All About The Chinese Space Programme

GO TAIKONAUTS!

龙腾太空

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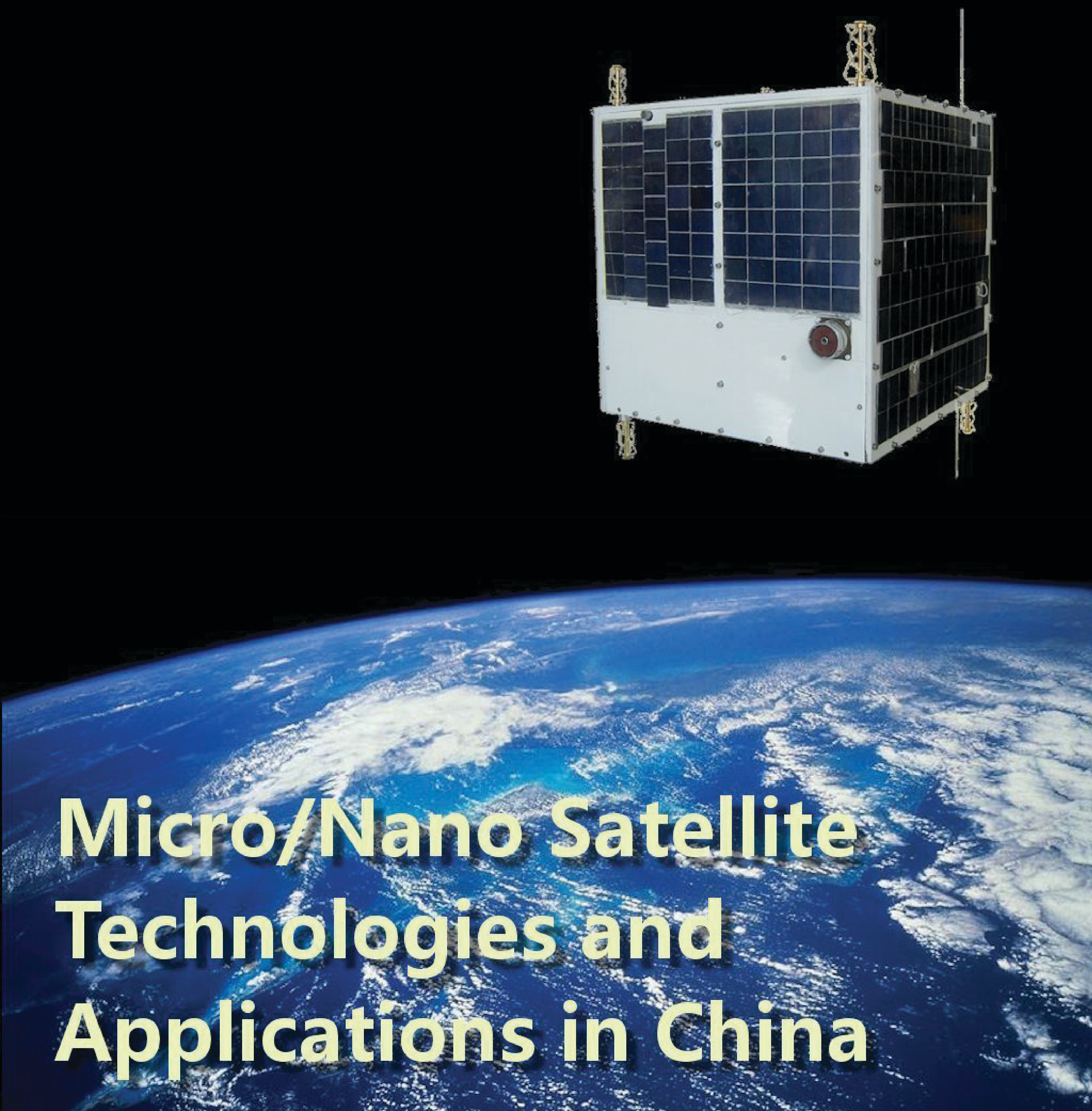

Micro/Nano Satellite Technologies and Applications in China

Editor's Note

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Quarterly Report

October - December 2014

Launch Events

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• On 20 October, at 14:31, a CZ-4C lifted off from Taiyuan Satellite Centre and put ... page 3

Quarterly Report

January - March 2015

Launch Events

On the second last day of this quarter, China made its first space launch in 2015, again showing that the first quarter is off-season for the Chinese space programne. On 30 March, at 21:52, a CZ-3C rocket lifted off from the Pad 2, Xichang Satellite Launch Centre, sending the first test satellite ... page 10

Micro/Nano Satellite Technologies and Applications in China

Micro/nano satellite technologies are becoming more and more active in China, from universities to research institute and industries, from scientific research to technology demonstration and to practical applications. Some launched project examples are: Chuangxin-1 (CX-1), the first Chinese micro satellite used for telecommunication built in Shanghai; Naxing-1, the first nano satellite built by a Chinese university in Beijing; Banxing-1 (BX-1), a micro satellite used to provide in-orbit images of the SZ-7 orbit module to inspect the space module and to conduct in-orbit proximity operations, built in Shanghai as well; ZDPS-1A, the first pico satellite at kilogram level built by a Chinese university in Hangzhou; Tianxun-1 (TX-1), a micro satellite for Earth observation built by a university in Nanjing; Tiantuo-1, another nano satellite at kilogram level built by university students in Changsha, etc. ... page 15

Feature

Europe and China Join Space Science Expertise

The city of Liège (Belgium) welcomed the 11th edition of the ESWW (European Space Weather Week) from 17 to 21 November 2014. This annual event is organised by the Royal Observatory of Belgium, through the STCE (Solar-Terrestrial Centre of Excellence). Some 400 delegates of the community concerned by the aspects and effects of Sun-Earth interactions contributed to the success of this mainly scientific ... page 24

Sideline

Alexey Leonov: "I think China will be the second nation to land on the Moon."

On 18 March 2015, the world space community celebrated the 50th anniversary of the first space-walk in the history of mankind. In 1965, Soviet cosmonaut Alexey Leonov was floating in open space and stayed for 12 min 9 sec outside his Voshkod 2 spacecraft while his crewmate Pavel Belyayev was waiting for him inside. The Fédération Aéronautique Internationale - FAI (World Air Sports Federation) as the world governing body for air sports, aeronautics and astronautics world records, recognised Leonov's performance as a world record in the discipline "Extravehicular duration in space". On the occasion of the 50th anniversary, FAI published an interview with Alexey Leonov on its web ... page 26

Editor's Note

Finally, we did it without major delay! You may have noticed that the number of articles is less than that in previous issues and the length of some articles is also much shorter this time. Yes, it is a compromise we have to make to keep our work more sustainable. As all Go Taikonauts! members work on this publication in their spare time, it is probably the best way to keep the publishing frequency and at the same time deliver content with same good quality. We hope to get your understanding for this!

The cover story of this issue is on China's micro/nano satellites. Actually, it was a paper by Dr. Wu Shufan presented at the IAC (International Astronautical Congress) 2013. Although it was published more than one year ago, it is still the most comprehensive summary on China's micro/nano satellites. Dr. Wu is a renowned engineer in the Shanghai Engineering Center for Microsatellites (SECM), that has become the third largest satellite developer in China just after CAST and SAST. For example, the recently launched test satellite of the new generation Beidou global constellation is from SECM. We would like to thank Dr. Wu for his permission to publish his article in Go Taikonauts!

Europe has become an important partner in space for China. After the successful DoubleStar mission and the unsuccessful cooperation in the Galileo project, China and Europe are now engaged in a new space science mission. Theo Pirard and Jacqueline Myrrhe give an overview of one of the proposals - the INSTANT mission, in this issue. We hope that lessons learnt from previous cooperation will be helpful to ensure its success.

There is a very short article in this issue, labelled as "Sideline". It is an interesting comment by Alexey Leonov, the first space walker, on the Chinese space programme. Publishing it, does not mean Go Taikonauts! agrees with his point of view, but we want to provide diversified views. We will continue to publish more of such kind of short pieces in future issues.

(Chen Lan)

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Chinese Space Quarterly Report

October - December 2014

by Chen Lan

Highlights

- Kuaizhou launched again, variant Feitian 1 (FT-1) announced.
- Maiden launch schedule of CZ-5, 6, 7 updated, timetable of CZ-9 revealed.
- Tiangong 2 and cargo vehicle Tianzhou made progress, extensive testing on-going.
- Development of new manned spaceship kicked off, air-drop test in preparation.
- Chang'e 5-T1 circumlunar mission successful, high-speed skip re-entry tested.
- Chinese Mars and asteroid missions emerge with more evidence.
- China tests recovery system for fly-back rocket boosters.
- CAST develops air-breathing Helicon plasma thruster, aiming for Mars missions.
- China and Russia to cooperate on space stations.
- China and ESA sign agreement on human space flight.

Launch Event

The last quarter of 2014 was the busiest quarter in Chinese space history. China made 10 successful space launches in three months, setting a new national record for a quarterly launch rate:

- On 20 October, at 14:31, a CZ-4C lifted-off from Taiyuan Satellite Centre and put the YG-22 into orbit.
- On 24 October, at 2:00, Chang'e 5-T1, the most dramatic Chinese space mission in 2014, started when a CZ-3C/G2, an enhanced model with stretched core and boosters, took off from Xichang. The spacecraft flew by the Moon on 28 October and landed intact in north China on 1 November (see cover story of GoTaikonauts!, Issue 14 for details).
- On 27 October, at 14:59, SJ-11-08 was successfully launched by a CZ-2C from Jiuquan Satellite Launch Centre. It was said to be the last one in the SJ-11 series.
- On 15 November, at 2:53, in Taiyuan Satellite Launch Centre, a CZ-2C soared into the dark sky, putting the YG-23 into space.
- On 20 November, at 15:12, another YG series Earth observation satellite, YG-24, was successfully launched. This time, it was by a CZ-2D from Jiuquan.
- On 21 November, at 14:37, the Kuaizhou 1 small launcher made its second successful launch and sent the KZ-2, an integrated upper stage-satellite combination into orbit. Similar to the first launch in 2013, its launch pad is believed to be to the east of the CZ-2F and CZ-2D/4B launch pads in Jiuquan Satellite Launch Centre. It also created a new record of the shortest interval between two Chinese launches - within 24 hours, or exactly 23 hours, 35 minutes after the YG-24 launch.
- On 7 December, at 11:26, CBERS-4, the replacement for CBERS-3 which was lost during launch in December 2013, took-off successfully from Taiyuan on a CZ-4B.
- On 11 December, at 3:33, and on 27 December, at 11:22, two more YGs, the YG-25 and YG-26, were launched by a CZ-4C from Jiuquan and a CZ-4B from Taiyuan respectively. It was significant that 5 of 10 launches in the fourth quarter were for YG birds.
- On 31 December, at 9:02, a CZ-3A lifted-off from Xichang and sent the FY-2G (or FY-2-08) geostationary weather satellite into GTO. This launch on the last day of 2014 made a perfect ending of the year.

China made 16 space launches in 2014, all successful and two more than 2013, but still behind the peak numbers (19) in 2011 and 2012. However in 2015, it is likely that Chinese space launches might surpass the number 20.

Space Transportation

As maiden flights are still pending, from time to time there were reports on the new generation of launch vehicles, the CZ-5, 6, and 7. The second stage of the first CZ-7 set for rehearsal, completed assembly in Tianjin in early November followed by completion of the whole rehearsal rocket beginning of December. On 17 December, the launcher, including all stages and the boosters, departed to Hainan Island in the Yuanwang 21 rocket transportation ship. The ship arrived in Qinglan Port on 24 December. Two days later, the rocket stages were transported to the Wenchang launch site by highway. This was the first time a Chinese space rocket was transported to the launch site by sea.

On 25 November, the oxygen tank of the CZ-5's second stage completed a low temperature destructive test. In early December, the YF-77 cryogenic engine made its last planned test in the Institute 101 of AAPT (Academy of Aerospace Propulsion Technology) in Beijing. Meanwhile in Shanghai, SAST made a successful static-load test of the nose cone for the CZ-5 strap-on booster. The nose is in the shape of an oblique cone, which is used for the first time in Chinese launcher design. In early December, the first stage assembly of the CZ-5 was completed for a propulsion system test - one of the new launcher's most important tests.

Rounding up official reports in December, the CZ-6 will make its debut in mid-2015, and then CZ-7's maiden launch is expected for the end of 2015 or the first half of 2016, followed by the CZ-5 in the second half of 2016.

On 11 October, more than a hundred Chinese rocket engine scientists and experts gathered in Beijing for an academic symposium on the topic of "liquid fueled rocket engine", organised by the China Space Society. The focus of the symposium was on engines for the super-heavy launch vehicle. Unfortunately, media reports did not disclose related details. While on 7 December, Lei Fanpei, Chairman of CASC (China

One of the large diameter rings required by CZ-9.
(credit: China Space News)

left: The scaled model of Feitian 1, displayed in Zhuhai.
(credit: Chinese internet)

Aerospace Science and Technology Corp.), revealed a rough schedule. He told Xinhua that it may take 4-5 years from now to break through fundamental technologies including the overall design, the 460-tonne thrust kerosene engine and 220-tonne thrust cryogenic engine, as well as design and manufacture technologies for the 8.5 m diameter rocket stage. The schedule hints that governmental approval is expected around 2020. He also expects that the super-heavy launcher will make its maiden flight around 2030.

