A Brief History of Space Science in China

WU Ji [1,*]

National Space Science Center, Chinese Academy of Sciences, 100190, Beijing, China

Abstract: The article briefly reviews the development history of space science in China, from the preparation period in the 1950s and 1960s, the first science mission Double Star Program (DSP), to the current Strategic Priority Program (SPP) on space science of the Chinese Academy of Sciences (CAS). Both science objectives and payload technologies of the missions are addressed. The key management issues, such as long-term planning and the maximization of science output, are also mentioned. In addition, it also stresses the importance of international cooperation in space science.

Key words: space science, history, lifetime management, international cooperation

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1. Starting and foundation (1949–1970)

Space science is a cross-disciplinary research field created since the first artificial satellite Sputnik was launched in 1957 by USSR. Before that, the study of the earth magnetic field and atmosphere, the upper atmosphere and ionosphere in particular, fell into the scope of Earth science as its individual sub-branch. Chinese Scientists in those fields were mainly working at the Institute of Geophysics of CAS.

In 1957, right after the Sputnik was launched, several well-known scientists from CAS,

* Correspondence may be addressed at: wuji@nssc.ac.cn.

1. Dr. WU Ji is the President of Chinese Society of Space Research, and Former Director-General and Professor at the National Space Science Center (NSSC), CAS. Specialist in Space Science and Exploration, and Microwave Interferometric Imaging Theory and Technology, He is IEEE Fellow, Full Member of IAA, foreign member of Russian Academy of Sciences (RAS), member of Board of Trustees (BoT) of the International Space Science Institute (ISSI) and Chair of BoT of ISSI-Beijing. He also worked as Vice-President of COSPAR from 2010 to 2018. He has authored more than 100 peer-reviewed publications on key international and national journals, and 6 books, including two SF; and owns more than 10 patents.

Dr. WU has worked as the chief designer of Double Star Program Application System, Project Manager of Scientific Payload Subsystem of Chinese lunar exploration program CE-1, and CE-3, Chief Project Manager of Meridian Program, principle investigator of *Yinghuo*-1 spacecraft, and Chief Project Manager of CAS Strategic Priority Program on Space Science, in charge of 4 scientific missions (DAMPE, QUESS, SJ-10 and HXMT). He was awarded the Laurels Team Achievement Award of IAA in 2010, S&T Progress National Award (1st Cls) in 2010, Marcelo Nicolas Space Weather Award in 2017, Special Award of China Space Foundation in 2018, and International Cooperation Award of COSPAR in 2022. The Asteroid 10118 is named after him.

such as QIAN Xuesen (Hsue-Shen Tsien) and ZHAO Jiuzhang (Jeoujang Jaw), proposed to the central government that China should study and launch its own satellites. With the approval of the proposal, ZHAO Jiuzhang, director-general of CAS Institute of Geophysics, led a group of scientists and engineers, called the Group 581, to start the space research and satellite program in 1958.

As a matter of fact, China's industrial capability then cannot support the space program. For example, the semi-conductor industry did not exist at that time. However, to establish the research in upper atmosphere, which was the field of ZHAO, ionosphere and magnetosphere, and interplanetary physics is an urgent issue. A new institute in the field of space physics was then established by CAS, which was the first research institute in space science in China. ZHAO was appointed the director general of this institute.

