.S.-China space cooperation. Since none of our team members has U.S.-American roots or connections, we would have liked a U.S.-national to help us with such an analysis. All authors we approached declined our request for such a piece of content for very different reasons. But sometimes we got the impression that the fear of consequences when writing about China, is a driving hindrance for the one or the other author to take over such a work, in particular younger writers. If this really is the case, the "Wolf Clause" has spread fear against its own people and democracy has bitterly failed.

Consequently, the GoTaikonauts! team decided to do its own research and compilation of content. By doing so, we realised what an effort it became and how many facts and information needed to be taken from different sources and puzzled together. Maybe this was the actual reason why we could not find somebody to do the Sisyphus work for us? Saying that, we are grateful for the ground-breaking work done in the past by authors such as Brian Harvey [1], Gregory Kulacki [2], [3], [4] and Jin Xiaoming [5]. Their work was the basis for our timeline on U.S.-China space cooperation you can find on the next pages. While Brian Harvey's work provided the best overview on the technical cooperation efforts between the two countries, Gregory Kulacki's articles are the best account on the political and policy background. More than welcome was the paper by Jin Xiaoming [5] for getting hold of the Chinese perspective on this topic – in English! Not to forget to mention are the numerous web articles used to complement our timeline. However, we still think that facts are missing or incomplete. Any contribution from any reliable source is still welcome for later updates of our work.

After the compilation work was done and after looking at the details, a few things became obvious: Space science and technology cooperation between China and the U.S. has survived harsh political situations. The volume of human-to-human contact is enormous and has never been interrupted throughout the last decades. The Union of Concerned Scientists, with Gregory Kulacki as the China project manager, facilitated highly-valuable non-governmental direct contacts with Chinese scientists and engineers.

In his blog on the Union's website, he explains what the importance of grass-root personal interaction really means: "More than 100 Chinese scientists and engineers have participated in our annual Summer Symposiums on Science and World Affairs, and many have gone on to hold important positions in Chinese institutes. The China Project that I manage for the Union has used these relationships to expand dialogue and pursue joint research on the contention U.S. security issues that have long divided Chinese and U.S. scientists. In the process, we have established relationships with China's defence-science community that our counterparts in government cannot. We have used these relationships to ease Chinese anxieties about U.S. missile defences, U.S. discussions of developing new nuclear weapons, and the Pentagon's overblown rhetoric about 'space control'. We are starting discussions aimed at helping Chinese scientists to make decisions that reduce the risks of nuclear power. Scientists with access to good support networks and information can make a positive difference to government policies, or at least try to. The Union of Concerned Scientists has learned that the January 2007 anti-satellite test was approved in part thanks to distorted representations of data on space debris provided by the Chinese military. We watched with admiration as our Chinese research colleagues risked their careers to provide their government with more reliable information."

The biggest damage to date to the China-U.S. space relationship came from the Cox Report and the Wolf Clause. While the Cox Report has been the result of a group effort, the Wolf Clause is

President Hu Jintao tries on a baseball cap - to the surprise of onlookers - presented by an employee of the Boeing Company while visiting the Boeing Company on 19 April 2006. The New York Times reported that Hu was so familiar with the Boeing Company that he knew about recent sales of Boeing planes, and how many were being used in China. Financial Times said that Hu chose Seattle rather than the U.S. capital to visit, underscoring the importance China places on trades with Boeing, Microsoft and Starbucks. (credit: Photo/QQ)

Chinese Vice Minister of Science and Technology Li Xueyong speaks during a news conference held in the Media Centre of the 17th National Congress of the Communist Party of China (CPC), in Beijing, China on 16 October 2007. Li stated: "China sincerely wants to cooperate with the United States in space exploration and join the International Space Station project that has already involved 16 nations." (credit: Xinhua)

the brainwork of a single person. Again, the obvious question must be allowed, whether the meaning of democracy is to represent the will of the majority of the people or of a single person?

Unfortunately, Wolf had easy game because the U.S.-China relationship is still missing underlying principles, as Adam Segal, Ira A. Lipman Senior Fellow for Counterterrorism and National Security Studies, Council on Foreign Relations, recently stated in an interview: "It's a relationship still in search of its guiding principles. In the final days of the Cold War, after the United States opened relations with Beijing, we could balance ourselves against the Soviets, giving the relationship some shape. Then we had the tragedy of Tiananmen, which threw the relationship into disarray, but then we had China's joining the WTO in 2001, and so the focus was heavy on economic issues. So what we can expect is that the relationship is very cyclical - it has its good points and its rough periods, because the two sides are constantly bumping up against each other. We're entering a more bumpy period. But overall, given the widespread economic interdependence between the two sides and the increasing people-to-people contact, I suspect the damage will not be dramatic to the relationship, but we will continue to bump along."

Or as Jin Xiaoming puts it: "In strengthening the China-U.S. science and technology relationship, it is important to realize that more is at stake than scientific knowledge and technical know-how. Cooperation can have a broad impact on our mutual understanding. Cooperation in science and technology increases our knowledge of each other's systems; conversely, a better appreciation of our respective values can help us identify and remove obstacles to productive cooperation during this new phase." [5]

When U.S. President Barack Obama and Chinese President Xi Jinping met in June 2013 for their historic 2-day summit in Annenberg at Sunnylands resort, Xi called the summit "a new historical starting point" after China and the United States reopened diplomatic relations more than 40 years ago. Xi is reported to have said that he hopes the talks might "chart the future of China-U.S. relations." He posited that the "Chinese dream" of economic prosperity and national renewal is connected to the "American dream." If so, it seems as if there is more than common ground for a bright future.

Also, the two leaders reached consensus on building a new type of major country relationship characterised by no conflict, no confrontation, mutual respect and win-win cooperation. Xi spoke of his country as a global superpower now on a par with the United States and put the question "How can our two nations join together to promote peace and development in the world?" on the table. Although there was no mention of discussions on space matters, why not promoting peace and development for the whole world by using space exploration as a tool for a true global scientific, technological and societal cooperative undertaking? Mars is still waiting for mankind.

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Vice President Xi Jinping returns to Muscatine, Iowa, on 15 February 2012, where he first visited in 1985. He chatted with old friends and recounted his trip 27 years ago. He is presented a reprint of the Muscatine Journal newspaper from 1985 – the time of his first visit – by his old friend Sarah Lande. (credit: Photo/QQ)

No space between us! During the IAC2013 in September 2013 in Beijing, former NASA astronaut Sandra Magnus, and China's first female taikonaut Liu Yang, demonstrate how U.S.-China space cooperation could look like: friendly, easy and very beautiful. (credit: China Daily)

Chinese space experts in the U.S.A. before 1950: Qian Xuesen	Born and studied in China, earned a degree in mechanical engineering at MIT after arriving in the U.S. in 1935. Under Theodore von Kármán he acquired a doctorate from Caltech in 1939 and became a Director of the Jet Propulsion Laboratory. In 1950, the U.S. government detained Qian under suspicion of communist sympathies. After years of constant surveillance, Qian left the U.S. in 1955 for China where he became the "Father of Chinese Rocketry". [3]
Chinese space experts in the U.S.A. before 1950: Ren Xinmin	Earned his Ph.D. in engineering mechanics from the University of Michigan. Returned to China in 1949 and became the Chief Designer of the communications satellite project. He also was the lead negotiator when China tried to purchase one U.S. satellite. [3]
Chinese space experts in the U.S.A. before 1950: Wang Xiji	Engineering graduate of the Virginia Polytechnic Institute and State University. After his return to China he became one of the founding fathers of China's space programme. Only 37 years old, Wang led the efforts to found the CAS-Shanghai Mechanical and Electronics Institute in November 1958. Wang played a key role in many areas of the development of China's space programme, such as launchers, recoverable remote sensing satellites, Shenzhou spaceflight capsule, and experimental microsatellites. [3]
Chinese space experts in the U.S.A. before 1950: Tu Shancheng	Graduated and habilitated from Cornell University in 1953 where he stayed until 1956 as Assistant Professor. Upon returning to China he laid the foundations for the control systems for Chinese air-to-air and surface-to-air missiles and later for the control systems for communication satellites. He was the Lead Scientist and Head of the Project 863 Expert Committee for Space Technology and later the Director of the Science and Technology Committee of the Chinese Academy of Space Technology and Industry for National Defense (COSTIND). [3]
1950	The U.S. government detained Qian Xuesen under suspicion of communist sympathies. After 5 years of constant surveillance, Qian left the U.S. for China where he became the "Father of Chinese Rocketry". [4]
1966 – 1976	Cultural Revolution - "Great Proletarian Cultural Revolution."
April 1971	Technology embargo on China was lifted. [5]
May 1975	U.S. moved China up on the ladder of technology export control, from Group S to a particular Group P, which meant that China could buy from the United States, more and better technologies than what the Soviet Union could at the time. Subsequently, under U.S. administrations of Carter, Reagan and till the first 180 days of the first Bush administration, the general trend was to significantly liberalise the control over technology exports to China. [5]
Spring 1978	Deng Xiaoping held a meeting of the Special Committee during which he expressed his concern that the Chinese satellite programme is advancing too slowly. According to Space Analyst Gregory Kulacki, Deng tried to inspire his fellows, by saying: "If we invite a good teacher to give a lecture in the Great Hall of the People only 10,000 people can hear it, but if the same teacher were to give that lecture on television, and everyone had the equipment to receive it, that's a classroom of unlimited size." Deng decided to buy a U.S.-American communication satellite and to address the issue during the expected U.S. visit to Beijing in summer 1978. [3]