As Lei said and everybody knows, fundamental work on the super-heavy launcher has been underway since a few years. A related news in this quarter was that CALT (China Academy of Launch Vehicle Technology) worked together with some Chinese heavy machinery companies to develop aluminium alloy rings whose diameter is larger than 8 metres and that could be used on tanks of the super-heavy rockets. According to reports, at least two companies, Paike Forging and Guoguang Heavy Machinery, completed the forging of the ring. The one completed by Paike, made of 2219 aluminium alloy, has an outer diameter of 8.7 m and inner diameter of 8.3 m. Guoguang owns the world's largest 19,500-tonne free forging hydraulic press that was used to make the 8.7 m outer diameter ring.

During the Airshow China 2014, held in Zhuhai from 11 to 16 November, China Aerospace Science and Industry Corporation (CASIC) displayed a mobile small solid launch vehicle named Feitian 1 (FT-1). It was a variant of its Kuaizhou launcher where the only difference is that the integrated satellite-upper stage was replaced with a conventional payload and fairing. It aims at the commercial launch market with flexible launch options. The launcher has a length of 19.4 m, launch mass of 30 tonnes, and is able to send 300 kg into LEO. It has also a mobile capability and fast response capability of preparing a launch in four hours. At the Airshow, there was a scale model shown, including the mobile launch platform / transportation vehicle.

Since the first launch of Kuaizhou 1 in September 2013, China had never released any photographs of it. However, just about one week after the Airshow and three days after the second Kuaizhou 1 launch, it appeared in public. A launch photo and a close-up view of the launcher in testing published with an official KZ-2 launch report, shows that Kuaizhou 1 is almost identical to Feitian 1, its twin sister.

Kuaizhou 1's second launch on 21 November.
(credit: China Space News)

The revealed picture of the Kuaizhou 1 launch vehicle.
(credit: China Space News)

In the Airshow, SAST displayed the multi-sat upper stage (alleged same as the TY-1 stage revealed earlier). It has a working time of 48 hours after launch, and is capable of restarting for 20 times and of sending 10 satellites to different orbits.

Satellites

On 23 December, China announced the development of three more oceanic satellites HY-1C/D and HY-2B. Development would start in 2015. The HY-1C/D are ocean colour observation satellites that will replace the HY-1B in extended service, while the HY-2B is an ocean dynamics satellite to replace HY-2. In addition, it was revealed that early studies of a new generation of ocean colour satellites are also underway.

At the end of December, CAST (China Academy of Space Technology) completed an environmental test of the DFH-4E bus that is an enhanced model of DFH-4 using electric propulsion with a maximum mass of 6 tonnes. It was publicly displayed for the first time in the Airshow China 2014 in November. The first comsat using DFH-4E is the ZX-16 (or Ka-band Broadband Multi-media Telecommunication Satellite) due for launch in 2017. Another electric propelled comsat bus, the smaller DFH-3B, is also in final development. In October, the DFH-3B completed an ignition test of electric thrusters integrated with the satellite in vacuum status. The first satellite based on DFH-3B will be the SJ-13 communication satellite, according to a report in early December. It is interesting that the SJ (Shijian, meaning "practice") name is used by a communication satellite.

China's Space Science Pioneer Programme continued to make steady progress. On 30 and 31 December respectively, reviews on the engineering model development of the SJ-10 and the quantum satellite, or QUESS (QUantum Experiments at Space Scale) were done, marking the start of the flight model development. Two other missions in the same programme, the HXMT (Hard X-Ray Modulation Telescope) and DAMPE (DArk Matter Particle Explorer) started flight model development in December 2013 and September 2014 respectively. In addition, in mid-November, the SJ-10 recovery sub-system made an air-drop test successfully.

At the 9th SPIE Asia-Pacific Remote Sensing Symposium held on 13 October in Beijing, CAS proposed a constellation of six Earth observation satellites for the remote sensing of global changes. The six satellites will monitor atmospheric carbon, forest biomass, light at night, aerosols, glacier and ocean salinity respectively.

Manned Space Flight

In orbit, the Tiangong 1 celebrated its third anniversary. And then, on 25 and 26 November, it completed two orbit raising manoeuvres and entered an orbit of 369 km x 392 km, according to USSTRATCOM.

On ground, Tiangong 2 development has entered its final phase. At the end of December, the Tiangong 2 space laboratory completed payload installation and was delivered for electrical testing. The Tiangong 2 began assembly about one year before and is planned to be launched in 2016.

Tianzhou 1 cargo vehicle in testing. An open window at the unpressurised section is seen at the top. (credit: China Space News)

The Tianzhou cargo transportation vehicle, to be launched to Tiangong 2 for its maiden mission, also made progress. In mid-December, the semi-pressurised model of the cargo ship completed the thermal equilibrium test in the KM6 chamber, lasting 40 days. The semi-pressurised model consists of a pressurised section and an exposed section to carry space components or external payloads. The mass characteristics test of the semi-pressurised model was also reportedly completed in the same timeframe. It becomes more and more clear that the first Tianzhou ship to be docked with the Tiangong 2 will be a semi-pressurised model.

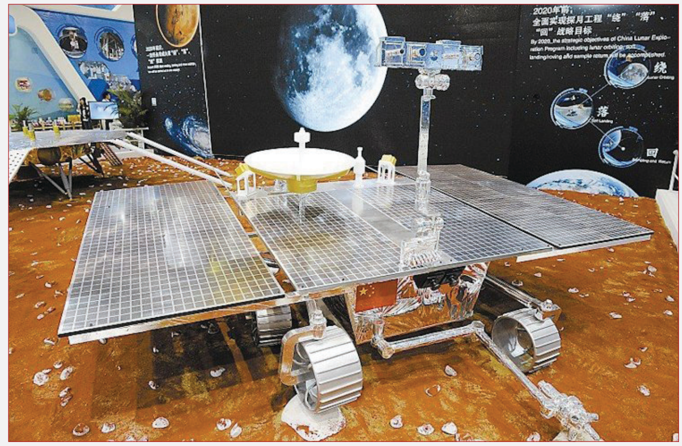
In parallel with the work for the Tiangong 2 mission, the development of the modular Chinese Space Station sped up. The first major test of the CSS, the static load test on the structure of the Tianhe resource module, was completed successfully some time in December, according to China Space News.

A little noticed news was that China has formally started development of a new generation of manned spacecraft. CAST started the study in June 2013. After three months of technical reviews and refining of the design, it was finally approved by the government in October 2014. In December, CAST revealed that they are preparing an air-drop test of a scale model of the new manned capsule, re-using the back-up parachutes of Shenzhou 10. According to information revealed earlier, the new manned spacecraft is similar to Apollo or Orion.

Lunar and Deep-Space Exploration

The Chang'e 5-T1, launched on 24 October, has as its primary mission objective the technical demonstration for the future lunar sample return mission. But it is actually China's fourth lunar probe as well, after Chang'e 1, 2 and 3. It also carried a commercial payload, the 4M (Manfred Memorial Moon Mission) from Luxspace, a Luxembourg-based micro-satellite manufacturer. After launch, the spacecraft entered a 200 km x 41,300 km lunar fly-by and free return orbit, while the third-stage, together with the 4M probe, entered a higher orbit with a perigee of more than 80,000 km. The Chang'e 5-T1 made a lunar fly-by on 28 October and entered the return trajectory on the same day. At 5:53, 1 November, at around 5,000 km above

The Earth seen from the Moon. The photo was taken by the Chang'e 3 lander and is one of the images released in December. (credit: CLEP)



Scale model of the Chinese Mars rover. (credit: Chinese internet)

the ground and at a speed of 10.8 km/s, the 300 kg re-entry capsule (nicknamed "Xiǎo Fēi" or Little Flyer), a scaled-down Shenzhou capsule, separated from the service module. At 6:42, it landed safely in Siziwang Banner, the same site Shenzhou capsules land, marking the first mission to the Moon and back since the Soviet Union's Luna 24 mission in 1976. It verified the high-speed skip re-entry technology, one of the biggest technical challenges in the Chang'e 5 sample return mission planned in 2017. The 4M probe also did a lunar fly-by, and mission operation continued for 250 hours before the successful ending, announced by LuxSpace on 4 November.

The capsule's successful landing did not mean the end of the mission, but the start of a comprehensive extended mission. On 23 November, the Chang'e 5-T1 service module flew-by the Moon and performed a lunar gravity assistant manoeuvre that was also a first for China. On 27 November, it entered a Lissajous orbit around the Earth-Moon L2 point with a period of 14 days to test orbital tracking and control technologies.

In the small hours of 15 December, Beijing Time, the Chang'e 3 lander entered again the hibernation mode after completion of the planned work on its 13th lunar day. Just a few hours before, at 21:14, the lunar probe passed the one-year mark on the lunar surface, and exceeded its designed working life. At that point the spacecraft started its extended mission. Chinese media did not mention whether the Yutu rover woke up in the three months (or three lunar days) of this quarter.

In mid-December, China released Chang'e 3 scientific data on the website of the Science and Application Center for Moon and Deep-space Exploration (moon.bao.ac.cn), including high-resolution images taken by the lander and the Yutu rover.

During 20 to 24 November, the 3,000 N engine developed for the lunar sample return mission made 37 successful test firings, concluding the reliability qualification testing.

Li Zhongbao, a CAST official, revealed during the Airshow China 2014 that China plans to send its first independently launched Mars probe in 2020, two years later than previously planned. It was re-confirmed by a higher official in a forum in late November. China's Mars mission includes an orbiter, a lander and a rover. CAST displayed the mockups of its proposed orbiter, lander and the 2 m long rover at the airshow. A few days earlier, SAST displayed another design of the Mars rover at an exhibition in Shanghai. There has been no information whether it has been approved by the government, but seemingly it was getting closer.

On 17 October, CAST and the Purple Mountain Observatory of CAS (Chinese Academy of Sciences) completed a review on an integrated asteroid sample capturing and analysis device jointly developed by the two organisations during the last two years. It confirmed that China is also preparing an asteroid mission. Earlier reports once revealed an ambitious asteroid mission proposed by SAST that could be launched in November 2017, fly-by the asteroid 12711 (1991 BB, or Tukmit) in August 2018, orbit the asteroid 99942 (2004 MN4, or Apophis, an Near Earth Object that will move close to the Earth within just 29,450 km on 13 April in 2029) for five months, then fly-by the Earth in May 2022 for a gravity assistance to reach the asteroid 175706 (1996FG3, also primary target of the ESA Marco Polo-R mission) in August 2023 and finally soft-land on it in December

The asteroid sample capturing device. (credit: Weibo/Purple Mountain Observatory)

2023. It will use electric propulsion. Similar to the Mars mission, there has been no information about this mission's approval and funding.

Advanced Technology

All the news here concern CAST.

By the end of December, Institute 508 of CAST had completed six air-drop tests of the parafoil used for the fly-back rocket boosters. Precise landing achieved in these tests marked a major breakthrough in China's re-usable launch vehicle development.

In late November, Institute 502 of CAST completed a ground demonstration system for in-orbit satellite refueling. CAST had successfully tested the full procedure of satellite refueling using this system. It was a project in parallel with the Tianzhou cargo ship refueling system in the manned space programme.

Latest information on the Chinese internet showed that CAST is also developing an air-breathing Helicon plasma thruster that is able to work without carrying any working substance. It is planned to be used on Mars orbiters in low orbit about 120-220 km above the Mars surface where it will capture very thin Mars atmosphere gas as a working substance. CAST had published a paper in 2012 for the 9th Annual Meeting of the Deep-Space Exploration Committee of the China Society of Space. In May 2012, a team of CAST completed laboratory testing of a principle prototype with an impulse of 2,188 seconds and a thrust of 20 mN. They were also developing an engineering model with an impulse of 2,600 seconds and a thrust of 100 mN, to be tested in orbit sometime after 2014.

International Cooperation

During 29 November to 3 October, the 65th International Astronautical Congress (IAC 2014) was held in Toronto, Canada. However, due to the "visa issue" on the Canadian side, many of the Russian and Chinese delegations, including Denis Lyskov, Deputy Head of Roscosmos and Xu Dazhe, Head of the China National Space Administration (CNSA), were absent from the Congress. The Chinese delegation submitted a number of papers and the few delegates present, attended several forums, but compared to the IAC 2013 in Beijing not much new information was released. (Please, read the report in GoTaikonauts!, Issue 14 for details)

During the Airshow China 2014 in mid-November, the China Manned Space Agency and the Russian Space Agency Roscosmos, discussed cooperation in the field of human space flight. On 18 November, TASS had a report on a trip of Oleg Ostapenko, Head of Roscosmos, to China. Ostapenko said that he discussed with China various fields of cooperation, including satellite navigation, remote sensing of the Earth and many other areas. He expected that the two countries were likely to see an exchange of manned flights to Russian and Chinese space stations in the future, as well as to organise joint deep-space exploration missions. He also noted that China is interested in producing Russian rocket engines on its territory. In early December, Chinese media quoted the Russian newspaper Izvestia as saying that China had submitted a proposal to Roscosmos consisting of more than 10 joint projects, including a visit by taikonauts to the ISS. However, this information could not be confirmed from other channels.