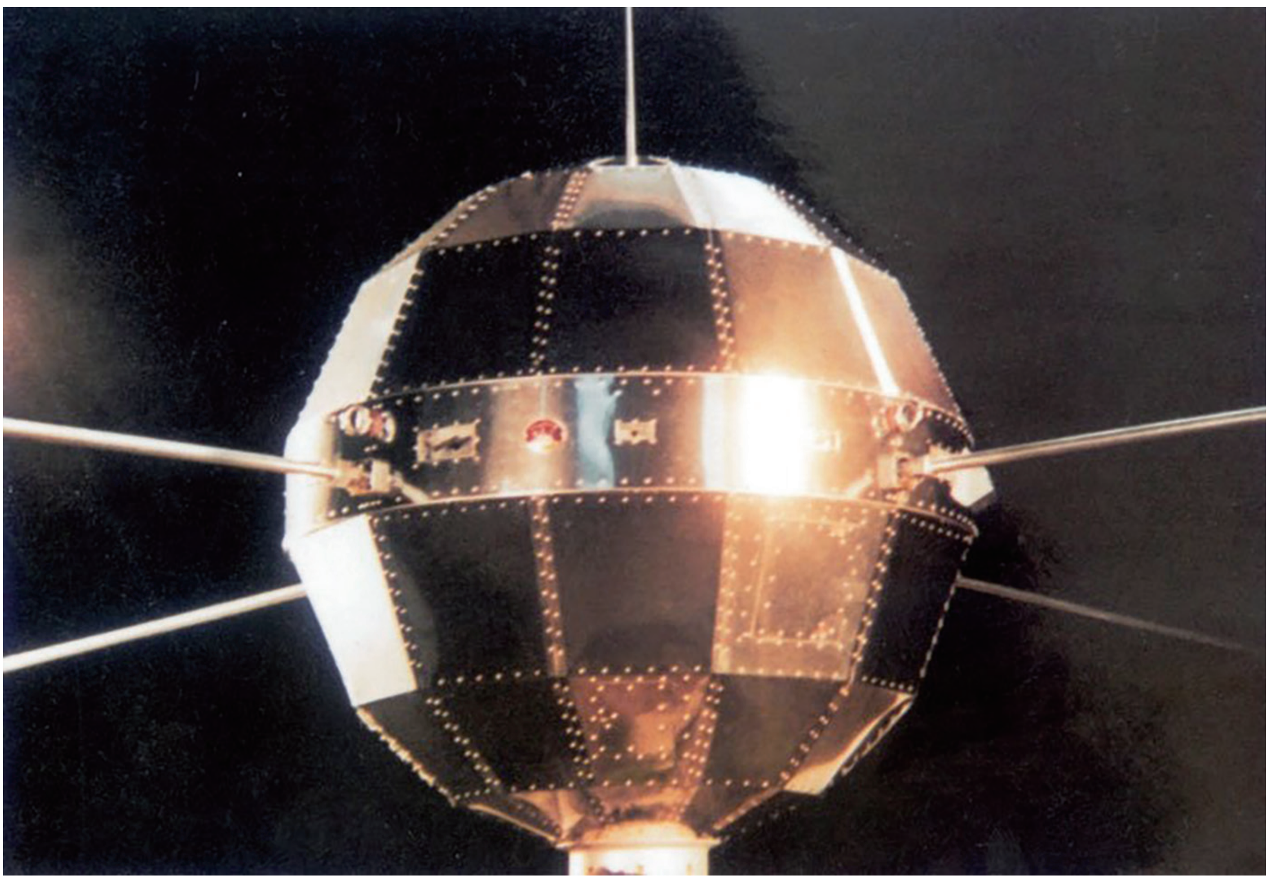
By the mid-1960s, China had built up its preliminary capabilities concerning launch vehicles, semi-conductors, and most importantly the fundamental knowledge of space. Subsequently, ZHAO sent a letter to the central government again to propose the first Chinese man-made satellite. The proposal was granted and the mission was named DFH-1, see Figure 1, which was successfully launched on April 24, 1970. This marks the beginning of space era for China.

2. Preparation period (1970–2000)

Since the launch of DFH-1, space scientists in this country had chances to put their research payloads, mainly particle detectors, on board of several missions, such as DFH-2 (SJ-1 short for Shijian-1), SJ-2, SJ-4 and SJ-5, etc. Yet, for about 30 years, there was no opportunity for them to have their own missions specifically designed for science exploration.

However, through the pig-

Figure 1 The first Chinese satellite DHF-1 launched on April 24 1970.



Graphic: NSSC

gy-back fly opportunities, scientists and engineers have mastered the fundamentals of building up the high energy particle detectors and atmosphere density detectors. These had laid down a solid foundation for proposing their own missions.

In the field of space astronomy, astronomers have also proposed several missions, such as the X-ray telescope in the 1970s, the 1-meter diameter optical space telescope, and Hard X-ray telescope in the 1980s and the 1990s. However, since the technology was not ready, all of them had not been accepted to enter the engineering phase.

At the same time, benefited from the recoverable satellite technology developed by the Chinese space industry in the 1970s and the 1980s, micro-gravity, material and life scientists did get some opportunities to fly their experiments, which have brought back some good results.