Xu Dazhe, Head of China National Space Administration, during a panel discussion at the IAA Heads of Agencies Summit on 10 January 2014 in Washington: "We are very happy to hear the news about the extension of the International Space Station till 2024. This means by the time when our station, the Chinese Space Station Tiangong to be built between 2018 and 2022 is in low Earth orbit will have a companion up there. And I hope that more countries should be participating in those space stations, whether it is the International Space Station or Chinese Tiangong space station." (credit: Go Taikonauts!)

During the press conference following the IAA International Space Exploration Conference, on 10 January, Bolden was hesitating to make any firm comments on the prospect of space cooperation with China. He clearly stated, that he cannot imagine that the IGA, the Intergovernmental Agreement, which laid the legal foundation for the ISS programme would be opened up to allow China to join. (credit: Go Taikonauts!)

Spring 1978	China was in secret negotiations with the U.S.-government aiming at the normalising of bilateral relations. Both countries were preparing a visit of representatives of the Carter Administration to Beijing in July 1978.
28 May 1978	China gets 1 gramme of Moon rock as a goodwill gesture. U.S. National Security Advisor Zbigniew Brzezinski hands it over to Chairman Hua Guofeng together with a symbolic Chinese flag, which is said to have been flown in space. [3]
July 1978	Under the leadership of the U.S.-President's Science Advisor and Director of the Office of Science and Technology Policy, Frank Press, "the most high powered science/technology delegation ever sent by the United States to a foreign country" (quote: U.S.-National Security Advisor Zbigniew Brzezinski) arrived in Beijing. The Head of NASA, Dr. Robert A. Frosch, and Heads of numerous U.S. government technical agencies were part of that delegation. The visit aimed at identifying the interests of both countries in science and technology cooperation. The delegation met in Beijing with Vice Premiers Deng Xiaoping and Fang Yi and other high-ranking Chinese officials. The meeting laid the foundation for subsequent cooperative agreements, including among others the Understanding on Cooperation in Space Technology, and the Agreement on the Exchange of Students and Scholars. The issue of purchasing a communication satellite was addressed. [5]
23 October 1978	As an outcome of the visit by the delegation under Frank Press an agreement was reached on a general framework for exchanges that would include students, scientists, and visiting scholars. The document was discussed and finally signed in Washington by the first Chinese governmental science and technology delegation, headed by Zhou Peiyuan, President of China Academy for Science and Technology (CAST), and an American team, headed by NSF Director Richard Atkinson. China would send 500-700 persons to the U.S. in 1978-1979, and the U.S. would support sixty students and scholars to go to China during the same period, with the understanding that other American students would go to China under separate arrangements. On 26 December, five days before the U.S. and China formally established diplomatic relations on 1 January 1979, 52 Chinese students boarded a plane, destined for university campuses all over America. [5]
1979	On the eve of a NASA delegation visit to China in 1979, both sides were working toward a Memorandum of Understanding for the satellite purchase. The Ministry of Post & Telegraph suddenly realised that it did not have the funds to buy it. Upon learning of the situation, Deng called an emergency evening meeting in his residence with COSTIND Director Zhang Aiping, Deputy Director Ma Jie, Vice Councilor and State Planning Commission Director Yu Qiuli, and Chief Negotiator Ren Xinmin. Deng told the group, "The Americans are coming. Yu Qiuli should take responsibility for receiving them." Deng wanted Yu to find the funds and close the deal. Nevertheless, at the end of the visit there was no memorandum and the satellite deal did not go through, despite the will for making compromises on both sides. Until today, the reasons are not clear. It might have been a financial issue, or maybe lengthy negotiations put the two parties off or other possible misunderstandings on the volume of the purchase. It is said, that Hughes wanted to sell an existing satellite previously made for another customer but the Chinese wanted to supply some of their own parts to the satellite. [3]
01 January 1979	A "Joint Communiqué on the Establishment of Diplomatic Relations", dated 1 January 1979 was signed. Diplomatic relations between the U.S. and China experience a phase of normalisation. The U.S. uses space cooperation with China for political purposes against the Soviet Union. [3], [5]
31 January 1979	Deng Xiaoping and U.S. President Jimmy Carter signed the "Agreement between the Governments of the People's Republic of China and the Government of the United States of America on Cooperation in Science and Technology". It became known as the "umbrella agreement" and is the first formal cooperative agreement between the two governments which constructed an institutional framework for promoting bilateral science and technology exchanges. Three already existing agreements, among them the "Memorandum of Understanding on Cooperation in the field of Space Technology", were incorporated into the umbrella agreement through an exchange of letters. Also, it was agreed that a China-U.S. Joint Commission on Science and Technology Cooperation would be created and co-chaired by the U.S. President's Science Adviser and the Chairman of the Chinese State Science and Technology Commission (SSTC). The joint commission would meet annually to survey the burgeoning official scientific exchanges. Deng clearly saw science and technology as an important force in China-U.S. relations. During his visit to the U.S., Deng, who later put forward his famous observation that science and technology is the first productive force, made several stops to scientific institutions and technology corporations. With the signing of the umbrella science and technology agreement, almost every U.S. technical agency began to develop constructive relations with its Chinese counterpart, both as a matter of national policy and popular inclination. [5]