After Russia, Europe is also a major partner for China in space. Sino-European cooperation made the following progress in this quarter:

- On 11 December, Wang Zhaoyao, Director of the China Manned Space Agency (CMSA), met with Jean-Jacques Dordain, Director General of the European Space Agency in Beijing. The two leaders signed an agreement between CMSA and ESA concerning cooperation on human spaceflight activities. It signifies that Sino-ESA cooperation in the field of manned spaceflight has entered a substantial stage. Under this agreement, three potential cooperation areas are identified: joint scientific experiments and studies utilising in-orbit infrastructures (ISS and CSS) and ground facilities; astronaut selection, training, medical operations and astronaut flights; and space infrastructure cooperation in human exploration of Low Earth Orbit (LEO) and beyond.
- On 10 October, witnessed by Chinese Premier Li Keqiang and German Chancellor Angela Merkel, the two countries signed in Berlin a Memorandum of Understanding on the peaceful uses of outer space. The signing of the memorandum laid a solid foundation for the future cooperation between China and Germany.
- In a news release issued on 11 December, ESA stated that it was finalising its first experiment on a Chinese space mission: the 'Soret Coefficient in Crude Oil' experiment that will help to improve our understanding of oil reservoirs buried kilometres underground. It consists of six sturdy cylinders, each containing a millilitre of crude oil, pressurised to 400 times normal atmospheric level - the highest pressure items ever made for space. It will fly on the SJ-10 recoverable satellite near the end of 2015, along with 19 other experiments. The experiment package had already passed the whole gamut of testing at ESA's Technical Centre, ESTEC, in Noordwijk, the Netherlands, including the temperature shifts of orbital flight and the vibration and shocks of launch and re-entry.
- On 14 November, the first International Workshop of China Seismo-Electromagetics Satellite Mission was held in Beijing. CNSA, China Earthquake Administration (CEA) and ASI, the Italian Space Agency jointly hosted the workshop. Space scientists and seismologists from China and 10 other countries participated in the workshop. The satellite, jointly developed by China and Italy according to an agreement signed in September 2013, is currently in engineering model development and planned to be launched at the end of 2016.
- On 29 September, Yves-Louis Desnos, Head of Research and Development section in ESA's Directorate of Earth Observation Programmes, received the People's Republic of China Friendship Award - the country's highest honour for foreign experts who have contributed to China's economic and social progress - for his work in coordinating the collaborative Chinese - European Dragon Programme. The Dragon programme promotes the use of ESA, Third Party Mission and Chinese Earth observation satellite data within China for science and applications.

Space cooperation with developing countries also made progress. On 24 December, during the visits of Egyptian President Abdel Fattah Al-Sisi and Prime Minister General Prayut Chan-o-cha of the Kingdom of Thailand to China, the two countries and China published the Joint Press Communique/ Joint Statement in which enhancing space cooperation is a major part.

During 20-21 October, and 30-31 October, the International Space Science Institute Beijing ISSI-BJ, held the forums on the WCOM (Water Cycle Observation Mission) and the ASO-S (Space-borne Solar Observatory) respectively. Experts from China, the USA and major European countries discussed the scientific objectives, overall design and key technologies of the mission, as well as the possibility for international cooperation.

Space News reported on 5 December that China recently asked the U.S. Air Force to send the data on any potential on-orbit collisions directly to its satellite operators in the name of expediency. Gen. John Hyten, Commander of the Air Force Space Command, said the Air Force has long provided data to the parties involved. However, data to China and Russia must be routed through the State Department, and often through the Chinese and Russian foreign ministries, before reaching their military satellite operators. He said the Air Force would comply to the new procedure the next time it spots a potential collision involving Chinese space hardware.

Commercial Space

On 5 October, witnessed by Venezuelan President Nicholas Maduro, Yin Liming, President of China Great Wall and Manuel Fernandez, Minister of Science and Technology of Venezuela, signed the procurement contract of the VRSS 2 remote sensing satellite in Caracas, the Venezuelan capital. After the signing of the contract, President Maduro delivered a speech, naming the satellite “Sucre” after South America’s independence leader Antonio Jose Sucre. China and Venezuela firstly signed the agreement on the VRSS 2 satellite in July 2014. The VRSS 2 is scheduled to be launched in July 2017.

During the Airshow China 2014, China Great Wall signed two framework agreements with Apstar and Thaicom/IPStar. The Apstar agreement involves the development and in-orbit delivery of the Apstar 10 comsat at an undisclosed date. Thaicom will work with the Chinese side to develop and procure comsats for the Asia-Pacific area.

In the period from 2 to 6 December, a delegation from the Russian communication satellite operator RSCC visited China and talked with China Great Wall on the possibilities of cooperation on development, launch and operation of telecommunication satellites. Information on the internet indicated that RSCC has been affected by the Proton rocket’s poor track record in recent years, and is seeking alternative providers.

Probably encouraged by market progress, on 18 December, China Great Wall signed a bulk procurement agreement with CAST to procure 8 communication satellites based on DFH-4S, 4 and 4E to improve delivery efficiency.

In CAST, the Apstar 9 comsat had started AIT (Assembly, Integration and Test) since October. It was expected that AIT for the launcher would start in March 2015, and the launch would happen by the end of 2015.

On 8 December, CAST and Beijing Xinwei Telecom Technologies signed a strategic cooperation agreement to form a joint venture to push the development, construction and operation of the LEO communication system. The first experimental LEO comsat SCES (Smart Communication Experimental Satellite), jointly developed by Xinwei (for payload) and the Tsinghua University (for satellite bus), was launched in September. The satellite is to validate a global LEO communication system similar to Iridium and GlobalStar, based on the McWiLL technology. During in-orbit tests after launch, it achieved a bandwidth of 600 kbps using hand-held terminals. It is planned to launch a 64-satellite constellation by 2020 to cover 100% of the Earth’s surface. At the 2014 China Satellite Application Industry Forum which took place 27-28 November in Shanghai, the Xinwei Group and Tsinghua University were awarded the 2014 China Satellite Application Innovation Award in recognition of the great innovative achievement of the SCES. Wang Jin, the Chairman and biggest shareholder in Beijing Xinwei Telecom Technology is also the person who is behind Nicaragua’s US$50 billion Interoceanic Grand Canal project.

The above cooperation was also a move for the private sector to enter the Chinese space industry. Chinese new leadership has been pushing a new policy to reform the state owned companies with mixed state and private ownership since late 2013. On 18 December, CASC, the major contractor for China’s space programme, invited 1,300 private enterprises to an international forum on advanced aerospace materials and commercialisation in the eastern city of Ningbo. The initiative aims on fostering the development of the Chinese manufacturing sector. The CASC has offered 30 areas to the private sector for developmental partnership, including high-performance metal, organic polymer and electronic information. In the future, it will also promote the commercialisation of satellite application, clean energy, energy conservation and high-end equipment technologies.

Inspired by the New Space worldwide and latest domestic policies, private space begins to grow in China. In December, China’s first open source smallsat project was kicked off by the Kechuang Space Association (www.kcsa.org), an online space enthusiast community. It is planned to develop and launch the Kexing 1 satellite within two years, totally supported by the open source community.

Miscellaneous

Ground Facility

CAST made a breakthrough on ground simulation technologies. In a test in December, an article was heated to 1,850 degrees Centigrade in a dark vacuum chamber, which had never been achieved by China before. The new facility paves the way for the development of future spacecraft able to endure extremely high temperatures in space.

In December, a new large thermal vacuum chamber was completed in the Aerospace Dongfanghong Development Ltd, Shenzhou, a joint venture by CAST, HIT (Harbin Institute of Technology) and Shenzhen City Government to develop small satellites. The new chamber marks that Shenzhou becomes the third city after Beijing and Shanghai to have a facility at such a level.

Space Application

China planned to build a Beidou base station in the Antarctic as a major task of China's 31st Antarctic scientific expedition that began at the end of October 2014 and would end in early April 2015. The station will be built near China's Great Wall Station to obtain Beidou data in the Antarctic area to support future development of the Beidou navigation system.

Shanghai Galileo Industries Co. Ltd launched a 40-nanometre Beidou navigation chip at the end of November. The chip, to be put into mass production in the first half of 2015, is a radio frequency-baseband integrated multi-mode chip for mobile devices, comparable to Qualcomm's similar chip. The company was founded in 2005 to represent China's participation in Europe's Galileo Project.

Correction for the Quarterly Report in Issue 14: In the second sentence of the section "Launch Events" (SAST made four successful launches within 30 days using its CZ-2C, 2D, 4B and 4C launchers, ..."), the "2C" should be removed.

(Chen Lan)

Chinese Space Quarterly Report

January - March 2015

by Chen Lan

Highlights

- New generation of Beidou birds and the YZ-1 upper stage made their debuts.
- CZ-5 made key hot test firing, CZ-7 completed launch pad rehearsal, CZ-8 revealed.
- SAST develops heavy geostationary satellite bus - SAST 9000.
- Design details of the new generation manned spacecraft disclosed.
- Chang'e 5-T1 service module completed rehearsal of lunar orbit rendezvous.
- Chinese Mars mission still awaiting approval, to be launched in 2020 at earliest.
- New progress was made in the field of electric propulsion.
- China completed ground simulation of satellite in-orbit servicing.
- China and Europe to launch a joint science mission, lunar orbit telescope proposed.
- China and Europe completed frequency coordination on satellite navigation.

Launch Event

On the second last day of this quarter, China made its first space launch in 2015, again showing that the first quarter is off-season for the Chinese space programme. On 30 March, at 21:52, a CZ-3C rocket lifted-off from the Pad 2, Xichang Satellite Launch Centre, sending the first test satellite (with designation of I1-S) of the third generation Beidou navigation satellites into an inclined geosynchronous satellite orbit (IGSO). The satellite, based on a newly-developed bus and using many new technologies, is to test the Beidou global constellation to be completed by 2020 (see the 'Satellites' section for details).

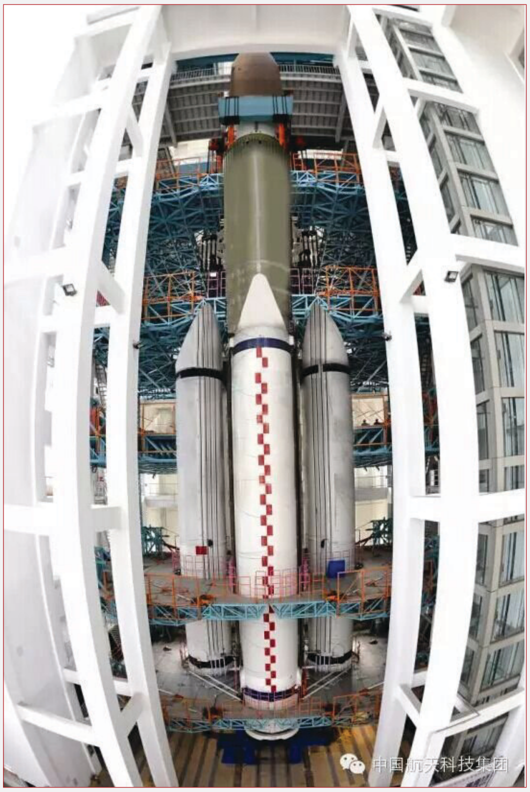
In this launch, the general purpose YZ-1 upper stage made its maiden flight and worked well for six hours and directly sent the satellite into IGSO. The YZ-1 will be used again in a dual-sat CZ-3B launch later this year for two more Beidou test satellites.

In mid-March, a CASC (China Aerospace Science and Technology Corp.) official said through Chinese media that China plans to launch more than 40 different spacecraft on 20 launches into orbit this year.

Space Transportation

This quarter marked major progress for the CZ-5 launch vehicle development. It was reported in early January that the fairing separation test was successfully completed in Tianjin. The fairing was the longest, heaviest and widest one ever developed by China. However, this was not the most significant milestone it reached. On 9 February, at 16:00, the first core stage of CZ-5 made its first propulsion system test in Beijing. Two YF-77 cryogenic engines at the bottom of the 33 m long stage ignited for 460 seconds, including 30 seconds of gimbaling firing. It was the largest ground test within the CZ-5 development programme and was said to be the largest scale cryogenic engine test in China. One and a half months later, the stage made its second test, again with success. The second firing lasted for 478.8 seconds and performed full duration gimbaling as in actual flight. In early March, the first complete CZ-5 vehicle, prepared for modal test, completed assembly, giving people the first glimpse of the full launch vehicle.

left: CZ-7 at the mobile launch platform in rehearsal in Wenchang Space Launch Centre (credit: Chinese internet)



right: A CZ-5 completed assembly in Tianjin. (credit: CASC)

Meanwhile, CZ-7 development was ahead of CZ-5. A full CZ-7 launch vehicle developed for launch pad rehearsal arrived in Wenchang Space Launch Centre at the end of December and the rehearsal started afterwards. During the rehearsal, the mobile launch platform, the rocket-pad interface, payload interface and vertical assembly, etc., were tested. All activities were finally completed before the Chinese New Year on 19 February. Supported by digital simulation made earlier, no major problems were encountered in the rehearsal. On 16 March, the test rocket returned to Tianjin by sea in the Yuanwang 22 rocket transportation ship.

In fact, the fastest development among new launchers was the CZ-6 and CZ-11. On 19 March, AAPT (Academy of Aerospace Propulsion Technology) issued a news release that it completed the final hot test firing for the third stage of the "new generation small launcher" (alleged CZ-11), paving the way for its maiden launch later this year. Liang Xiaohong, Head of CALT (China Academy of Launch Vehicle Technology), told reporters in the annual session of the People's Congress that CZ-11 will make its debut within this year. There was also information about another launcher to take-off this year, the CZ-6. A financial report from one of the related sub-contractors revealed that CZ-6 will carry 20 smallsats on its maiden flight.

Also, Liang Xiaohong said in a media interview that the super-heavy launch vehicle development had received R&D funding from the government. He expected that it would take 15 years for development once full funding is approved. Further news on 20 January coincided with that by Liang that a large flow nozzle designed for the cryogenic engine of the super launcher (alleged YF-220) made a successful hot test firing.

Finally, Liang revealed interesting information that China is studying a new launcher named CZ-8 that will be a sun-synchronous orbit launcher. But he did not give any details about the new launcher.