3. The first science mission: Double Star Program (2000–2010)

Space science missions have the characteristic of either having new science payloads to provide new insight into the universe, or arriving at new places that have never been reached before by human beings. By the time of the 1990s, although new science payloads were not completely ready, Chinese space technology had been advanced enough to materialize the reaching of new places in the geo-space, for example a higher orbit than the geostationary orbit.

LIU Zhenxing, a space physicist from the Center for Space Science and Applied Research (CSSAR), which is evolved from the Institute of Space Physics created by ZHAO, proposed a mission called Double Star Program (DSP) in 1997, to fly two spacecraft into the magnetosphere, one in equatorial orbit with an apogee of 10 earth radius (the highest for Chinese space program) and the other in polar orbit with an apogee of 4 earth radius (also a place that has never been reached by China). The science payloads were based on the existing capability of CSSAR. These payloads have been on board of several application satellites previously and were considered as mature technologies. The scientific objective of DSP is to study the macro coupling responses during the solar event and the properties of the dynamics of the magnetosphere during its own sub-storms.

The mission was well responded by European Space Agency since its Cluster mission needed a partner mission in order to achieve a multiple-points measurement of the magnetosphere.

It also benefited from the national development program of China. The Chinese white paper on space activities in 2000 says that space technology, space application and space science are the three major pursuits of Chinese government (Information Office of the State Council of the People's Republic of China, 2000). The proposal of DSP from CAS was then accepted to enter the engineering phase in 2001 and two spacecraft TC-1 and TC-2 were launched at the end of 2003 and in mid-2004 respectively. An artistic view of DSP is shown in Figure 2.

In order to have similar and jointly calibrated science payloads both on DSP and Cluster missions, ESA has provided 8 science payloads on board of DSP. In this sense, DSP became a joint mission with ESA. Besides the science payloads, ESA also provided a ground station and a science data center to DSP program. The data, of course, was 100% shared between DSP and Cluster.

The most advanced science payloads from Europe were from France, Austria, UK, etc. The cooperation certainly helped the advancement of Chinese science payloads, such as magnetometers, hot ion detectors, neutral atom imagers, etc. Without DSP, the capability of science payloads in space physics will take much longer time to be advanced.

DSP was truly the first Chinese space science mission proposed by scientists, designed according to the science objective requirements and operated by the scientists after launch. More than 200 peer reviewed papers were published using DSP data alone or jointly with Cluster data. DSP team was granted the first prize of the State Science and Technology Progress Award, and the joint team of DSP and Cluster was awarded the International Academy of Astronautics (IAA) Laurels for Team Achievement. Both awards were given in 2010, 9 years after DSP was approved.

4. Making long term planning

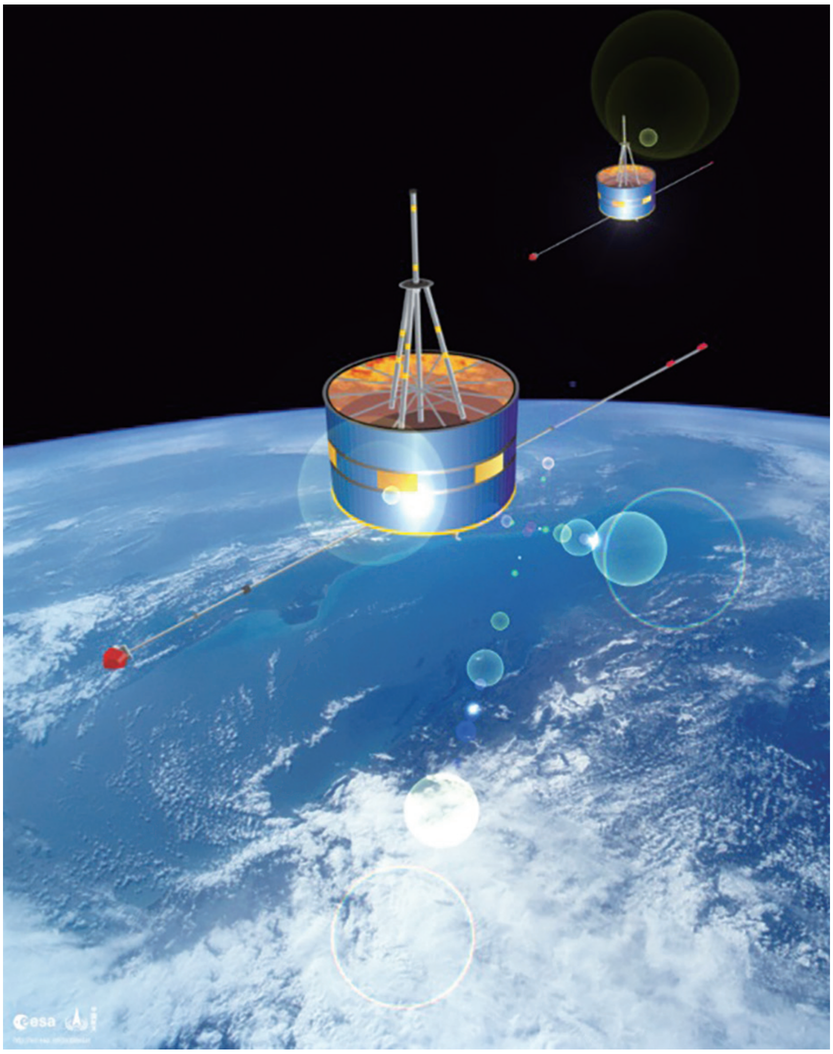
To further develop space science and expand from space physics to space astronomy, solar and terrestrial physics, interplanetary physics, space earth science, micro-gravity physics, material science and life sciences, a long-term planning is needed after DSP.