2 February 1979	Deng Xiaoping, Vice Premier of the People's Republic of China State Council, visits the Johnson Space Flight Center in Houston. He was briefed by Johnson Space Center Director Dr. Christopher C. Kraft. A complete review of NASA's manned space programme was given, using exhibit scale models and flight simulators. Deng was also given a briefing during his tour of the Mission Control Center MCC.
April 1980	Commerce Department changes China's Technology Transfer Category from Y to P allowing U.S. firms to sell high technology to China at twice the rate of that sold to USSR and its satellites, and to transfer selected "dual use" technology to China. [5]
25 September 1980	A Chinese Delegation visits NASA's Glenn Research Center.
1981	CAST begins discussions with NASA on the topic of science and technology exchanges.
1983	Secretary of Defense Caspar Weinberger visits China and proposes linking Sino-American military exchanges and technology transfer to detailed strategic roles and missions to be shared by Washington and Beijing, but China declines. [5]
23 March 1983	U.S.-President Ronald Reagan holds his infamous SDI speech (Strategic Defense Initiative). That initiated a discussion within the Chinese political circle about the importance of science and technology for the development of a country. Space Analyst Gregory Kulacki states that this debate re-ignited the Chinese manned spaceflight project. [3]
May 1983	Secretary of Commerce Malcolm Baldridge moves China from category P to V ("friendly state") category for purposes of reviewing technology transfer licenses controlled under the auspices of Commerce Department's CCL. [5]
11 July 1983	President Ronald Reagan's message to the Congress reads: "It is in our fundamental interest to advance our relations with China. Science and technology are an essential part of that relationship and I have taken steps recently to ensure that China has improved access to the U.S. technology it needs for its economic modernization goals. We will continue to assist China through mutually beneficial cooperative efforts in science and technology." [5]
1984	U.S.-President Ronald Reagan travelled to China bringing an impressive programme of scientific exchanges on the way which would also aid the modernisation of China's military. [3]
1985	NASA and AIAA visit China.
First half of 1986	In the first half of 1986, the Chinese government decided to put the commercial launch business under the China Great Wall Industry Corporation, the international business arm of China's space industry. The new launch service department was led by Wu Keli. Later in the same year, a representative office was set-up in Los Angeles. Huang Zuoyi became the only full time staff of this office. In 1986, Wu und Huang visited numerous customers in the United States. Their efforts paid off. In just one year from January 1986 to January 1987, two contracts and five reservation agreements were signed, though most of them later turned out to be disappointments. Among them, the most dramatic one is the Westar 6. It was a Hughes 376 communication satellite recovered from orbit by STS-51A in 1984, and then resold to Western Union. Westar 6 was just within CZ-3's 1,400 kg GTO capability. But after the reservation agreement was signed, Western Union was re-organised and the satellite was purchased by the Houston-based Teresat. Again, a launch agreement was signed with the latter in June 1986 and the formal contract on 28 January 1987. Shortly after that, Teresat was closed down. Just one month later, another short-lived company who took over the satellite signed the contract with China, and terminated it shortly too. It was on 2 January 1989 when Asiasat signed the launch contract with CGWIC that the satellite's fate was finally decided – still to be launched by the CZ-3 as originally planned. Asiasat is a consortium of Hong Kong-based Hutchinson Telecommunications, the UK's Cable & Wireless, and the China International Trust and Investment Corporation (CITIC), a pioneer of satellite communication in China and Asia. As Asiasat 1 is a U.S.-made satellite, the export license needed to be issued by the U.S. government became a trouble. The U.S. side refused for two major reasons the license. 1) Chinese launches are sponsored by the government and this is unfair to its competitors. 2) When a U.S. satellite is on Chinese territory, there would be risks of leaking sensitive technologies. China's position is that Chinese launch service is only a supplement to the international market and no threat to major players. At the same time, China would take all measures to guarantee safety of U.S. secrets. To solve the problem, the two governments had two rounds of difficult negotiations in November 1988 and January 1989 and finally signed three MOUs on technology safeguard, launch responsibility and international trade issues in January 1989. According to the agreement, China would be able to launch no more than 9 U.S. made communication satellites in the next 5 years. However the Tiananmen Square incident in June 1989 interrupted the process. After long time of hard negotiations, the Bush Administration decided to review the export license case-by-case and granted the waiver to export the Asiasat 1 on 21 December 1989, less than four months before the scheduled Asiasat 1 launch. [7]

October 1986	Caspar Weinberger, U.S. Secretary of Defense, visits China to discuss options for the use of China's rocket launchers for commercial purpose and the further liberalisation of U.S. technology transfer policies. Weinberger was shown the Xichang Satellite Launch Centre. [5]
1986	Huang Zuoyi had already studied and drafted a heavy launch vehicle, a strap-on version of CZ-2C, to launch the largest communication satellites in the market. The idea got support from many people, including Liu Jiyuan and the CALT Director Wang Yongzhi. The idea also attracted Hughes and Aussat (later Optus), the largest Australian satellite operator. In October 1986, Hughes visited China for the first time. In January 1987, the Ministry of Astronautics briefly agreed the plan to develop the CZ-2E to launch commercial payloads. [7]
05 February 1987	Liu Jiyuan went to the U.S. for signing a reservation agreement with the Hughes Corporation. The envisaged rocket would be a modified CZ-2C, which would be renamed as the CZ-2E. [2]
January 1988	Hughes won the bid of Aussat to build two HS-601 model satellites, the largest communication satellite at that time. The launch service contract with China for launching those two satellites was signed on 31 October 1988. [7]
October 1988	After the Challenger disaster, the Reagan government allowed U.S. satellite companies to buy Chinese launch service on a case-to-case waiver base. A formal agreement was signed in October 1988. That procedure continued with George H.W. Bush and Bill Clinton. Clinton even simplified the waiver-approval process. Space analyst Gregory Kulacki thinks, that the "U.S.-China collaboration in commercial satellite launches played a role in China's decision not to build a space shuttle." [4]
31 October 1988	China Great Wall Industry Co. won a contract to launch two Hughes-made satellites, Optus B1 and B2, on-board the CZ-2E until June 1990. It was a great achievement for the Chinese negotiators because when the contract was signed, all what CALT had was Huang's design and feasibility studies and the new launch vehicle was still sitting on the drawing board. The contract was also a great challenge for China. It asked for a test launch within 18 months, before 30 June 1990. If China failed to meet the schedule, the contract would be terminated and a fine of one million USD would be incurred. [7]
January 1989	A Sino-U.S.-American Memorandum of Agreement was signed which granted China the permission to launch 9 commercial satellites made in the U.S. within the next 5 years. This quota was extended to 11 satellites for the 1995-2001 time frame. One pre-condition for the permission was that China would not offer prices more than 15 % below Western rates. [1]
21 December 1989	The U.S. gave permission for the launch of Asiasat 1 in April 1990, less than four months before the scheduled launch. The Bush Administration also approves the export of two other communications satellites to be launched on Chinese launch vehicles. The U.S. also removes restrictions on U.S. Export-Import Bank financing to U.S. firms doing business with China. [1], [5]
1989	After the violent unrest during the Tiananmen events in 1989, sanctions were imposed by the U.S. to limit the transfer of space technology to China and to suspend high-level contact between officials on both sides. Bush signed an executive order, which virtually stopped all dual-use technology exports to China. And the effort to liberalise control on technology exports to China was suspended. U.S. satellites became subject to International Traffic in Arms Regulations (ITAR), making it impossible to launch Western satellites on Chinese launchers. These sanctions are still in effect. Prior to 1989, U.S.-China space cooperation was mainly focussed on export licensing of U.S. satellites. That business added to 1 billion USD in revenue for U.S. satellite manufacturers. The Office of the U.S. Trade Representative (USTR) regulated the export licenses and the number of satellites allowed to be launched on Chinese rockets. [4], [5]
12 February 1990	Asiasat 1 arrived in Xichang Satellite Launch Centre, together with the Hughes launch support team and U.S. government security guards. Asiasat 1 was guarded around the clock by a team of 18 U.S.-American security guards. [1]
07 April 1990	Launch of Hughes-built Asiasat 1 on a CZ-3. History was made when CZ-3 sent the Asiasat 1 into GTO accurately. Chinese entered the international commercial launch market. It was also the first time a recovered satellite returns to space. [1], [7]
30 April 1991	With the conclusion of the bilateral IPR negotiations, the U.S. and China extended the umbrella science and technology agreement for another five years and added a new annex with strengthened provisions on IPR protection. This extension permitted the two sides to continue cooperative activities and plan and negotiate new tasks under the existing protocols. [5]
May 1991	U.S. Government refuses to grant approval of export license for U.S. components to equip a Chinese domestic communications satellite and bars U.S. companies from participating in Chinese satellite launches. It also restricts the transfer of computer and missile technology to China. In addition, U.S. companies are barred from selling technology and equipment to the China Precision Machinery Import Export Corporation (CPMIEC) and Great Wall Industry Corporation. [5]