Satellites

The new Beidou satellite launched on 30 March, was developed by the Shanghai Engineering Center for Microsatellites (SECM), CAS (Chinese Academy of Sciences). It is based on a new bus particularly developed for the Beidou global constellation. It has capabilities of autonomous navigation and inter-satellite communication. It also used a large number of domestically made components including the Loongson CPU developed by CAS. SECM has become a major satellite maker in China just after CAST (China Academy of Space Technology) and SAST (Shanghai Academy of Spaceflight Technology). There are more than 30 satellites in its launch list, including the DAMPE (DArk Matter Particle Explorer), the QUESS (QUantum Experiments at Space Scale), the TanSat (carbon dioxide sniffer), and the Sino-Franco SVOM astronomical satellite.

In recent years, China has made fast progress on civil Earth observation satellites with the Gaofeng (meaning 'High Resolution', in short: GF) programme. On 6 March, the GF-2 satellite, China's first sub-metre resolution (0.8 m) civil imaging satellite, launched on 19 August 2014, was delivered to users, the Ministry of Land and Resources and other 19 government bodies. On the same day, a CNSA (China National Space Administration) official told reporters that GF-4, the first geostationary imaging satellite with nearly real-time capability and Earth resolution of 50 m, will be launched by the end of 2015. And GF-3 and 6, the high-resolution radar satellite and the hyper-spectral satellite, will be launched in 2016. CNSA was also pushing for the approval of the GF-6 and 7 satellites - the latter is a cartographic satellite as replacement of Ziyuan 3 (ZY-3). Primary user of both ZY-3 and GF-7 is the National Administration of Surveying, Mapping and Geoinformation. It seems that China has put all national level civil Earth observation satellites (excluding weather and oceanic satellites) under the GF programme. In March, it was reported that the camera for the GF-4 completed its vibration test.

China's latest weather satellite was the FY-2G geostationary meteorological satellite launched on the last day of 2014. It reached its geostationary position at 7:40 on 6 January 2015 and started in-orbit testing immediately. The National Satellite Meteorological Centre received the first visible image on 8 January and the first infrared image on 26 January. In-orbit testing would last for three months.

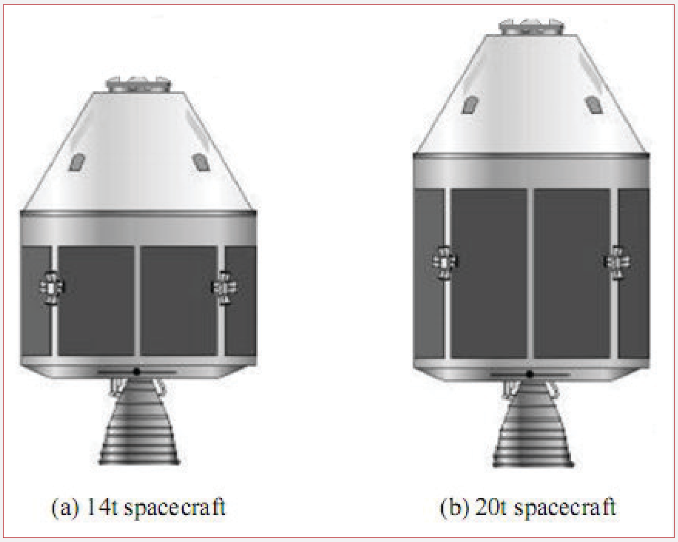
FY-2's successor, the new generation geostationary meteorological satellite FY-4, reached a major milestone after years of development. It formally switched to the stage of flight model development on 28 January. In early February, the heat balance test of the lightning imaging sensor, a key payload of FY-4, was completed in CAST.

A more advanced model of FY-4, the FY-4M microwave satellite, had also entered early stage development. There is cooperation with ESA on this project. On 30 January, a joint design review of the ground models of the GIMS (Geostationary Interferometric Millimetre wave atmospheric Sounder) proposed by NSSC (National Space Science Centre) and the Geo Sounder proposed by ESA, was completed in ESA's technical centre ESTEC in Netherlands. The microwave sounder will be one of the most important payloads of the FY-4M satellite. NSSC started research on the sounder in 2005 and completed a full-scale working prototype with equivalent resolution of 50 km in 2012.

In January, SAST completed the vibration test of a significant new satellite bus, the heavy satellite bus SAST 9000. SAST 9000 was reportedly a high orbit remote sensing platform aiming for geostationary high-resolution imaging satellites, geostationary ELINT satellites and super SAR satellites, etc. The report did not reveal its size or mass.

Manned Space Flight

A paper whose authors include Zhang Bainan, Chief Designer of Shenzhou since 2004, published one year ago on Acta Aeronautica et Astronautica Sinica, was recently dug out and published on the Chinese internet. The paper, entitled Concept Design of the New Generation Multi-purpose Manned Spacecraft, gave many details of the proposed spaceship. It has two versions. The 14 t, 6-people model is for LEO and Mars missions, and the 20 t, 4-people model for lunar landing. Both have the same capsule but with the service module of different length. The orbital module, the same as the one on Shenzhou, was removed. It is able to fly independently for 21 days and more than 2 years when docked with the station. The capsule is cone shaped (similar to Apollo and Orion) and is able to re-enter from



The new generation manned spacecraft.
(credit: Acta Aeronautica et Astronautica Sinica)

deep-space. The recovery system includes multiple parachutes and airbags, allowing landing at sea.

Work for the Tiangong 2 mission continued. On 3 January, it was reported that the Tiangong 2 space laboratory had completed the assembly and payloads installation, and was delivered for electric testing. On 20 March, the propulsion sub-system of the Tianzhou 1 cargo vehicle completed the pad rehearsal in Wenchang.

Lunar and Deep-Space Exploration

Chang'e 3 continued working well on the Moon. On 14 January, the Chang'e 3 lander woke up again and entered the 14th lunar day after its landing. Most of the equipment, including the camera pointing device, jointly developed by CAST and the Hong Kong Polytechnic University, completed testing in the extended mission. Though there were no specific reports on the lander and the rover's status afterwards, Ye Peijian, Chief Scientist of the Chang'e 3 programme, told Xinhua on 3 March, that Yutu is still working but cannot move, and its voltage had dropped after repetitive contraction and expansion, indicating that hope of its recovery is dim.

In space, the Chang'e 5-T1 service module was busy in the first quarter during its extended mission. On 4 January, it left the orbit around the EM-L2 point, and on 11 January at about 3:00 made a lunar orbit insertion burn, entering a 200 x 5,300 km lunar orbit and finally a 200 km orbit around the Moon on 13 January. During 6-7 February, the spacecraft performed three orbital adjustments, or the so-called phase control, to verify orbital control technologies for the future lunar orbit rendezvous and docking in the Chang'e 5 sample return mission. During 7-9 March, it made another series of orbital manoeuvres but this time it played the role of ascent stage to simulate lunar orbit rendezvous and docking. In the next steps of the extended mission, the service module would map the landing area for the Chang'e 5 mission and perform more scientific experiments such as investigation of the reversal of the gravitational field of the Moon.

The Chang'e 5 development on the ground also continued to make steady progress. On 6 January, the 3,000 N engine developed for Chang'e 5 completed its first lifetime test firing lasting 9 days. On 30 March, the propulsion systems of the lander and the ascent stage passed a review with products delivered for assembly. They were modified from the thermal control test articles and will be used on the Chang'e 5 "demonstrator". It was believed that this demonstrator was to be used in ground based tests to simulate landing and ascent.

There was finally some news about Chang'e 4, the half-completed backup of Chang'3 with an uncertain future. China announced in March that the Chang'e 4 mission welcomes public capital and private companies to be involved. It could be used as a platform for engineering development, technology verification and application. The final mission design will depend on the participation of public capital and international cooperation. Wu Ji, Head of the NSSC, CAS, said in a presentation at the (U.S.) National Research Council's Space Science Week meeting on 31 March, that the revised Chang'e 4 mission, now scheduled for 2020, will use a more powerful launch vehicle that will allow for a heavier spacecraft and feature a landing in a different region of the Moon, including possibly the far-side.

Wu Ji also revealed a message about China's first Mars probe, said to be launched in 2018 according to earlier reports. He said that the Chinese government had yet to formally approve the proposal and the mission was tentatively scheduled for 2020.

Advanced Technology

In this quarter, China achieved a number of advances in the field of electric propulsion as follows:

- In January, CAST completed the lifetime test of the LIPS-200 ion thruster lasting more than one year. It accumulated 6,000 hours of firing time and more than 15,000 times of ignition, enabling the satellite's working life for at least 15 years. It will soon be used on China's new communication satellite.
- On 19 February, the 6th Academy (AAPT - Academy of Aerospace Propulsion Technology) completed the three-year-long lifetime test of the cathode in its 80 mN Hall Effect thruster. It accumulated 18,000 hours firing time with more than 15,000 times of ignition, both of which far exceeds its design specification.
- During 13-18 March, the flight model of another Hall Effect thruster, the LHT-100 developed by CAST, completed the ignition test in an integrated ground simulation environment, paving the way for its application in space.
- On 20 March, CAST completed a review on an R&D project named "the electric propulsion using field emission for precise control". The project was formally approved. This new electric propulsion system is suitable for micro satellites with micro-Newton level precise control.

In January, SAST completed a ground simulation of in-orbit satellite servicing including close proximity approach, docking, component replacement using a robotic arm and propellant resupply. It paves the way for the future robotic spacecraft to perform in-orbit satellite repair and resupply. SAST spent three years to develop the ground simulation system based on an air-floating platform.

International Cooperation

There was noticeable progress on space cooperation between China and Europe:

- On 12-16 January, the 4th Frequency Compatibility Coordination Meeting was held in Prague, Czech Republic. The two sides agreed to coordinate frequencies used by the Beidou and Galileo navigation systems under the framework of the ITU, ending the dispute lasting 8 years.
- ESA and NSSC (National Space Science Center), CAS had received 15 proposals for the joint space science mission from the science communities in the ESA Member States and in China by the submission deadline on 16 March. One of the proposed projects is called Discovering the Sky at the Longest Wavelengths (DSL) with a series of spacecraft in lunar orbit to observe the universe from the Moon's dark side. Other proposals include an X-ray imager called SMILE that would study Earth's magnetosphere, and SIRIUS, an extreme-ultraviolet telescope that would look at 'hot objects', such as stellar coronae, in the Galaxy. The proposed missions will now be assessed for their technological feasibility and scientific merit. By the end of this year, the pool will be narrowed down to a winner or a handful of contenders, which will enter a study phase of around two years, with a final go-ahead expected in 2017. ESA will contribute just more than €50 million (US$53 million) to the project, which China is expected to match.
- On 29 January, CNES of France and CNSA signed an agreement to speed up development of the CFOSAT, the Sino-France oceanic satellite. Scheduled to be launched into orbit by June 2018, CFOSAT is designed to study ocean surface wind and wave conditions to improve forecasts for marine meteorology and knowledge of climate variations. It will have a wave-scatterometer spectrometer (SWIM: Surface Waves Investigation and Monitoring) supplied by CNES, and a scatterometer (SCAT) supplied by CNSA.
- On 20 January, the Sino-Italy Electric Propulsion Joint Laboratory was formally established in CAST. It was formed by CAST and ALTA, a leading electric propulsion company, according to the framework agreement signed during the IAC 2013 in Beijing (compare: Go Taikonauts!, issue 10).

China and Russia also have a close partnership in space, with the following activities in this quarter:

- On 19-20 January, the first Sino-Russian Bilateral Space Science Workshop was held in Beijing. More than 70 experts from the two countries discussed topics on solar and space physics, planetary physics, astrophysical, micro-gravity and space life science.
- Russia and China have signed a cooperation agreement in the field of satellite navigation during the first meeting of the China-Russia Cooperation Program Committee on Satellite Navigation on 10 February. The Committee was established according to the outcome of the Regular Meeting Committee between the two governments in October 2014. During the official visit to China, Igor Komarov (Igor Komarov is Director General of Roscosmos since 21 January 2015) and Xu Dazhe, Heads of the two space agencies, also discussed issues of bilateral cooperation in the field of electronic components for rocket construction and building rocket engines. But no details were given.
- On 12 January, TASS reported that Sergey Savelyev, the Deputy Chief of Roscosmos had ruled out the possibility of a Chinese spaceship docking with the ISS, due to technical issues such as a higher inclination of the ISS orbit. He denied an earlier report quoting Roscosmos' former Head Oleg Ostapenko of the plan for taikonauts to visit the ISS and cosmonauts to visit the CSS. Savelyev also told TASS that possible dockings of Russian spaceships with the Chinese station "are not taken seriously" at this moment. He indicated that the most probable projects in the immediate future, are joint experiments onboard the Russian segment of the ISS, and might further include experiments onboard OKA-T orbiting unmanned modules, the planned free-flying platforms occasionally docking with the ISS.
- On 27 January, another TASS report revealed that Russia has drafted a proposal for a joint space station for the five BRICS nations: Brazil, Russia, India, China and South Africa. The document, compiled by Russia's Military-Industrial Commission, could become a subject of discussion during this year's BRICS summit.

In recent years, China has strengthened space cooperation in South-East Asia. The following events were reported in the first three months of 2015:

- On 11 March, the first meeting of the Sino-Indonesia Joint Committee on Space Cooperation was held in Beijing, setting a new starting point in space cooperation between the two countries.
- On 2 February, a workshop on a feasibility study for the APSCO Multi-role Smallsat was held in Beijing, pushing the long-stalled project a small step forward.
- Thai Prince of Songkla University (PSU) Phuket campus, signed a Memorandum of Understanding (MoU) with China's National Space Science Center (NSSC) on 27 January to solidify an agreement for further collaboration between the two organisations in the areas of space science and technology research.
- On 12 February, a partnership agreement was signed between the China Centre for Resources Satellite Data and Application (CRESDA) and the Centre for Remote Imaging, Sensing and Processing (CRISP) of the National University of Singapore (NUS). It is Singapore's first official collaboration with China in the field of space and satellite technology. Under the agreement, CRISP will be appointed as the main station in South-East Asia to directly receive and distribute data from the CBERS 4, the China-Brazil Earth Resource Satellites, launched on 7 December 2014.