Since 2006, CAS was asking CSSAR (later became the National Space Science Center, or NSSC, in 2015) to lead a strategic study for a long-term planning for space science up to 2025, which was later extended to 2030. The plan was expected to cover all sub-disciplines of space science (Ji WU, 2016).

In the same period, China's manned spaceflight program entered the application stage using space labs and later space stations, after the successful return of YANG Liwei, the first Chinese astronaut sent into space, on SZ-5, in Oct. 2003. How to utilize these manned spaceflight platforms became an important issue for the national program, which provides opportunities to micro-gravity physics, and material and life sciences. The external platform outside of the station also provides the experimental opportunities for earth remote sensing payloads and some of the astronomical telescopes.

Also benefited from this breakthrough, China considered a new area of space activities in lunar exploration, the *Chang'e* program, in 2004, aiming at a three-step approach, *i.e.* orbiting, landing and finally sample return. The *Chang'e* program provided a step forward for lunar science and served as good preparation for missions targeted at Mars and further outer planets in interplanetary science.

As an independent long-term planning, the space science satellite program supports space astronomy, solar and terrestrial physics, and space earth science. The study was called "Calling Taikong", meaning the quests from Chinese space scientists. The study had been published both in Chinese and English (Ji WU, 2017; Ji WU, Chi WANG, and Quanlin FAN, 2022), drawing wide attention from space science community all over the world. The long-term planning was updated several times later in 2020 and 2024.



Graphic: NSSC

Figure 2 Double Star Program.

5. Strategic Priority Program (2011–now)

With the guidance of the long-term planning, CAS has included space science into its Strategic Priority Program (SPP) in 2011. In its first phase, four science missions had been approved, *i.e. Wukong* (Dark Matter Particle Explorer, DAMPE), SJ-10 (a recoverable satellite for micro-gravity and life sciences), *Mozi* (Quantum Experiment at Space Scale, QUESS), and *Huiyan* (Hard X-ray Modulation Telescope, HXMT). The scientific objectives of them are listed in Table 1.

The five missions listed above all have produced significant science outputs. For example, DAMPE has observed the most accurate spectrum in the high energy band of electrons, and protons. HXMT has discovered the strongest magnetic field in the universe. QUESS has confirmed and demonstrated the photo entanglement at the longest distance of 1,000 km. Shijian-10 has experienced the complete development process from embryo to blastaea in space.

Up to 2021, the science results of SPP missions have published in *Nature*, *Science*, *Physical Review Letters* and many scientific journals. The total number of publications has exceeded 1,500 and more than 2/3 of them were published in English.

With the success of the four missions in SPP on space science, CAS started its second phase of SPP on space science, called SPP II, in May 2018. Benefited from the pre-study and a so called background study which is very close to phase A study of the engineering phase, CAS selected four new missions, *i.e.* *TAIJI*-1, GECAM (Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor), ASO-S (Advanced Solar Observatory in Space) and EP (Einstein Probe), plus two international cooperation missions: SVOM (Space-based multi-band astronomical Variable Objects Monitor) and SMILE (Solar wind Magnetosphere Ionosphere Link Explore). Table 2 lists the main scientific objectives of them (Ji WU, Chi WANG & Quanlin FAN, 2022).