August 1991	Launch of Optus 1 with an U.S.-American kick motor, Star 63F. [1]
February 1992	Having received written assurances that China would adhere to the guidelines of the Missile Technology Control Regime, the U.S. Government lifts high-technology sanctions imposed against China in May 1991 for missile exports to Pakistan. [5]
13 August 1992	Launch of Hughes-built Optus B1 on CZ-2E. [1]
September 1992	China's government approved the human spaceflight programme but did not announce it to the public until 1997. [2]
21 December 1992	The Optus B2 launch ended in a launch failure. The real reason was never officially revealed. In August 1994 Optus B2 was replaced by Optus B3. [1]
August 1993	Citing evidence that 'items related to the M-11 missiles have been transferred by China to Pakistan', the Clinton Administration bans U.S. companies for 2 years from exporting items related to rockets and satellites to China or Pakistan, including a ban on dealing with 10 Chinese aerospace companies. [5]
January 1994	Clinton Administration announces that commercial satellites under Department of Commerce auspices are not subject to August 1993 restrictions and that export licenses for them could be approved. [5]
21 July 1994	Launch of Hughes-built Apstar 1 on CZ-3. [1]
27 August 1994	Launch of Hughes-built Optus B3 on CZ-2E. [1]
October 1994	The U.S. lifts August 1993 high-technology trade sanctions imposed on China for missile exports to Pakistan. In return, China pledges not to export ground-to-ground missiles featuring the primary parameters of the Missile Technology Control Regime. [5]
November 1994	Successful launch of Asiasat 2. [1]
December 1994	Successful launch of EchoStar. [1]
1994	Since the mid-1990s, U.S.-President Clinton was challenged by a hostile Congress under the lead of Republican Newt Gingrich. Republicans run a campaign to influence the course of the U.S.-China policy. It was reported that satellite manufacturers, who would gain from the use of Chinese launcher, made donations to the Democrats, while at the same time launch service providers, who would like to avoid the Chinese competition, supported the Republicans financially. [1]
1995	Negotiation with Motorola Corporation took place. Motorola booked a series of Long March 2C launches to LEO for 22 of the new Iridium global communication system of satellites. (Iridium consists in total of 66 satellites) [1]
25 January 1995	In January 1995, the fourth CZ-2E exploded after launch. The Hughes-built Apstar 2 communication satellite, launched with the Star 63F upper stage, was lost and six persons in a nearby village were killed. [1]
28 November 1995	Launch of Lockheed Martin-built Asiasat 2 on-board of CZ-2E. [1]
28 December 1995	Launch of Lockheed Martin-built Echostar on-board of CZ-2E. [1]
February 1996	Clinton Administration lifts sanctions imposed in 1989 to allow for transfer of four communications satellites from the U.S. to China. [5]
14 February 1996	The most serious accident happened when the new 3-stage CZ-3B made its maiden flight carrying an Loral-built Intelsat 708 communication satellite. Because of a malfunction of a control unit, the rocket changed its attitude from vertical to horizontal just after lift-off and hit a hill 1.85 km away. Six people, including a senior rocket engineer, were killed. Hughes and Loral workers were accused of having handed over to Chinese officials responsible for the accident investigation sensitive technical information with potential military uses. This in turn, led to an additional investigation. [7], [4]
March 1996	The Clinton Administration transfers responsibility for approving Chinese satellite launch licenses from the State Department to the Commerce Department. [5]
15 April 1996	Urged by international insurance companies, China established an independent review committee (New Decade Institute) consisting of six space experts from the United States, Germany, France and Britain, to assess the results of the failure investigation made by China, as the premise to insure the follow-up Apstar 1A launch. According to Chinese records, it was founded on 15 April and terminated on 13 May. Only two meetings, one on 22-23 April in the United States and the other on 30 April-1 May in Beijing, were held. [7]
07 July 1996	Successful launch of Apstar 1A with Long March 3. [1]

18 August 1996	In August, the CZ-3's upper stage prematurely shutdown the engine, leaving the Hughes-built Chinasat 7 (ZhongXing 7) in a lower orbit. In the period from 1992 to 1996, China successfully launched 6 commercial communication satellites. They are Optus B1 and B3, Apstar 1 and 1A, Asiasat 2 and Echostar 1. There was also progress on securing new contracts. The largest contract in this period is the Iridium launch deal that could be seen as exchange of Chinese investment into the Iridium Programme. But failures had already cast a shadow on Long March's path to the market. At least 3-4 signed contracts were cancelled. They included Echostar 2, Asiasat 3, Globalstar. [7]
19 August 1997	China resumed commercial space launches by putting the Loral-built Agila 2 communication satellite into orbit using an improved CZ-3B. [7]
28-31 August 1997	NASA astronauts Shannon Lucid and Jerry Ross visited China privately to participate in the First International Conference on Science Fiction from 28 to 31 August 1997 in Beijing. Both were part of a bigger U.S.-group consisting mainly of Sci-Fi writers. In total 2,000 people from all over the world joined the congress. Shannon Lucid was born in Shanghai and spend some of her childhood there.
01 September 1997	Demonstration launch with CZ-2C-SD from Taiyuan Satellite Launch Centre. This demonstration was a requirement from the contract with Motorola before the launch of all 12 LEO communication satellites on 6 launches would be given green light. From December 1997 to June 1999 China fulfilled its commitment for Motorola/Iridium and got a record high market share of over 10% in this period. [1]
16 October 1997	Launch of Loral-built Apstar 2R from Xichang Satellite Launch Centre with CZ-3B. The Long March 3B-version made another two successful launches in 1998, sending two domestic commercial communication satellites into orbit.
1997	U.S. satellite companies Hughes and Loral were accused of having leaked sensitive technologies to China during the CZ-2E and CZ-3B failure investigations. U.S. Justice Department begins investigating. As a consequence, Hughes and Loral were put under pressure to admit liability and had to make settlements with the Department of Defense. Hughes was then taken over by Boeing and Loral had to undergo bankruptcy measurement. Lockheed Martin was suspected to have helped China to develop the Smart Dispenser transfer stage for Iridium launches, which is considered as having military potential. [1]
March 1997	Vice President Al Gore and Premier Li Peng co-chaired the first U.S.-China Environment and Development Forum in Beijing.
May 1997	Loral applies for a waiver asking permission to launch another satellite on a Chinese rocket. The U.S. imposed sanctions on Chinese entities and persons for chemical weapons-related sales to Iran. China calls the sanctions "entirely unreasonable." [5]
1997	China did not stop in making efforts. A few contracts were signed with non-U.S. satellite manufacturers in late 1990s and early 2000s. For example, the Atlantic Bird 1 and two HKSATs, made by Europe and Israel respectively, as well as a Korean small satellite. However, because all have U.S. made components, the contracts were never executed. They were either switched to other launch providers such as Ariane or cancelled. [7]
08 December 1997	Iridium 42 and 44 launch with CZ-2C-SD from Taiyuan Satellite Launch Centre resulting from the contract with Motorola on the launch of 12 satellites on 6 launches. [1]
25 March 1998	Iridium 51 and 61 launch with CZ-2C-SD from Taiyuan Satellite Launch Centre resulting from the contract with Motorola on the launch of 12 satellites on 6 launches. [1]
02 May 1998	Iridium 69 and 71 launch with CZ-2C-SD from Taiyuan Satellite Launch Centre resulting from the contract with Motorola on the launch of 12 satellites on 6 launches. [1]
June 1998	The House of Representatives voted 409:10 to set-up a nine-person special committee to investigate the transfer of space technology to China and appointed as Chairperson Californian Republican Christopher Cox. Concerns about China having taken advantage of its contracts with the U.S.-American space industry to acquire information useful for the construction and targeting of ballistic missiles. Hughes satellites used advanced technology arrays that could be used for electronic signals gathering – perceived as a high risk to technology transfer. Additionally, satellite companies were accused of insufficiently protecting their satellites during transit to the launch pad. [1]
19 August 1998	Iridium 3 and 76 launch with CZ-2C-SD from Taiyuan Satellite Launch Centre resulting from the contract with Motorola on the launch of 12 satellites on 6 launches. [1]
20 December 1998	Iridium 11A and 20A launch with CZ-2C-SD from Taiyuan Satellite Launch Centre resulting from the contract with Motorola on the launch of 12 satellites on 6 launches. [1]