The Chinese space programme also extended to Latin America. On 26 February, Argentina's lawmakers of the National Congress gave approval for building a Chinese satellite tracking station in the country's Patagonia province. A 35 m diameter antenna will be built as part of China's deep space tracking network. The first mission it is planned to support, will be the Chang'e 5 lunar sample return mission in 2017.

Commercial Space

Chinese media updated news on the status of two commercial satellites in development:

- The ground station of LaoSat 1 was completed in Vientiane in March. It is part of the deal to in-orbit deliver a DFH-4S satellite to be launched in 2015.
- During the Chinese New Year holidays in February, the Belarus communication satellite completed assembly, laying the foundation for the follow-on mechanics testing.

On 6 January, a Chinese startup "New Space" company, Space Vision, launched a project labeled as "tourism at the edge of space". It plans to send a passenger cabin to 40,000 m above the ground using a super helium balloon to experience something similar to a real space flight. The company will select 10 people from applicants who will pay RMB 500 thousand (US$80,000) and participate in 100 hours of parachute training for the 5-hour flight. It had scheduled the first test flight in July and the first commercial flight by the end of this year. Jiang Fang, the President of the company, is also the first Chinese who booked a sub-orbital space flight on the Space Adventure vehicle in 2005. Jiang said his company had received technical support from multiple space research centres in China for its tourism project.

Artist's impression of the 'edge of space' tourist vehicle.
(credit: Space Vision)

Miscellaneous

Ground Facility

In the Xichang Satellite Launch Centre, facilities on Pad 3 including the launch tower, completed a new round of conversion to support the launch of CZ-3C. The pad was originally built for the CZ-3 basic model and was reconstructed before the Chang'e 1 launch in 2010 to support the CZ-3A launch vehicle. It is expected to be put into use in the second half of 2015.

After a construction period of three years, the micro-vibration test laboratory was put into use in CAST. Micro-vibration resistance is key to the image quality of high-resolution imaging satellites. During its construction, the laboratory had already been used to test dynamic vibration characteristics of the GF-2 satellite that verified the design of the satellite's vibration isolator.

In mid-March, the China Remote Sensing Satellite Ground Station (CRSSGS) of CAS revealed to Chinese media that a new ground station, named the Arctic Station, will be built in Sweden. It will be the fourth station and the first overseas station to expand the current network which includes the three existing stations in Miyun, Beijing, Kashi, Xinjiang and Sanya, Hainan, respectively. CRSSGS is a member of the Landsat Ground Station Operations Working Group and is responsible for receiving and distributing data from LANDSAT, SPOT, RADARSAT, ENVISAT, and all Chinese resource satellites.

(Chen Lan)

Micro/Nano Satellite Technologies and Applications in China

by Wu Shufan, Chen Hongyu

BX-1 satellite (credit: Go Taikonauts!)

Micro/nano satellite technologies are becoming more and more active in China, from universities to research institute and industries, from scientific research to technology demonstration and to practical applications. Some launched project examples are: Chuangxin-1 (CX-1), the first Chinese micro satellite used for telecommunication built in Shanghai; Naxing-1, the first nano satellite built by a Chinese university in Beijing; Banxing-1 (BX-1), a micro satellite used to provide in-orbit images of the SZ-7 orbit module to inspect the space module and to conduct in-orbit proximity operations, built in Shanghai as well; ZDPS-1A, the first pico satellite at kilogram level built by a Chinese university in Hangzhou; Tianxun-1 (TX-1), a micro satellite for Earth observation built by a university in Nanjing; Tiantuo-1, another nano satellite at kilogram level built by university students in Changsha, etc. There are many on-going projects for micro/nano satellites in universities, research institutes, and space industries across China. Recently, several universities in China are participating in the QB50 project in Europe, by providing CubeSat platforms to carry science payloads from QB50 for space science. This paper gives a general overview of past and on-going projects and activities in the small/micro/nano satellite engineering sector in China, discuss their related technologies, research and development activities and applications, introduce the major players in the micro/nano satellite sector in China, and provide a prospective outlook to the near future.

I. Introduction

Since the mid-1980s, small satellites with a mass below 1,000 kg became more and more active and popular in space science and engineering. Entering the 21st century, satellites became even smaller and smaller, with the emergence of micro satellites, nano satellites, and pico satellites. Generally speaking, the classification of small/mini/micro/nano/pico satellites is mainly based on their mass[1], while there are many different definitions for the range of each satellite category given by different authorities and manufacturers[3]. In this paper, a SmallSat has a mass between 500 and 1,000 kg, a MiniSat has a mass between 100 and 500 kg, a MicroSat has a mass between 30 and 100 kg, a NanoSat has a mass between 1 kg and 30 kg, and a PicoSat has a mass below 1 kg. Compared to traditional large satellites, the small satellites have many advantages and special features in terms of technology and applications, some of them are listed here:

- Miniaturisation in mass, size, and structure.
- Minimisation of overall system design.
- Faster building time.
- Faster innovation.
- Lower cost of manufacturing.
- Ease of mass production.
- Lower overall cost for launch.
- Ability to be launched in groups, or 'piggy-back'.
- Ideal test-bed for new technologies.
- Minimal financial loss in case of failure.
- Enhanced capability via satellite network.
- Using formations or constellations to gather data from multiple points.
- In-orbit inspection or as a companion of a larger satellite.
- And more …

The international space community has seen a steady increase of small/mini/micro/nano satellites over the whole satellite production, as illustrated in Figure 1.

The development of micro/nano satellites in China is in its infancy compared to the rest of the world. The first micro satellite built in China was launched 10 years ago. Since then, around 10 micro/nano satellites have been manufactured and launched into space by China, with different purposes and applications. Many new players are joining the club of micro/nano satellites, leading to a rather more prospective future.

II. Small/Micro/Nano Satellite Projects and Applications in China

The development of small satellites in China started in the 1990s, and the launch of the small science satellite of SJ-5 in 1995, representing the maiden flight of the CAST968 platform, which marked the first Chinese small satellite[2]. From then on, up until the end of 2011, China has launched 45 various small/mini/micro/nano satellites, plus 2 more satellites being bought from SSTL of the UK. These 45 indigenous satellites are manufactured by 10 different players in China, accounting for about 38.46 % of the total 117 satellites launched in China during this period[3]. Among them, 3 satellites fall in the category of NanoSats, 8 satellites in the category of MicroSats, and the rest fall within the category of small and mini satellites, as illustrated in Figure 2. When classified by their mission purposes, In Orbit Demonstration (IOD) amounts to 11 %, space science amounts to 9 %, Earth Observation takes up another 9 %, and the remaining 69 % are used for military services. When looking at their users or customers, 16 % are used by

No	Satellite	Manufacturer	Launch Date	Mission	Remarks
1	SJ-5	CAST	1995.5.10	space science, IOD	300 kg, 1.2 m cube box, CAST968A prototype, modulated platform design, USB transponder
2	HY-1A	CAST	2002.5.15	ocean resources survey	368 kg, size: 1.2×1.1×1 m, 3-axis stabilised, GPS orbit determination, SADM device, SSO orbit maintenance
3	HY-1B	CAST	2007.4.11	ocean resources survey	More advanced payloads for ocean resources observation
4 5	HJ-1-A HJ-1-B	CAST	2008.9.6	Earth observation, environment and disaster monitoring	payloads: optical instrument and SAR, constellation of 2+1 satellites, resolution 5-300 m, see Ref [4]
6	BJ-1	SSTL & Beijing City	2005.10.27	Earth observation	166.4 kg, size: 900×770×912 mm, 5 years orbit life
7	Tsinghua-1	SSTL & Tsinghua Uni.	2000.6.8	Earth observation, education, environment and disaster monitoring	49 kg, size: 330×330×640 mm, CMOS camera, data storage and transfer
8	NX-1	Tsinghua University	2004.4.18	Earth observation and technology IOD	< 25 kg, size: 0.04 m^3, 3-axis stabilised, on-board software can be fully uploaded from ground
9	TC-1	China SpaceSat Co	2003.12.30	Double Star, cooperation with ESA	335 kg, cylinder shape 2.1(d)×1.4(h) m, orbit: 550x66,970 km, inclination: 28.5 deg
10	TC-2	China SpaceSat Co	2004.7.25	Double Star, cooperation with ESA	343 kg, orbit: 700×39,000 km, inclination: 90 deg
11	SY-2	China SpaceSat Co	2004.11.18	Earth observation, technology IOD	CAST2000 platform, ~300 kg, IOD for attitude control, new power system, modular structure, etc.
12	SY-1	HIT	2004.4.18	Earth observation technology IOD	204 kg, magnetic & wheel attitude control, high agility, pointing accuracy and stability, CCD camera
13	SY-3	HIT	2008.11.5	new technology IOD	compact design, on-board autonomy
14	CX-1A	SECM	2003.10.21	LEO telecommunication	88 kg, size: 590×590×650 mm, 3-axis stabilised
15	BX-1	SECM	2008.9.25	companion of the SZ-7 space module, IOD	40 kg, in-orbit release, rendezvous and fly-around, new tech on battery, cold-gas propulsion, USB transponder, etc.
16	CX-1B	SECM	2008.11.5	LEO telecommunication, space science	mass: 203 kg, size: 900×900×800 mm, orbit: 791 km
17	ZDPS-1A	Zhejiang University (ZJU)	2010.9.22	technology IOD, MEMS	3.5 kg, 150×150×150 mm, optical hemispheric camera
18	YH-1	SAST	2011.11.8	Mars exploration	115 kg, 750×750×600 mm, failed to reach the Martian orbit due to launch
19	TX-1	NUAA	2011.11.9	new technology IOD	61 kg, size side cylinder φ694mm×876mm
20	TT-1	NUDT	2012.5.10	technology IOD, AIS, camera, space science	9.3 kg, 425×410×80 mm

Table 1: Mini/micro/nano satellites launched in China by the end of 2012 (non exhaustive)

scientific research institutes and universities, 13 % are used by governments for civil services, and the remaining 69 % used for military customers[3]. Table 1 provides a brief overview of some small satellite projects which are publicly reported.

Since this paper focuses on the micro/nano satellites, with a mass below 100 kg, only the micro/nano satellites listed in Table 1 are briefly discussed in more detail below.

II.I CX-1 Micro Satellite

CX-1 (ChuangXin-1, also called Innovation No. 1)[1] is the first micro satellite built in China to be used for low Earth orbit satellite communication. It serves as a 'store and forward' communication satellite, developed by SECM. It weighed 88 kg at launch and had dimensions of 0.59 m x 0.59 m x 0.59 m, with a rectangular box-shape as illustrated in Figure 3. It was

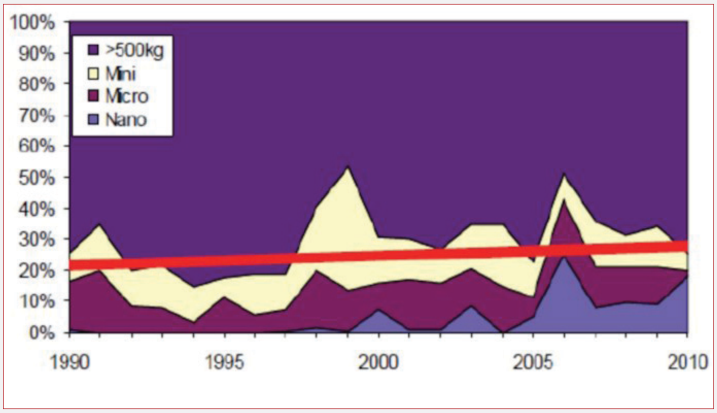


Figure 1: Constitution of global launched satellites [3]

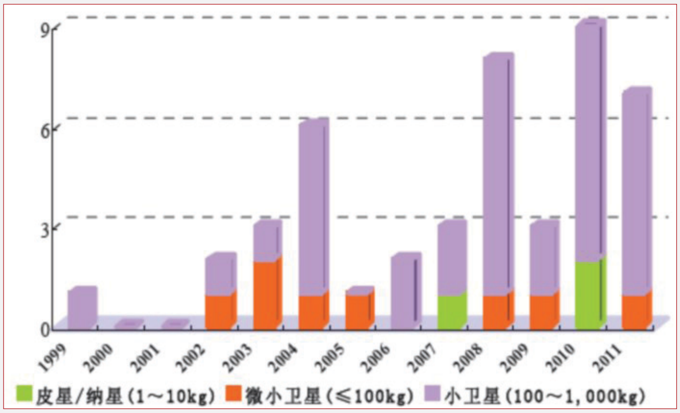


Figure 2: Small satellites launched in China [3]

launched on 21 October 2003 on a CZ-4B launch vehicle as a passenger (i.e. piggy-back) of CBERS 2 (China Brazil Earth Resource Satellite) from the Taiyuan Space Centre. It flies on a sun synchronous orbit of 751 kilometres, 99.7 minute orbital period and 7 day regression cycle. CX-1 has several UHF frequency band communication transceivers, and operates at 2.4 kbps and 19.2 kbps. Equipped with bias momentum wheels, magnetic torquers and a gravity-gradient boom, it is a three-axis stabilised micro satellite

CX-1 has demonstrated many key technologies for micro satellites, such as LEO spread spectrum communication, active magnetic control, orbit prediction and satellite autonomous self-management, etc. Additionally, much progress was also made in the miniaturisation of its ground communication terminals, which weigh just a bit more than 200 g, being developed based on wireless software technologies. The terminals are equipped with the satellite calendar prediction function with time receiving/dispatching capabilities, and thus can withstand various strong disturbances.