6. Lifetime management of science missions

Together with the guidance of the long-term planning, a management procedure in the lifetime of a science mission was also studied. The procedure starts from long-term planning, calling for proposals, and ends with in-orbit operation, and mission evaluation and conclusion. One of the key issues of this procedure is the maximization of science output.

From the beginning, in order to have the best proposals, the bottom-up process was adopted. The bottom-up process is a common procedure used in many space agencies. The advantage of it is to maximize the motivation of the science community and also ensure the science output when the mission is implemented. It is proposed by the science team and will be their responsibility to produce best science according to their proposed objectives. For the proposals on the table of the management team or agency, there are two criteria which should be used to evaluate them. Namely the science impact of the mission's science objectives once they are realized, and the influence of its science objectives or how many scientists might use the data.

Along with the development phase, a chief scientist of the mission should be appointed. He or she has the responsibility to make sure that the development will not go anywhere else and drift away from the proposed objectives. The chief scientist has the right to say "no" if he or she finds anything wrong in that direction.

The data policy is also an important issue in the management

TABLE 1 Missions of SPP I and Their Science Objectives

Mission	Main Science Objectives	Date of Launch
DAMPE	Observation of high-energy electron and γ-ray to search for dark matter.	Dec. 17, 2015
SHIJIAN-10	Study the fundamental law of matter and life under micro-gravity and space radiation environment	April 6, 2016
QUESS	Distribution of quantum photons from space to ground and study their property of entanglement; Distribution of quantum keys and use them for ground confidential communication tests	August 16, 2016
HXMT	High spatial resolution observation of Galaxy to discover and study the black holes and extreme physics around them	June 15, 2017

TABLE 2 Missions of SPP II and Their Science Objectives

Mission	Main Science Objectives	Date of Launch
TAIJI-1	Technology demonstration for gravitational wave measurement	Aug. 31, 2019
GECAM	All sky survey of hard X-ray burst and electromagnetic correspondent measurement of gravitational wave	Dec. 10, 2020
ASO-S	Study of solar flares and CME and its relations, by observation of solar magnetic field, hard X-ray and corona graphic imaging	Oct. 9, 2022
EP	High spatial resolution imaging of the transient universe with large field of view soft X-ray telescope to study active stars and black holes	Jan. 9, 2024
SVOM	Sino-France joint mission to study the most distant explosions of stars, the gamma-ray bursts	June 22, 2024
SMILE	Sino-ESA joint mission to study the interaction between solar wind and magnetosphere with innovative X-ray imager and UV imagers from large elliptical orbit	Expected in 2025

procedure. It is not simply called an open data policy, but a policy that aims to produce the best science. Therefore, for different types of missions, such as an observatory type, or a dedicated experiment type, the data policies might be slightly different. The key is that the policy aims to produce the best science instead of just opening up the data.

A complete diagram of the life time management broken down to several phases is shown in Figure 3 (Ji Wu, 2021).