1998	The Clinton Administration approves another Loral satellite launch waiver. [5] Congress launched an investigation against President Clinton to investigate whether he was selling space technology to the Chinese military in exchange for campaign contributions. Administration officials admitted that Clinton's waivers were politically motivated and intended to be an incentive for China for not to trading missile technology to Iran and Syria. No charges were filed.
1999	The Cox Commission named after chairman Christopher Cox (Republican, California) report was published. The language in the report was heavily relying on the "dual-use" argument. It put an end to commercial cooperation in space, including agreements to launch U.S. satellites on Chinese rockets. The 1989 Tiananmen Sanctions originally banned these launches, approved during the Reagan Administration, but Presidents Bush and Clinton both granted waivers to U.S. satellite manufacturers seeking to take advantage of available Chinese launch services. The Cox Report ended the satellite launches and led to tighter restrictions on all scientific and technical cooperation with China. U.S.-made satellites and satellites with U.S.-made components becomes impossible to be launched by any Chinese launch vehicles. George W. Bush did not challenge these restrictions. Chinese revenues from launching satellites fell from 148 Mio USD in 1997 to 23 Mio USD in 1999 to nil in the years 2000-2005. The global market by that time was estimated to be worth between 1 to 2,7 Billion USD.
April 1999	Vice President Al Gore and Premier Zhu Rongji co-chaired the second U.S. China Environment and Development Forum in Washington.
11 June 1999	Iridium 14A and 21A launch with CZ-2C-SD from Taiyuan Satellite Launch Centre resulting from the contract with Motorola on the launch of 12 satellites on 6 launches.
1999	The Motorola Iridium project went into bankruptcy – the Iridium fleet (including the Chinese-launched satellites) were taken over by the Department of Defense for its military communication network.
200?	The U.S. pressured Europe to limit Chinese participation in the Galileo project, the European version of a Global Positioning System. China began building its own system.
2000	The China Sanction Act of 2000 severely limits U.S.-China interactions, while a 2011 defence appropriations measure added additional restrictions, including barring NASA from using funds to host visits from official Chinese delegations.
After 2000	Facing an unfavourable market environment, China changed its strategy after 2000. The first move was to switch to European satellite manufacturers. But removal of all U.S. components from a high performance communication satellite turned out to be a difficult decision to all satellite operators, unless it has to be launched in China. As a result, the strategy is only partially successful.
August 2002	Problems with obtaining U.S. visas have become a serious obstacle to U.S.-China cooperation in science and technology. Starting in August 2002, almost every visa applicant from a non-waiver country - including China, India, and six other top suppliers of international students to the U.S.- must be interviewed by a U.S. consular official. On 23 August 2002, organisers of the IAC protested about the treatment of dozens of Chinese scientists and engineers.
10-19 October 2002	53rd International Astronautical Congress, Houston, Texas, U.S.A. All but two of the seventy Chinese delegates were denied visas for the congress, which was held in Houston. The Head of the Chinese Delegation, Luan Enjie, stranded on the Canadian border and was left waiting for his visa. He finally returned home without participation in the congress. Those few who attended were searched or followed by FBI agents. The delegates and conference organisers only learned of the decision at the last minute, leading to the sudden withdrawal of most of the Chinese papers. [1]
2003	China publicly asked to join the ISS programme. Over time, China repeated its wish for being part of the project but the main refusal came from political circles in the U.S.
2004	Yang Liwei visits the U.S. as a private guest. No formal contact with NASA. [1]
12 April 2005	China launched the first ITAR-free/ITAR-compliant satellite, Apstar 6, from Xichang Satellite Launch Centre on-board CZ-3B. Apstar 6 was built by Alcatel, now Thales Alenia (TAS) and owned by the Hong Kong-based APT communications. This historical event marked China's return to the commercial launcher market after seven years. Following the Apstar 6, the domestic operator Chinasat signed two contracts with Alcatel to manufacture Chinasat 9 and Chinasat 6B. They were launched by the CZ-3B in 2007 and 2008. [1]
2005	Mae Jemison, NASA astronaut on STS-47 mission in 1992 and now Principal of the 100 Year Starship organisation, tours China and the Chinese space agency.
2006	China Great Wall Industry was sanctioned for supplying equipment to Iran. The assets of CGWI were frozen by the U.S. federal government and the company was forbidden to do business with U.S.-American companies. These sanctions were lifted in summer 2008. China had to make commitments to monitoring its trading activities and not to have dealings with countries considered to be proliferation risks to the U.S., like Iran. [1]

2006	Just before China entered the second phase of its space station plan, then-Director of the Chinese National Space Agency (CNSA), Sun Laiyan, told reporters that China might not need to construct and operate its own space station if China were allowed to join the ISS project. At the time, NASA Administrator Michael Griffin was preparing to visit China for talks.
September 2006	NASA Administrator Michael Griffin led NASA's first high-level delegation to China consisting of 6 persons, including William Gerstenmaier, Head of Space Operations and NASA astronaut and Shanghai-born Shannon Lucid. The Delegation spend five days in Beijing and Shanghai, visiting: Chinese Academy of Space Technology (CAST); the Beijing National Satellite Meteorological Centre; Academy of Sciences' Technical and Physical Research Institute (inspecting Chang'e instruments). The White House and U.S. State Department permitted the visit on the grounds that it did not include talks about manned spaceflight or participation in the ISS and was focused on scientific cooperation. Still, critics from Congress said that the delegation was visiting an enemy. The only concrete result was an agreement to meet once a year and on data sharing from the LRO and Chang'e lunar mission. A second meeting on Deputy Director level in July 2008 established a working group on Earth science. In September 2013, Michael Griffin comments about this historical visit in SpaceNews: "My thought back then is the same as it is now. The Chinese are obviously intending to have a fully loaded space program. … But - and this is a key 'but' - China will not cooperate with us because they think we're such good guys. They will want to do so if, and only if, we have a space program sufficiently grand in its scope and goals that it is clearly in their interest to work with us. Right now, we have little to offer. ... We have no sensible overarching civil space policy, no grand goals, no compelling plans. Why would they want to work with us?" … "I do understand the national security concerns about giving away technology. However, I think 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. It is never wrong for the U.S. to try to figure out ways to engage with other societies, whether or not they are friends or adversaries. If you are talking, you are not fighting." [1], [spacenews.com]
2007	U.S. rejects a request by China to help out with the U.S. deep-space communications network on the Chang'e lunar mission.
January 2007	China successfully destroys one of its own decommissioned weather satellite. This tests of anti-satellite weaponry made China immediately the third biggest creator of space debris.
2007	Chi Mak, a Chinese living and working in Southern California was convicted of conspiracy to export U.S. defence technology to China and sentenced to 24 ½ years in prison.
05 July 2007	Launch of ITAR-free TAS-built Zhongxing 6B with CZ-3B. [1]
16 October 2007	China hopes to become the 17th nation joining the International Space Station (ISS) project, Vice Minister of Science and Technology Li Xueyong said. "China sincerely wants to cooperate with the United States in space exploration and join the International Space Station project that has already involved 16 nations," said Li, as a delegate to the 17th National Congress of the Communist Party of China (CPC), on the sidelines of the event.
2008	After the successful launch of Zhongxing 6B, the U.S. Congress introduced budget amendments to punish any European or other country having any dealings with China. [1]
09 June 2008	Launch of ITAR-free TAS-built Zhongxing 9 with CZ-3B. [1]
29 September 2008	The Congressional Research Service publishes the report: China's Space Program: Options for U.S.-China Cooperation
2008	A second meeting, following the visit of the NASA delegation under Administrator Griffin in 2006 was conducted on Deputy Director level in July 2008. A working group on Earth science was established. [1]
2009	A small group from the Astronaut Centre of China (ACC) including its Director paid a visit to NASA's Johnson Space Centre. The delegation watched in the Mission Control Centre a life-transmission from a Space Shuttle mission where the crew performed spacewalk repair work on the Hubble Space Telescope and real-time operations aboard the International Space Station. [6]
Spring 2009	Eutelsat announced it would launch its next satellite, the ITAR-free Eutelsat W3C on a Long March rocket. (launched successfully on 11 October 2011) U.S.-Congressman Dana Rohrbacher (California) threatened sanctions against Eutelsat. Arianespace Chairman and CEO Jean-Yves LeGall said after that announcement to AFP: The choice of China "leaves us extremely perplexed". Eutelsat's decision to let China launch its satellite could be interpreted as being "hostile to the United States." he said. "We are shocked that it has been put in place." [1]