II.II NX-1 Nano Satellite

NX-1 (NaXing-1, or NanoSat-1) marked the first nano satellite in China below 30 kg, developed by Tsinghua University together with its joint venture of Space Science and Technology Satellite Technology Ltd. It weighed 25 kg, with a 6 side-panel configuration as shown in Figure 4. It was launched as a piggy-back by a Long March 2C rocket from Xichang Satellite Launch Center at 16:00 UT on 18 April 2004, together with the main passenger, the SY-1 satellite built by the Harbin Institute of Technology (HIT). It had an orbit of 598 km, and is three-axis attitude stabilised, carrying a set of new technology demonstration instruments, including a CMOS camera for Earth observation, a MEMS inertial sensor, a GPS receiver, etc. The mission is aimed at new technology in-orbit demonstration (IOD), including new sensors, on-board software up-loads, CMOS imaging in space, orbit control and maintenance, among others.

II.III BX-1 Micro Satellite

The BX-1 (BanXing-1), a companion micro satellite of the SZ-7 manned spaceship, was developed by SECM, with a mass of 39.8 kg (including 1.0 kg of propellant). Its deployment marked the smallest micro satellite in China used for in-orbit monitoring of a manned spaceship. Its configuration is illustrated in Figure 5, with a volume size of 450 × 430 × 450 mm. The BX-1 mission had mainly three tasks for in orbit experiments in the Shenzhou VII mission: the in-orbit release, capturing images of the SZ-7 spaceship, and the companion flying (flying around) experiment.

Figure 3: CX-1 micro satellite

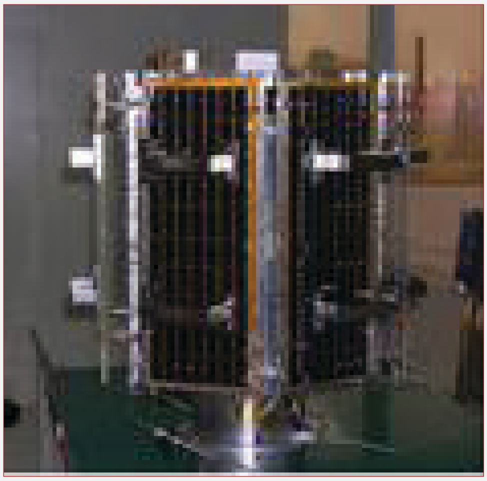


Figure 4: NX-1 nano satellite

BX-1 carried two small cameras, a wide field-of-view camera and a narrow one, to meet the requirement to provide high-resolution colourful imagery of the Shenzhou-7 spaceship from several metres to several kilometres, with a frame rate of up to 12 fps. These two cameras share the same electrical circuits. A real-time image compression algorithm is applied on-board to improve the storage efficiency. The wide-FOV camera has a focal length of 10 mm, with a FOV of 35 × 45 degrees. The narrow one has a focal length of 50 mm with a FOV of 7 × 9 degrees.

BX-1 was a three-axis stabilised spacecraft, with attitude measured by three sun sensors, a rate sensor and a magnetometer and controlled by one bias momentum wheel and three magnetic torque rods. The spaceship

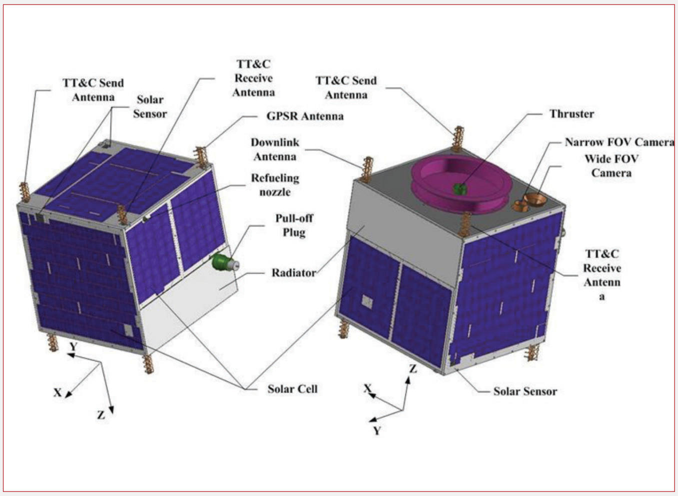


Figure 5: Configuration of BX-1

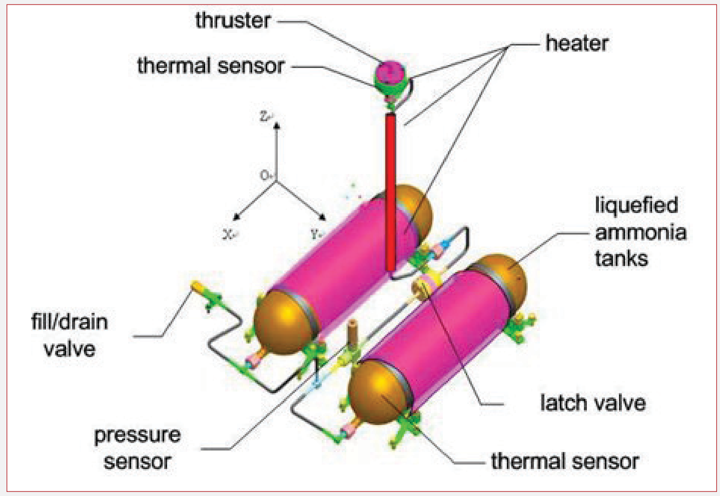


Figure 6: BX-1 Cold-Gas thrusters

pointing accuracy was about 2 degrees, with a stability of 0.1 °/s.

The cold-gas propulsion system of BX-1, as illustrated in Figure 6, used liquid ammonia as propellant, which has many advantages such as non-pollution, low cost and small control impulse, and is well-suited for micro satellites. It consists of one fill/drain valve, one filter, one latch valve, one pressure sensor, one cold gas thruster, a set of heaters, two liquefied ammonia tanks and two thermal sensors.

The BX-1 companion satellite used a USB TT&C mechanism, controlled by BACC through S-band antennas. The uplink of S-band TC commands had a rate of 2,000 bit/s, while downlink had a rate of 4,000 bit/s. BX-1 was also equipped with a high-speed S-band down-link at a rate of 768 kbit/s, for rapidly transmitting in-orbit observation data to the ground. The TT&C and data downlink sub-systems can back up each other in case of failure.

In the Shenzhou VII mission, it was the first time that a micro satellite, the BX-1, was released successfully in orbit from a manned spaceship of China, so that imagery data and videos of the manned spaceship flying in orbit were obtained in real-time. Figures 7 & 8 illustrate two example pictures taken by BX-1 at different times after its release. The total companion flying time was up to 100 hours. The technologies, such as the orbital manoeuver for target approaching, companion flying and maintenance, have been successfully validated and demonstrated through this mission. It demonstrated a new and promising application field for micro satellites – in-orbit companion flying, formation flying, and potential docking with a space station or another satellite.

II.IV ZDPS-1A Nano Satellite

ZDPS-1A marked the first kg-level satellite in China, which was wholly self-developed by a student team from Zhejiang University in Hangzhou. As China's smallest satellite so far, the ZDPS-1A, weighing a mere 3.5 kilograms, had a cube shape with a side length of 15 centimeters, and required a working power source of only 3.5 Watts, as illustrated in Figure 9. It was used to demonstrate the pico satellite platform and verify advanced technologies such as MEMS and miniaturised optical hemispheric imaging. The satellite comprises the electrical power system (EPS), S-band transponder, instruction execution

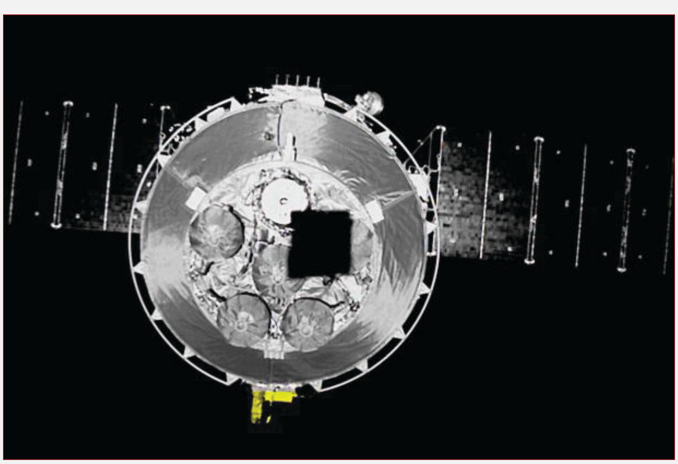


Figure 7: Photo of SZ-7 taken by BX-1 at 6 sec after release

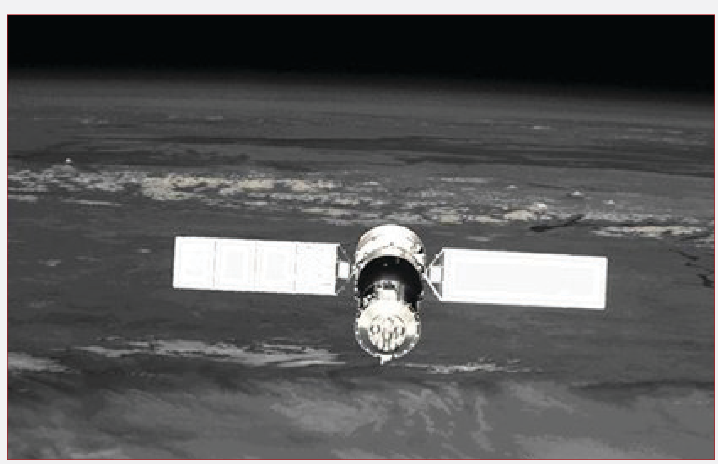


Figure 8: Photo of SZ-7 taken by BX-1 at 230 sec after release

Figure 9: ZDPS-1A nano satellite

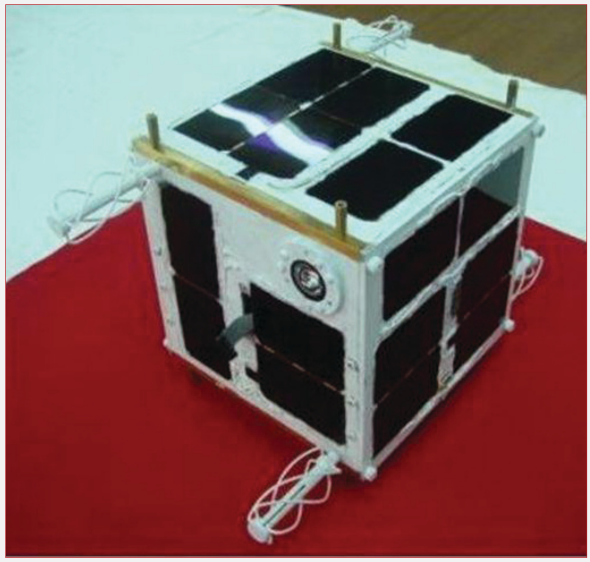


Figure 10: The TX-1 micro satellite

Figure 12: Tsinghua-1 micro satellite

unit (IEU), three-axis stabilisation ADCS, on-board computer (OBC) and payloads, structure and thermal control sub-systems, and the deployment structure.

II.V TX-1 Nano Satellite

TX-1 (TianXun 1) is a micro satellite built by the Nanjing University of Aeronautics and Astronautics. The mission was mainly for technology demonstration as the first effort of the university in satellite engineering. With a total mass of ca. 60 kg, its main payload was a 2.5 kg CCD camera built by Suzhou University, with a resolution of roughly 30 meters. It has a special shape with 6 side panels, sized 694(d) x 856(h) mm as illustrated in Figure 10. It was launched as a piggy-back on 9 November 2011 from the Taiyuan Space Center, together with the Yaogan 12 satellite, by an LM-4B rocket. It had an orbit of 483 km with an inclination of 97.4 degrees.

II.VI TT-1 Nano Satellite

The TT-1 (TianTuo 1) was a 9.3 kg nano satellite built by the National University of Defense Technology (NUDT), with a size of 425 × 410 × 80 mm. The satellite performed experiments on optical imaging, detection of on-orbit atomic oxygen intensity and received signals from the marine Automatic Identification System (AIS). Its major characteristic is the one-board design philosophy, i.e. the satellite is built based on one board to integrate all the necessary electronics and functions, as illustrated in Figure 11.

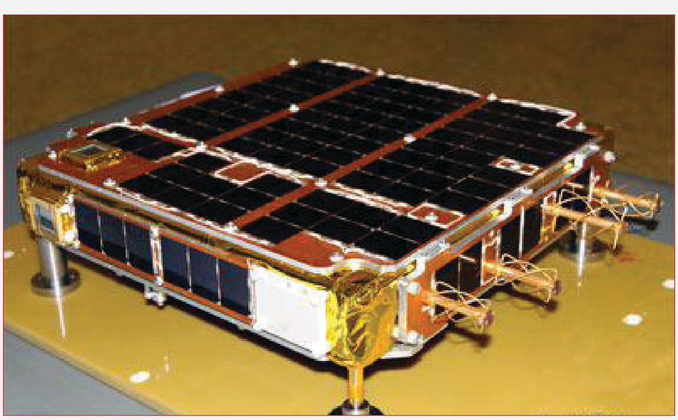


Figure 11: The TT-1 nano satellite

II.VII Tsinghua-1 Micro Satellite

Tsinghua-1 represents the first micro satellite in China for Earth observation, which was built by SSTL in the UK with an engineering team from Tsinghua University. It served as the first demonstrator for the Disaster Monitoring Constellation (DMC) and carried multi-spectral Earth imaging cameras providing 39-meter nadir ground resolution in 3 spectral bands. It also carried out research in low Earth orbit using digital store-and-forward communications, a digital signal processing (DSP) experiment, a Surrey-built GPS space receiver and a new 3-axis micro satellite attitude control experiment. It utilises three reaction wheels to provide full 3-axis agility on a micro satellite platform. Figure 12 illustrates its configuration. It was launched on 28 June 2000, together with Nadezhda 6/COSPAS and SNAP-1 nano satellite from SSTL, on-board a Kosmos 3M launcher.