17 July 2009	74-years-old and seriously ill Dongfan “Greg” Chung, a Boeing stress analyst with high-level security clearance, was convicted in the United States’ first economic espionage trial of six counts of economic espionage and other federal charges for storing 300,000 pages of sensitive papers in his home in Southern California. Prosecutors alleged the papers included information about the U.S. space shuttle, a booster rocket and military troop transports. U.S. District Judge Cormac J. Carney said he didn’t know exactly what information Chung had passed to China over a 30-year period but sentenced him to more than 15 years in prison. [1]
31 August 2009	Launch of ITAR-free TAS-built Palapa D with CZ-3B. [1]
22 September 2009	Organised by the U.S. Space Foundation, NASA astronauts Fred Gregory and Tom Hendricks visited China. They could watch taikonauts Yang Liwei and Zhai Zhigang during training and visited CAST to see the Tiangong space lab, Shenzhou 8 and Chang’e 2. [1]
15-18 November 2009	During U.S. President Barack Obama’s first visit to China he met with Hu Jintao. Both leaders of state signed an official U.S.-China Joint Statement on 17 November 2009: “The United States and China look forward to expanding discussions on space science cooperation and starting a dialogue on human space flight and space exploration, based on the principles of transparency, reciprocity and mutual benefit. Both sides welcome reciprocal visits of the NASA Administrator and the appropriate Chinese counterpart in 2010.” A high-level forum, the U.S.-China Strategic and Economic Dialogue, was established. [spacenews.com], [4]
15 October 2010	Three Republicans, John Culberston, R-Texas, Robert Aderholt, R-Alabama, and Dana Rohrabacher, R-California, joined Republican Frank Wolf in a letter to NASA Administrator Charles Bolden, requesting a full briefing on his visit to China upon return to the U.S. They criticised Boldens efforts and a potential Chinese delegation’s visit to the U.S. The four lawmakers demanded assurances that there are no plans for human spaceflight collaboration. Another letter to Bolden from two Democrats and a Republican lawmaker urged the Administrator to consider a common docking interface for a joint rescue capabilities for U.S., Russian and Chinese space crews. Bill Gerstenmaier, NASA's Associate Administrator for space operations, mentioned the docking interface responding to a question on the outcome of Bolden's visit to China. "We didn't specify a docking design, but we specified an interface that if you could meet this interface you could potentially dock to space station in the future," Gerstenmaier said. [spaceflightnow.com]
End October 2010	NASA Administrator Bolden lead a NASA Delegation on a visit to China. The group included Peggy Whitson, Head of NASA Astronaut Office, and Bill Gerstenmaier. The delegation visited China’s space port for all manned launches in the Gobi Desert, the Jiuquan Satellite Launch Centre (JSLC) facilities and its control centre. “I am pleased that NASA was able to meet its objectives for the visit, which included becoming acquainted with relevant Chinese space officials and institutions, better understanding Chinese human spaceflight programs and plans, and reaching a common understanding of the importance of transparency, reciprocity and mutual benefit as the underlying principles of any future interaction between our two nations in the area of human spaceflight,” Bolden said in a written statement.
16 November 2010	During an address to the staff at one of NASA’s main manned spaceflight facilities, the Marshall Space Flight Center in Huntsville, Alabama, Administrator Bolden spoke about his recent visit to China: ”But I happen to be one who kind of every once in a while just wonders about what things could be like if we were able to bring more countries into the partnership.” Regarding the human space flight programme he said: “So it’s a different environment than what we’re accustomed to. The People’s Army runs everything. That’s just the way it is.” Bolden said, he explained to his Chinese counterparts, that a possible cooperation needed to be linked to certain principles and would have to be carried out for mutual benefit. Bolden concluded with an interesting anecdote: “My final night there, I met with the big head of their human space flight program who ironically is also head of their anti-satellite program. An odd mix of responsibility. He is a Three-Star, a Lieutenant General in the People’s Liberation Army, Air Force or something. And he started out the conversation. He introduced the conversation and he said they’re going to be very candid. We don’t need you. We don’t need the United States, and you don’t need us. But the potential, if we choose to work together, is incredible. I thought that spoke volumes.”
2010	Organised by the American Institute of Aeronautics and Astronautics, an U.S. industry delegation followed after Bolden’s visit. [1]
2009/2010/2011	Presidential Science Adviser and Office of Science and Technology Policy (OSTP) Director John Holdren travelled three times to China within the time period 2009-2011. He discussed U.S.-Chinese scientific and technical cooperation in many areas, including space science and exploration. No concrete programmes emerged from these contacts. A second joint statement was signed in January 2011, committing the two countries to “deepen dialogue and exchanges in the field of space” and to “continue discussions on opportunities for practical future cooperation in the space arena, based on principles of transparency, reciprocity, and mutual benefit”. [4]

15 April 2011	Republican Representative Frank Wolf inserted language into a continuing resolution to fund the U.S. government in April 2011 that forbids NASA "to develop, design, plan, promulgate, implement, or execute a bilateral policy, program, order, or contract of any kind to participate, collaborate, or coordinate bilaterally in any way with China." Wolf chairs the Commerce, Justice and Science Sub-Committee of the House Appropriations Committee, which funds NASA. Frank Wolf's Chief of Staff said NASA Administrator Charles Bolden's visit to China in October 2010 prompted his boss to impose the ban. Bolden neglected to consult with Wolf prior to his visit, as former NASA Administrator Michael Griffin did four years earlier. This upset the Virginia congressman, who is wary of any contact between NASA and its counterparts in China: "We don't want to give them the opportunity to take advantage of our technology, and we have nothing to gain from dealing with them.", he was quoted. The "Wolf Clause" was signed into law by U.S. President Barack Obama. When Obama did so, he compromised to the Republicans to avoid possible bankruptcy and consequently government shutdown.
April 2011	Lei Fanpei, Vice President of China Aerospace Science and Technology Corp. (CASC) participates in U.S. National Space Symposium. He appealed to the U.S. government to lift its ban on space cooperation with China.
May 2011	Third round of China-U.S. Strategic and Economic Dialogue (S & EC) held in Washington. The two sides published accomplishments of the dialogue, which includes cooperation in science and technology.
May 2011	The Secure World Foundation and Chinese Academy of Science hold a joint conference on Asian space policies.
16 May 2011	Chinese journalists were denied access to a NASA facility for reporting on the launch of STS-134 with the Alpha Magnetic Spectrometer - AMS. China contributed the superconducting magnets for AMS. NASA revoked the media passes granted to journalists from China due to the "Wolf Clause" which was signed into law by Obama one month earlier.
Summer 2011	The Obama Administration sent proposals to the Congress for a unified licensing regime to operate through the Department of Commerce – one that would include commercial satellites and ultimately make it easier for satellites to fly on Chinese launchers.
07 October 2011	China launched Eutelsat's ITAR-free Eutelsat W3C on a Long March CZ-3B rocket.
December 2011	For the first time since China launched its first satellite China surpassed the U.S. in the number of space launches.
20 December 2011	Ileana Ros-Lehtinen, Chairwoman of the U.S. House of Representatives' Foreign Affairs Committee, and two fellow senior Republican lawmakers send a letter to Secretary of State Hillary Clinton to ask for clarification on "unrestricted" satellites sold by Thales Alenia Space for launch on Chinese rockets.
2011	The Obama Administration found ways to circumnavigate the "Wolf Clause". U.S. President Barack Obama declared all bilateral scientific activities with China as being part of his Foreign Policy.
January 2012	The State Department quietly warned Thales Alenia Space (TAS), a joint venture of France's Thales Group, which owns 67 %, and Italy's Finmeccanica SpA Group, owning 33 %, that export licenses needed by its U.S. suppliers might be denied, absent greater cooperation in an investigation of a matter, that satellites sold by the manufacturer to China are not free of license-requiring U.S. parts, and that TAS illegally exported it to China. TAS advertises its Spacebus 4000C2 as the first Western commercial communications satellite without any part subject to U.S. control. The company confirmed it has sold eight such "unrestricted" satellites to international customers, five of them already launched by China with the other three to follow. Export denials to a rival could be a boost to U.S. manufacturers such as Lockheed Martin, Boeing, Orbital Sciences and Space Systems/Loral, a unit of Loral Space & Communications, that have lost as much as half their global satellite market share in recent years. The U.S. share of global satellite exports has dropped from about 75 % in 1995 to between 35 % and 50 % in the past seven years. [Reuters]
31 March 2012	Launch of ITAR-free TAS-built Apstar 7 with CZ-3B. [1]
July 2012	According to the "Asian Scientist Magazine" U.S. and Chinese scientists discussed space collaboration during a session behind closed doors at the sidelines of the annual COSPAR Scientific Assembly 2012 in Mysore, India taking place from 14-22 July 2012. It seemed to be an attempt to explore ways of collaborating in the field of space science and technology (COSPAR = Committee on Space Research).
04 September 2012	The International Lunar Observatory Association (ILOA) of Kamuela, Hawaii has signed in Kamuela a Memorandum of Understanding with the Beijing-based National Astronomical Observatories of China (NAOC) of the Chinese Academy of Sciences. The ILOA has Memoranda of Understanding with China National Space Administration (CNSA) and the NAOC to exchange observation time between China's Lunar near-Ultraviolet Telescope (LUT) aboard Chang'e-3 and the ILO-X Precursor and ILO-1 Moon South Pole missions currently in development for launch in 2015-2016. The deal is the first such U.S.-China collaboration centered on using China's Chang'e-3 Moon lander. [ILOA]

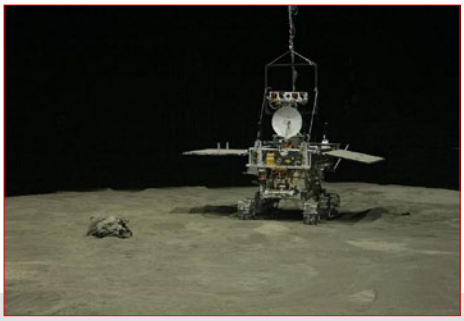
February 2013	Republican Congressman Frank Wolf, Chairman of the House Science, Space and Technology Committee, Republican Lamar Smith, and Senate Judiciary Committee Ranking Minority Member Senator Chuck Grassley, requested clarification if there was political influence on a decision to terminate a federal probe into the activities of foreign nationals working at NASA's Ames Research Center. The probe was aimed at determining if any of those nationals or others at NASA Ames may have given space defense technology to China. U.S. President Obama issued a report on commercial espionage in January 2013 that described Chinese interest in "unmanned aerial vehicles, and other aerospace/aeronautics technologies." Wolf severely criticised the leadership at NASA Ames for allowing young Chinese engineers to attend a session of the International Space University held at the Ames facility in 2009.
March 2013	A Chinese delegation of Earth science specialists intended to participate from 12-14 March in a meeting of the Committee on Earth Observation Satellites (CEOS) Strategic Implementation Team at NASA Langley. Republican Frank Wolf interfered by stating that NASA officials violate federal law if they host Chinese government officials. That reminder to NASA that federal law bars hosting of Chinese officials at NASA's Langley Research Center was a consequence of recent congressional worries why a federal investigation into national security leaks to the Chinese government was shut down. In a letter to NASA Administrator Charles Bolden, Wolf said "I am writing to remind you that the hosting of official Chinese visitors at facilities belonging to or utilized by NASA is prohibited ... except in cases where NASA has provided appropriate certifications to the committees on Appropriation of the House of Representatives and the Senate no later than 14 days prior to the visit." [permanent.com]
08 March 2013	Frank Wolf set-up a press conference. He called for NASA to immediately shut down the NASA's Technical Reports Server NTRS because it allegedly contains sensitive information which would give China and other national adversaries technologies they could use against the U.S. At the same time, Wolf cited an unnamed Chinese national (on 13 March identified as Bo Jiang) who worked at the NASA Langley Research Center, "who was allegedly provided access and information he should have otherwise been restricted from receiving" and that: "It is my understanding that this Chinese national is affiliated with an institution in China that has been designated as an 'entity of concern' by other U.S.-government agencies." [permanent.com]
16 March 2013	FBI arrested the 31-year-old former NASA contractor Bo Jiang while boarding a flight to China from Washington's Dulles International Airport where he was on transit. Bo, a Chinese national was never charged with spying before. FBI said he lied to understate the total amount of data storage and number of laptops he was taking back to China, which became the grounds for his detention. Whether or not he lied is open to interpretation. He was later cleared when officials failed to find sensitive information on his laptop, just pornography he had downloaded in violation of agency rules. [permanent.com]
19 March 2013	NASA Administrator Charles Bolden was quoted by saying about NASA: "We're the only agency of the federal government that does not have bilateral relations with China..."
20 March 2013	In hearings before the Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies Charles Bolden announced: "I have ordered a moratorium on granting any new access to NASA facilities to individuals from specific designated countries. Specifically: China, Burma, Eritrea, Iran, North Korea, Saudi Arabia, Sudan and Uzbekistan. While this review is on-going I have also ordered that any remote computer access to NASA resources be terminated for those from the same specific designated countries." In addition, Bolden announced that on-site access to NASA facilities was also being limited or curtailed for citizens of these countries.
25 April 2013	During a House Armed Services Committee hearing, the Chairman of the panel that oversees space programmes, Representative Mike Rogers of Alabama questioned Pentagon spokeswoman Lieutenant Colonel Monica Matoush about the Pentagon lease of China's Apstar 7 satellite for its U.S. Africa Command, already requested in May 2012. Matoush explained that Apstar 7 provides "unique bandwidth and geographic requirements" for "wider geographic coverage". Apstar 7 is operated by APT Satellite Holdings Ltd. The state-owned China Aerospace Science & Technology Corp. holds 61 % of Hong Kong-based APT, according to data compiled by Bloomberg. [Businessweek]
07-08 June 2013	A historic 2-day summit between Chinese President Xi Jinping and U.S. President Barack Obama takes place in Annenberg at the Sunnylands resort. The two leaders reach consensus on building a new type of major country relationship characterised by no conflict, no confrontation, mutual respect and win-win cooperation. There was no mention of discussions on space matters. Xi, who declared the summit "a new historical starting point" after China and the United States reopened diplomatic relations 40 years ago, spoke of his country as a global superpower now on par with the United States. "How can our two nations join together to promote peace and development in the world?" Xi asked. [Xinhua]
13 June 2013	Barbara Morgan, first teacher in space during STS-118 mission in August 2007 sends a letter with greetings and wishes to Wang Yaping, who gave a space lesson to 60 Mio Chinese students during her Shenzhou 10 mission on-board Tiangong 1.