III Major Micro/Nano Satellite Players in China

Small satellites, especially micro/nano satellites, are emerging very quickly, and thus attracting more and more attention and players. From industrial enterprises, there are mainly the China SpaceSat Co. and its daughter companies, the Shanghai Academy of Space Technologies (SAST), and the Shanghai Engineering Center for Microsatellites (SECM). Meanwhile, more players are emerging from universities, such as Tsinghua University, Harbin Institute of Technology (HIT), Nanjing University of Aeronautics and Astronautics (NUAA), Zhejiang University (ZJU), National University of Defence Technologies (NUDT), as well as Northwestern Polytechnical University (NPU), Beijing University of Aeronautics and Astronautics (BUAA), and

Nanjing University of Science and Technology (NUST), etc. In the following sections, a brief introduction to the major players is elaborated based on publicly available information.

III.I China SpaceSat Co.

China SpaceSat Co. Ltd. (also called Dongfanghong Satellite Company, or DFH) is a spin-off company from the Chinese Academy of Space Technology (CAST), the flagship in China's satellite engineering. DFH was inaugurated in 2000, focusing mainly on small and mini satellite engineering technologies and applications. It entered the stock market in Shanghai, becoming a well-known enterprise for small satellite engineering[6]. It has developed and produced several small satellite platforms, which are used in missions for mobile communication, ocean exploration, surveying and mapping, defence and others, as well as aerospace components, such as space-borne and ship-borne navigation terminals, aerospace power supplies, aerospace film heaters and others. Together with its subsidiaries, such as the Aerospace Dongfanghong Development Ltd. in Shengzhen, it has developed a few matured small satellite platform buses, such as CAST1000, CAST968/2000, and CAST3000, and is continuing to develop new satellite buses, e.g. CAST 4000. It will remain the major player in small/mini satellite engineering in China, and has the ambition to enter into the micro satellite engineering field.

III.II SAST

Shanghai Academy of Spaceflight Technology (SAST) is another flagship, in parallel to CAST, in China's satellite engineering. Its main business focuses on meteorological observation, remote sensing, electronic surveillance, etc., all with big satellites. However, recently it entered also into the small and mini satellite fields, with a representative product of the scientific mini satellite YH-1, for Mars exploration, which failed due to a launcher failure. It has the plan to develop a small satellite platform, the SAST100, which will play an active role in China's small/mini satellite sector.

III.III SECM

The Shanghai Engineering Center for Microsatellites (SECM) is the major player in micro/nano satellite engineering in China. It was inaugurated on 15 September 2003, with joint investments from the Chinese Academy of Sciences (CAS) and the Shanghai City Government. It holds also the Chinese Academy of Science's united key micro satellite laboratory and serves as a postdoctoral study site in electronic science and technology. Meanwhile, it is qualified to enrol and cultivate Master's and Doctoral students.

The predecessor of SECM was the Chinese Academy of Science's Shanghai Department of Microsatellite Engineering, a unit within the Shanghai Institute of Microsystem and Information Technology (SIMIT), with staff from the SIMIT and the Shanghai Institute of Technical Physics, as well as the SAST and Shanghai Telecom Co., Ltd. It began independent research and development of the first Chinese micro satellite weighing less than 100 kilograms in 1999: the CX-1, as discussed above. The main research fields of SECM include: the integrated design and development of micro, nano, and pico satellites, research work on key technologies for low Earth orbit communication and high-precision micro satellites, as well as exploration and research into new technologies in micro satellite control systems, on-board computers, power supply and application systems. SECM has adapted to international space science's ever-developing technology and applications, insisting on innovations in technology, structure, and mechanisms, while also enthusiastically engaging in both international and domestic multilateral collaboration. Driven by its work in micro, nano, and pico satellite system technology and applications, SECM is engaging in research on innovative space-related technologies, bringing along R&D work on MEMS, new materials and components, new energy resources and new payload types. SECM is becoming a technical platform and innovation base in the development of micro, nano, and pico satellites for the Chinese Academy of Sciences and the Shanghai City Government.

With rapid development, SECM is extending its business into mini and small satellite engineering. It is now engaged in manufacturing several small/mini satellites, such as SVOM, TANSat, and QUESS, as well as the navigation satellites of the Chinese Compass (Beidou) system. It is also building a large satellite, DAMPE, with a mass far above 100 kg. It will continue to be the prime player in micro/nano satellites, and extend its business into small and eventually large satellite engineering.

III.IV Tsinghua University

The School of Aerospace of Tsinghua University was founded in 2004 on the basis of the Department of Engineering Mechanics. It consists of two departments, and two research centres, the Space Center, and the Aeronautics Technology Center. The space centre has engaged in the research and development of micro/nano satellite engineering. Two satellites, the Tsinghua-1 and NX-1, have been developed and launched into space by the university and its partners. They are still active in developing and providing sensors and components, as well as platforms for micro/nano satellites.

III.V Harbin Institute of Technology (HIT)

The Harbin Institute of Technology (HIT) was founded in 1920. It has been making great contributions to China's space technology and engineering. The Shenzhou Series Spaceship Project has received massive assistance from HIT in the field of large-scale land-based space simulation equipment, returning cabin deformation and orthopraxy (right practice) welding technology, 3-axis simulation experimental platform and fault diagnosis. In 2004, the mini satellite SY-1, constructed mainly by HIT, was the first mini satellite fully developed and launched by a Chinese university. In 2008, HIT launched its second mini satellite – SY-3. The two satellites were developed by its Research Center of Satellite Technology (RCST), which was founded in 1998. Its research activities cover a wide range of satellite engineering, such as satellite dynamics, guidance and control, experimental validation of small satellites, novel concepts and applications of small satellites, miniature technologies of small satellites, etc. It is engaged in several micro/nano satellite projects, such as the QB50 CubeSat mission.

III.VI Zhejiang University (ZJU)

Zhejiang University (ZJU) has developed the ZDPS-1A nano/pico satellite, representing the smallest satellite ever built in China up to the time of writing this paper. It was built by a group of teachers and graduate students from the Department of Information Science and Electronic Engineering (ISEE), based on which the university has set up the research centre for micro satellites, dedicated for nano and pico satellite research and engineering. It is very active in developing smart sensors and actuators, and components and sub-systems for nano/pico satellites. Currently it is developing a few new nano satellites, as well as participating in the QB50 CubeSat mission.

III.VII NUAA

The Nanjing University of Aeronautics and Astronautics (NUAA) is another university engaged in micro satellite engineering. In the early 20th century, it set up the Academy of Frontier Science, aimed at developing key scientific research fields, promoting the growth of new cross-disciplines, and exploring key aviation areas. Under the academy, the Microsatellite Engineering Technology Research Center was built-up, which has developed its first satellite, the TX-1 micro satellite. Built in 1952 by merging a few aeronautical departments of several universities, NUAA has featured mainly with aeronautical technologies, while in recent years, it has extended its scope into space technology, as well as social disciplines.

III.VIII NUDT

The National University of Defence Technology (NUDT) is a comprehensive national key university under the dual supervision of the Ministry of National Defence and the Ministry of Education. Over the past 50 years NUDT has developed into a comprehensive university of science, engineering, military science, management, economics, philosophy, literature, education, law and history. The satellite research and development is carried out in it's Institute of Space Technology. Their first nano satellite, TT-1, is featured with a single board configuration. They are now in the process of developing their second nano satellite, as well as a CubeSat for the QB50 mission.

III.IX Other Emerging Universities in Micro/Nano Satellite Technology and Engineering

With the rapid and attractive development of micro/nano satellites in China, more and more universities are starting-up their satellite projects and research activities, though no satellites have been built and launched. Beijing University of Aeronautics and Astronautics (BUAA), one of the major aerospace universities in China, has started its micro satellite project, the BUAA-Sat, for a couple of years, it participates also in the QB50 mission of the EU. Northwest Polytechnical University (NPU), another major aerospace university in China, has also set up a key laboratory for micro satellites under the support of the Shanxi provincial government. It participates in the QB50 project and serves as the regional QB50 coordinator for Asia. Nanjing University of Science and Technology (NUST) is another university which has entered into the nano/pico satellite engineering field. NUST is participating in the QB50 project and has a plan to build and launch a CubeSat soon. ShanghaiTech University, a newly set-up technical university in Shanghai, has participated the QB50 project by contributing the STU-1 Cubesat, together with the CAS key laboratory for micro satellites in SECM.

Additionally, a few top-level Chinese universities, such as the Beijing University, Nanjing University, Shanghai Jiaotong University, etc., have shown their interest in satellite engineering. Some of them had shown the intention of participating in the QB50 project, but failed to proceed. Sooner or later, they might become new members in the micro/nano satellite club in China.

IV Perspective

Small satellites, especially the micro/nano satellites, are becoming more and more attractive in the worldwide space community. In the past decade, the introduction of the 'CubeSat standard' has brought the micro/nano satellite into a 'CubeSat Era', which has greatly pushed forward nano satellite technologies and applications.

IV.I The CubeSat Era

In 1999, the CubeSat concept and standard were developed by the California Polytechnic State University and Standford University, which set up a set of standards or specifications to help universities worldwide to perform space science and exploration[7]. A CubeSat is a type of miniaturised satellite for space research that usually has a volume of exactly one litre (i.e. a 10 cm cube), has a mass of no more than 1.33 kg, and typically uses commercial off-the-shelf components for its electronics. Since then, the CubeSat standard has been accepted worldwide and inspired many universities to develop their own CubeSat project and technologies, which further produced a lot of spin-off high-tech companies dedicated to the CubeSat community. The standard 10 x 10 x 10 cm basic CubeSat is called a '1U' CubeSat, meaning one unit. CubeSats are scalable along only one axis, by 1U increments, based on that, CubeSats such as a '2U' CubeSat (20 x 10 x 10 cm) and a '3U' CubeSat have been built and launched. The CubeSat standard has brought the NanoSat world into a 'CubeSat Era'[8], as illustrated in Figure 13.

IV.II Worldwide Future Perspective

The field of micro/nano satellites has entered into a fast and wide development period and has grown considerably, boosted by ever-increasing space application demands, technology advancements, the entrance of new developers, and wider applications. The CubeSat standard, triggering a worldwide CubeSat campaign, further speeds up this development pace. Looking at the near future, there are many space projects and missions dedicated to the micro/nano satellite community, such as[8]:

- QB50 project will launch a network of 50 2U/3U CubeSats in 2014/2015.
- NRO Colony I will launch 12 CubeSats over the next few years.
- NRO Colony II will launch an additional 20-50 CubeSats following Colony I.
- DARPA Airborne Launch Assist Space Access (ALASA) plans to launch approximately 36 microsatellites beginning in 2015
- Additionally, micro/nano satellite initiatives are underway, such as Innovative NanoSat Experimental Series (INXE) and DARPA F6.

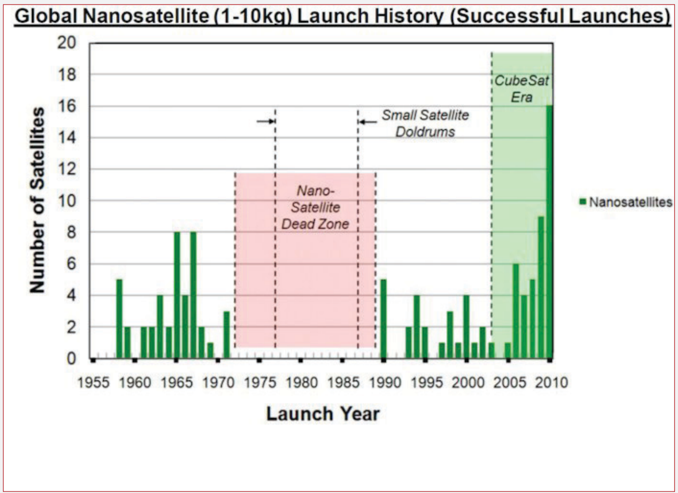


Figure 13: Global NanoSat (1-10 kg) launch history (credit: SpaceWorks[8])

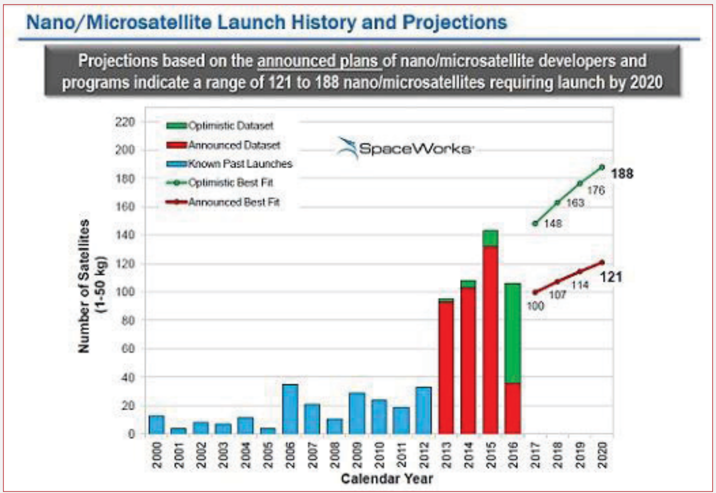


Figure 14: Micro/NanoSat (1-50 kg) Launch Demand History and Projections (credit: SpaceWorks[10])

From another perspective, with continued advances in the miniaturisation and capability increase of electronic technology and the use of satellite constellations or networks, micro/nano satellites are increasingly capable of performing commercial missions that previously required micro or mini satellites. For example, a 6U CubeSat standard has been proposed to enable a constellation of 8.1 kg Earth-imaging satellites to replace a constellation of five 156 kg RapidEye Earth-imaging satellites, at the same mission cost, with significantly increased revisit time: every area of the globe can be imaged every 3.5 hours rather than the once per 24 hours with the RapidEye constellation. More rapid revisit time is a significant improvement for nations doing disaster response, which was the purpose of the RapidEye constellation. Additionally, the nanosat option would allow more nations to have their own satellite for off-peak (non-disaster) imaging data collection[9].