July 2013	Chinese Vice Premier Wang Yang and State Councilor Yang Jiechi co-chaired with U.S. Treasury Secretary Jacob Lew and U.S. Secretary of State John Kerry in Washington the fifth round of Strategic and Economic Dialogue (S&ED). [Xinhua]
16-20 September 2013	During the United Nations-China-IAA Workshop on Human Space Technology, Franklin Chang-Diaz is presenting his VASIMIR invention, a plasma rocket concept. Chinese experts were showing interest in a test of this propulsion system on the Chinese Space Station.
23-27 September 2013	NASA Administrator Charles Bolden attended the 64th International Astronautical Congress (IAC) from 23-27 September. On the sidelines of the IAC, Bolden hold a private meeting with Bai Chunli, President of the Chinese Academy of Science (CAS) on 25 September 2013. According to a statement by CAS, they “exchanged frank opinions on pragmatic cooperation in relevant fields in the future”. NASA and CAS also agreed to participate in a multi-national effort to monitor the glacial movement in the Himalayas. [4] NASA astronauts Leroy Chiao and Sandra Magnus are also taking part in the IAC 2013. Sandra Magnus, together with Liu Yang, had an astronaut appearance at Beihang University in Beijing. Sandra Magnus commented on that event one day later: “We had a wonderful time sharing our experiences. I had an opportunity to spent more time with Liu Yang at the Beihang University. We spend a few hours talking with students and sharing our stories. It was a real delight and I know we look forward to interacting more in the future.”
October 2013	A letter from Frank Wolf to Charles Bolden reads: “Dear Administrator Bolden, Earlier this year, I invited you to meet with an impressive group of Chinese human rights activists in my office. I appreciated your willingness to sit with them and hear their stories. As you witnessed, to a person, each loved their country and were rightly proud of their heritage. But all sought fundamental change. They longed to live in a land where they could worship freely, speak openly and enjoy the basic protections of a constitution grounded in rule of law. …” Wolf added, following the rejection of admission for the Chinese participants to the Kepler conference: "I believe the center has become a rat's nest of inappropriate and possibly illegal activities that appear to have occurred with the concurrence of the center's leadership." … "Nonetheless, it appears that federal law enforcement felt there was a solid case against certain Ames staff members involving export violations. Yet there has been no accountability at Ames for these alleged criminal violations. This is inexcusable."
November 2013	Administrator Charles Bolden told an audience at Gettysburg College that NASA is resuming cooperation with China on space geodesy. NASA and China signed a cooperative agreement on space geodesy in 1997 and renewed it in 2010. Activities under that agreement were suspended after Congressman Frank Wolf included the “Wolf Clause” into language to a continuing resolution to fund the U.S. government in April 2011.
November 2013	NASA officials denied six Chinese scientists permission to attend the Kepler Science Conference at the NASA Ames Research Center. The denial was based on their interpretation of the intent of the language in Wolf’s law which prohibits Chinese nationals to enter NASA facilities. Two leading U.S. space scientists scheduled to participate in the Kepler Science Conference, Geoff Marcy, an astronomy professor at the University of California, Berkeley, and Debra Fischer, professor of astronomy at Yale University, decided to boycott the conference to protest NASA’s decision to deny invitations to Chinese applicants. Marcy is reported to have called the ban on Chinese scientists “completely shameful and unethical.” Other international participants in the conference supported the call for a boycott if the Chinese were not admitted. NASA than extended an invitation for the Chinese applicants to re-apply and finally, access was granted.
December 2013	U.S. Vice President Joe Biden concluded a two-day official visit to China in early December capping a fruitful year of high-level exchanges and dialogues, whose frequency and achievements were rarely seen in the past decades. [Xinhua]
December 2013	The Lunar Exploration Analysis Group (LEAG) is taking China’s Chang’e 3 robotic landing on the Moon as the starting point for organising a letter writing campaign “Destination Moon” to Congress to underscore the importance of the Moon. LEAG is assisting NASA in the planning of the scientific lunar exploration. “We were waiting to see if Chang’e 3 landed successfully and it did! Now we want to champion the moon from the U.S. side,” Clive Neal, a leading lunar scientist at the University of Notre Dame’s Department of Civil and Environmental Engineering and Earth Sciences and a member of LEAG’s executive committee told space.com. [space.com]

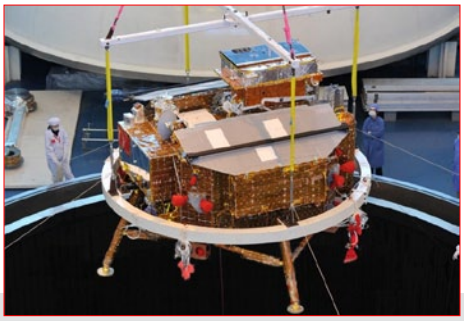
19 December 2013	Republican lawmaker Frank Wolf wrote a letter to President Barack Obama to organise a White House conference early in 2014 to develop a mission concept for a U.S.-led return to the Moon within the next 10 years. “As China prepares to send a series of increasingly advanced rovers to the moon in preparation for what most observers believe will ultimately be human missions, many are asking why the U.S. is not using this opportunity to lead our international partners in an American-led return to the moon,” Wolf said. In his lengthy letter, he urges Obama to direct the U.S. space programme toward a “lunar-focused human exploration program that will reaffirm America’s space leadership for the 21st Century.” [space.com]
09 January 2014	A big Chinese Delegation participates in International Space Exploration Forum – ISEF in Washington DC. The Head of Delegation, Xu Dazhe gave three talks during the one-day conference behind closed doors.
February 2014	Virgin Galactic excludes Chinese nationals (as well as North Koreans and Iranians) from sub-orbital flights offered by the Virgin Space company because of fears of spying.

Gallery

Chang'e 3 and Yutu



Yutu in indoor field-testing. It was suspended to simulate lunar gravity. (credit: Xinhua)



Chang'e 3 was placed into the KM-6 thermal vacuum chamber for testing. (credit: China Space News)

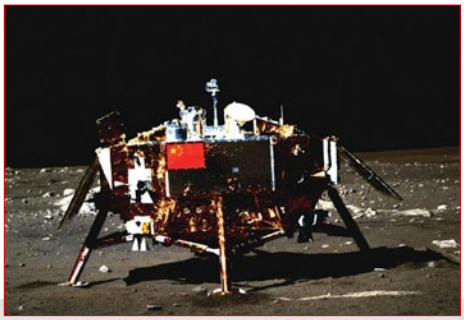
The Long March 3B lifted-off at 1:30 on 2 December 2013, sending Chang'e 3 into a direct trans-lunar orbit. (credit: Xinhua)

An image taken by the descent camera before landing. When it was taken, Chang'e 3 was about 99 m above lunar surface. (credit: CLEP/CAS)

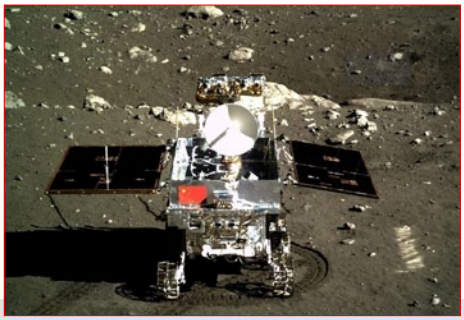
Lunar landscape around the landing site. The image, at 5:54 on 15 December 2013, was the first image taken by the topographic camera on the lander after the lunar-landing. (credit: CLEP/CAS)

The Lander seen from Point A. The picture was taken by the panoramic camera on the rover between 20:44 to 20:52 on 15 December 2013. (credit: CLEP/CAS)

The lander seen from Point B. The picture was taken by the panoramic camera on the rover between 3:43 to 3:50 on 16 December 2013. (credit: CLEP/CAS)

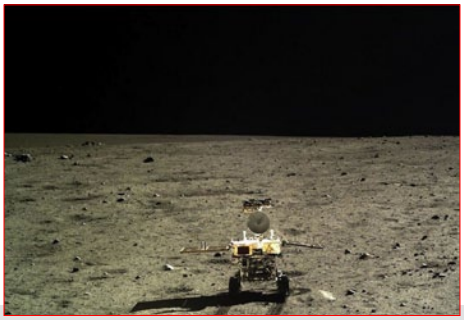


The lander seen from Point D. The picture was taken by the panoramic camera on the rover at 6:50 on 22 December 2013. (credit: CLEP/CAS)

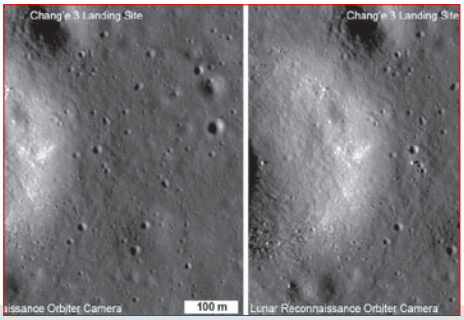


Yutu on the lunar surface. The picture was taken by the topographic camera on the lander at 23:41 on 15 December 2013, after it made a U-turn near Point A. (credit: CLEP/CAS)

Yutu on the lunar surface. The picture was taken by the topographic camera on the lander at 4:57 on 16 December 2013. The rover's location is near Point B. (credit: CLEP/CAS)



Yutu on the lunar surface. The picture was taken by the topographic camera on the lander at 2:48 on 22 December 2013. The rover's location is near Point D. (credit: CLEP/CAS)



Images captured by LRO showing Chang'e 3 and its rover. The left image was captured on 30 June 2013, while the right one was captured 03:52:49 UT on 25 December 2013. The Chang'e 3 lander (big white dot with shadow) and the rover (smaller white dot below the former) can be seen at center of the image. (credit: NASA)