Based on the past launch history and the known launch needs in the near future, SpaceWorks[10] has made a prediction of the global launches of micro/nano satellites in the range between 1 and 50 kg, as illustrated in Figure 14. As may be seen, in 2020, the predicted launch need on micro/nano satellites lies between 121 and 188 per year, which is more than the current total launch number of all satellites worldwide per year.

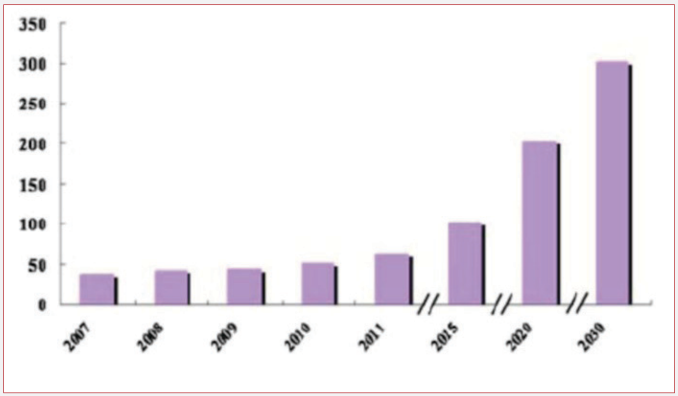


Figure 15: History and prediction of in-orbit satellites in China

IV.III Perspective in China

In China, the micro/nano satellite sector is still in its start-up phase. So far, only approximately a dozen of micro/nano satellites have been built and launched, and none of them are based on the CubeSat standard. However, this situation is changing. More players are joining this community in China, making the ambition or practical plan to design and build micro/nano satellites. For example, 7 teams from universities and institutes are participating in the QB50 projects, contributing 7 2U CubeSats in the near future. The table below gives an overview and prediction of the current micro/nano satellite players and on-going projects or missions in China.

Ref [3] made a rough counting of the on-going micro/nano satellite projects in China, which shows that ca. 10 nano satellite (< 10 kg) projects are currently on-going, and ca 20 micro satellite (10-100 kg) are on-going. Meanwhile, the overall number of satellites in orbit in China are predicted to increase rapidly, from the current 50 in 2011 upto 200 in 2020, and 300 in 2030, see the prediction chat in Figure 15, based on an estimation from the Chinese National Space Agency (CNSA). Among them, it can be foreseen the ratio of micro/nano satellite will certainly be increased accordingly.

V Summary

It can be predicted that there is a rapid and widespread development in China in the micro/nano satellite field, to eventually catch up with the international movement.

No	Player	Micro/Nano Satellites
1	China SpaceSat	Entering into the micro satellite field through its subsidiary company, the Aerospace Dongfanghong Development Ltd. in Shengzhen.
2	SECM	BX-2, Open NanoSat Platforms, CubeSat missions, STU-1 for QB50, and etc. It has many on-going activities. It is and continues to be the major industrial player in China in the micro/nano satellite sector, while also extending into small/mini satellite engineering. It is dedicated to innovative technologies and applications.
3	HIT	It is active in micro satellite engineering, and is entering into the nano satellite sector, e.g. via its Lilac-1 CubeSat for the QB50 project.
4	Tsinghua University	Active in nano satellite projects, sensors and components, for new technology demonstration.
5	ZJU	ZDPS-2 nano satellite, PhoneSat, ZJU-1 CubeSat for QB50, it stays mainly in the area of nano/pico satellite engineering.
6	NUAA	Active in microsatellite engineering
7	NUDT	NanoSat projects for AIS, a 2U CubeSat for the QB50 project, continues to be an active player in the field of nano satellites.
8	BUAA	BHSat, & 2U CubeSat for QB50 – is about to become active in micro/nano satellite engineering expert.
9	NPU	2U CubeSat (NPU-1) for QB50
10	NUST	2U CubeSat (NUST-1) for QB50

Table 2: Active micro/nano satellite players and projects in China

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Europe and China Join Space Science Expertise

Europe and China aim at cooperation around space weather observatories

by Theo Pirard

The city of Liège (Belgium) welcomed the 11th edition of the ESWW (European Space Weather Week) from 17 to 21 November 2014. This annual event is organised by the Royal Observatory of Belgium, through the STCE (Solar-Terrestrial Centre of Excellence). Some 400 delegates of the community concerned by the aspects and effects of Sun-Earth interactions contributed to the success of this mainly scientific event.

During Session 3, related to space-based observing systems, a presentation was made of an innovative, small mission concept for solar and heliosphere science from the L5 (Lagrange) location. This mission, described by Benoît Lavraud from IRAP (Institut de Recherche en Astrophysique & Planétologie, Toulouse) is named INSTANT for INvestigation of Solar-Terrestrial Activity aNd Transients). It is currently proposed as a joint opportunity of the European Space Agency (ESA) and the China Academy of Sciences (CAS) in the ESA S-class mission programme. INSTANT consists of a 300 kg spacecraft based upon a “Made in Europe” 3-axis micro satellite bus and a 60 kg scientific payload. The actual plan calls for a Long March-2C launch in 2021 (during solar maximum period) and for an arrival at L5 position in 2023.

INSTANT is one of the favourite candidates for the selection in mid-2015 of a next S-class mission for ESA. Its payload will consist of instruments from France (IAS, IRAP), China (NSSC), United Kingdom (RAL), Germany (University of Kiel), and the Czech Republic. The budget, estimated at around some 100 million Euros, will be divided between ESA and CAS. It is described as a crucial tool for space weather forecasts.

Web Resources

link to the website of the 11th edition of the European Space Weather Week:
http://www.stce.be/esww11/

Can INSTANT become an instant success?
ESA and CAS are looking for an interagency scientific space mission

by Jacqueline Myrrhe

Fast mission selection processes are not really one of the strengths of the European Space Agency, ESA. Even less of an ESA strength are expedited mission implementations. However, what ESA and CAS (Chinese Academy of Sciences) are currently up to, is the selection and finally the implementation of a joint space science mission at a terrific speed.

It was only in November 2013, that ESA and CAS issued the announcement for the planned joint mission which would be implemented by ESA’s Directorate of Science and Robotic Exploration and the Chinese National Space Science Centre (NSSC) under the CAS. As a first step, the scientific communities in Europe and China were invited to get known to each other and to start communicating about responding to a joint call for proposals for such a mission. For that purpose, two comprehensive workshops have taken place in 2014, where scientists and space experts from ESA Member States and China have been presenting exciting scientific ideas for international space cooperation projects.

The 1st workshop on 25-26 February 2014 in Chengdu, China, saw 27 presentations and 18 poster presentations with highly versatile mission proposals ranging from space astronomy to solar physics, and space physics to fundamental physics.

The 2nd workshop gathered the two communities on 23-24 September 2014 in Denmark’s capital of Copenhagen.

For the Copenhagen workshop, the Programme Organising Committee (POC) scaled the programme down to 14 presentations and 5 posters while containing the wide scientific range of research. The INSTANT mission was still on the agenda and might have a chance to get even further. One of the advantages in the INSTANT mission concept is the mix of scientific objectives which include objectives of the once envisaged Kuafu space weather project. Kuafu had been a hopeful proposal for an ESA-China cooperation project in 2012. (compare: GoTaikonauts!, Issue 6) Unfortunately, the financial situation in the ESA Member States by that time did not allow for any – even not tiny – extra budget during the decision making process at the Ministerial Council in 2012. As a consequence, Kuafu had been dropped.

On 19 January 2015, ESA and CAS issued the “Joint Call for a Mission from the Chinese Academy Of Sciences (CAS) and the European Space Agency (ESA)” with the goal “to define a scientific space mission to be implemented by ESA and CAS as a cooperative endeavour between the European and Chinese scientific communities. The mission selected as an outcome of the present Joint Call will follow a collaborative approach through all the phases: study, definition, implementation, operations and scientific exploitation.”

ESA and CAS listed in their joint call the criteria the proposals have to meet:

- The proposed mission has to aim at a launch readiness in 2021.
- Proposals have to be co-signed by two Co-PIs, one affiliated with an ESA Member State institution, the other with a Chinese institution.
- Proposals have to explicitly demonstrate compliance with the technical and programmatic boundary conditions defined by ESA and NSSC…
- Data policy will have to comply with ESA and NSSC rules; this implies that all data will have to be public after a one-year proprietary period during which the data are the exclusive property of the Co-PIs for the purpose of scientific exploitation.
- All stages of the mission's scientific preparation and exploitation have to be carried out by joint teams. Data rights will be in all cases shared.
- Payload has to be jointly provided by European and Chinese teams.

The size of the contribution from ESA is envisaged to be comparable to that of a small (S-class) mission in the Science Programme, with a similar sized contribution from the CAS.

As is usual for ESA science missions, the ESA Member States are assumed to provide the European contribution to the payload elements.

Space segment requirements:

- spacecraft launch mass: < 300 kg;
- payload mass: < 60 kg;
- payload power: < 65 W;
- payload technology readiness: TRL ≥ 6 (ISO scale) for all payload elements;
- platform technology readiness: TRL ≥ 7 (ISO scale) for platform equipment;
- development schedule: < 4 years;
- lifetime in orbit: 2-3 years;
- potential launchers: from Kourou: Soyuz as passenger, VEGA as passenger or shared launch; from China: Long March 2C or 2D possibly as passenger;
- orbit: No a priori limitation, provided compatibility with launchers and schedule constraints;
- additional requirements: Compatible with the applicable debris regulations; Free from ITAR restrictions.

The scientists had time to respond until 16 March 2015. Until April, ESA and CAS were jointly screening the submitted proposals, looked into technical and programmatic feasibility, evaluated how realistic the proposed schedule is, how the mission fits into the budget constraints, and what the availability of funding for the payload elements is. Currently, the scientific peer review is on-going, carried out by a joint, co-chaired committee of European and Chinese scientists. The peer review committee will provide its advice to ESA and CAS, who will take the final decision about which proposal or proposals to select for a study phase. In late 2015, a selection of the proposal(s) for further study can be expected. The study phase is planned for 2 years while the implementation phase of 4 years would lead to a launch by 2021.

Provided all goes according to plan, ESA and China will see an interesting project evolving which gives both sides the opportunity to learn from each other in an unprecedented way - regardless which mission will finally make it to the launch pad. Even if INSTANT might not be the mission to fly, maybe ESA has learned substantially from this holistic approach for mission evaluation and later instant mission implementation.

Web Resources

web link to the Chinese website with information on the joint CAS-ESA space mission in Chinese language:
http://jm.nssc.ac.cn/

web link to the presentations of the 1st workshop:
http://sci.esa.int/cosmic-vision/53072-esa-and-cas-planning-for-a-joint-mission/?fbodylongid=2236

web link to the list of posters of the 1st workshop:
http://sci.esa.int/cosmic-vision/53072-esa-and-cas-planning-for-a-joint-mission/?fbodylongid=2237

web link to the presentations and posters from the 2nd workshop including the presentation on the INSTANT mission which was given on 24 September at 09:50 h:
http://sci.esa.int/cosmic-vision/54130-2nd-workshop-on-planning-for-a-joint-scientific-space-mission/?fbodylongid=2298

web link to the "Joint Call for a Mission from the Chinese Academy Of Sciences (CAS) And The European Space Agency (ESA)":
http://sci.esa.int/cosmic-vision/55262-joint-call-for-a-mission-from-the-chinese-academy-of-sciences-cas-and-the-european-space-agency-esa/

Alexey Leonov:
"I think China will be the second nation to land on the Moon."

by Jacqueline Myrrhe

Portrait of Alexey Leonov with his signature (credit: Fédération Aéronautique Internationale - FAI) and logo of the Soviet Voshkod 2 mission (credit: Wikipedia)

On 18 March 2015, the world space community celebrated the 50th anniversary of the first space-walk in the history of mankind. In 1965, Soviet cosmonaut Alexey Leonov was floating in open space and stayed for 12 min 9 sec outside his Voshkod 2 spacecraft while his crewmate Pavel Belyayev was waiting for him inside. The Fédération Aéronautique Internationale - FAI (World Air Sports Federation) as the world governing body for air sports, aeronautics and astronautics world records, recognised Leonov's performance as a world record in the discipline "Extravehicular duration in space". On the occasion of the 50th anniversary, FAI published an interview with Alexey Leonov on its web portal.

For the interview, Leonov was answering questions on his motivation for becoming a cosmonaut, on his extravehicular activity 50 years ago, his memories of this historic event and also on the cosmonaut selection process in the Soviet Union.

Additionally, Leonov was addressed with the question on the future of aeronautics to which he gave an interesting answer: "The International Space Station operations will carry on by extending the amount of time crews spend on board by one year. In 2 or 3 years' time, Chinese astronauts will be able to join the Station. The lunar landing programmes are making slow progress in the USA and Russia, and intensive research is being conducted in China. I think China will be the second nation to land on the Moon. We are also looking at ways at how to land on Mars, but the mission won't be able to take place earlier than in 2035, if all goes well on Earth."

For the full interview, consult the webpage:
http://www.fai.org/fai-slider-news/39340-interview-with-alexey-leonov-the-first-man-to-walk-in-outer-space