7. International Cooperation

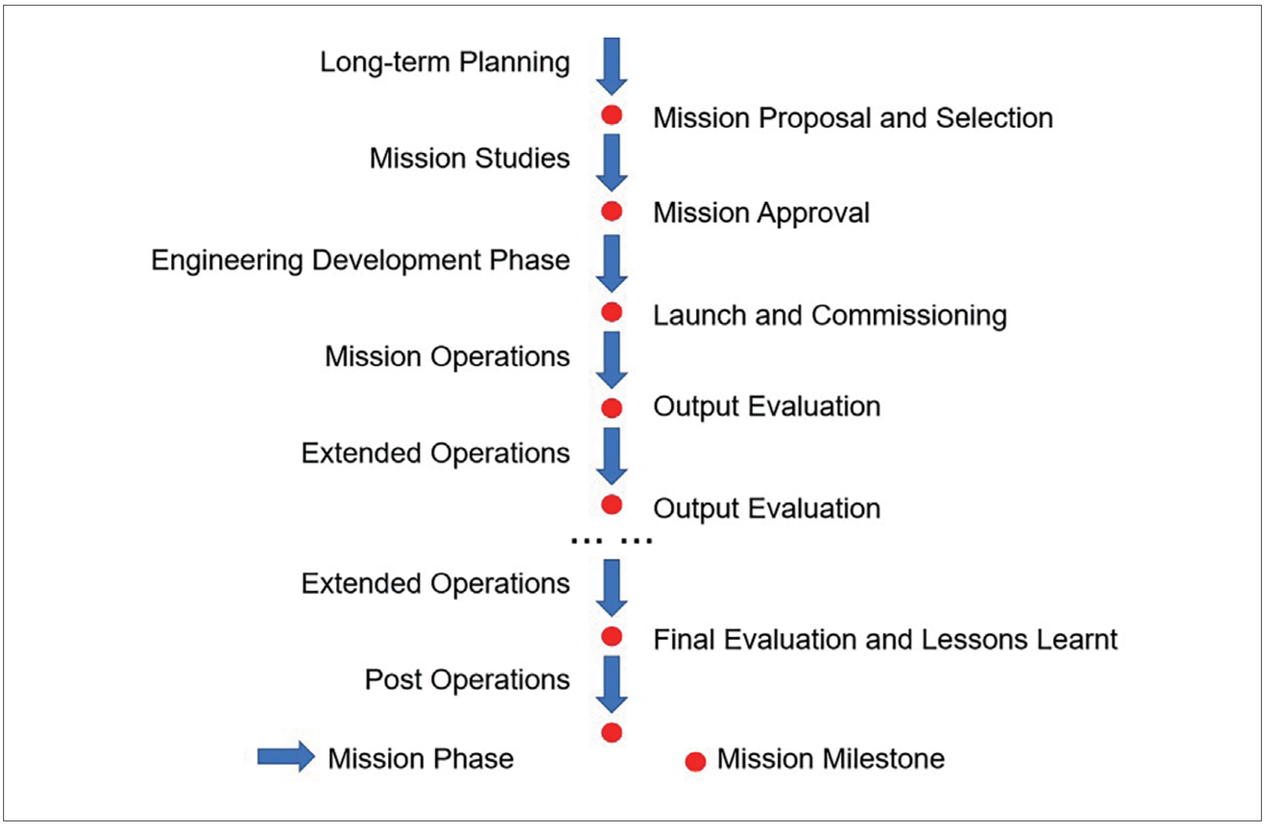
International cooperation is one of the most important aspects of space science management. Starting from DSP, international cooperation has been considered a key element of a proposal, or even a merit when it is evaluated.

In order to lay down a solid ground for future cooperation, having a regular meeting mechanism between the management agencies is important. Another important way to prepare a good cooperation is to organize joint forums to bring scientists of cooperation partners together, so as to generate common interests and innovative ideas.

With European countries, starting from 2004 after the successful launch of DSP, we established an annual bilateral meeting mechanism at the agency level, and joint science workshops are held from time to time. In 2015, after two joint workshops organized by CAS and ESA, 13 joint proposals entered the short list after a joint call. Then a careful selection was conducted by a joint science committee, and the SMILE mission stood out for implementation (Ji WU, BAI Qingjiang and XU Yongjian, 2021).

Before 2011, CAS has several connections with NASA, some universities and research institutes in the US. However, after the Wolf Amendment of the US congress, it became extremely difficult to have bilateral relations. In order to continue the contacts between the young scientists, at least if not for all, CAS and the National Academy of Sciences of the US set up a regular forum for young scientists. Each year, both sides selected 8 young scientists under 40 years of age to meet twice in China and in the US respectively. The mechanism continued until the pandemic.

Russia is also an important country, and had great contributions to the development of space science in China in the past, especially in the early years of the space age. In 2000, CAS and Russian Academy of Sciences, and its Siberia Branch in particular, set up a joint research center for



Graphic: NSSC

Figure 3 Lifetime of space science mission.

space weather. It is still an active joint research mechanism after 24 years. Joint workshops have been continuously organized every two years in both countries alternatively.

In 2008, a piggy-back opportunity of flying to Mars on the Russian Phobos-Grunt mission was available for CAS. A small Mars satellite of 110 kg, called *Yinghuo*-1, was developed aiming to measure the magnetic field and particle environment of Mars. It was also intended to measure the Martian ionosphere together with Phobos-Grunt spacecraft using occultation method in low frequency radio band. Unfortunately, due to the failure of departure from the Earth's orbit, *Yinghuo*-1 together with Phobos-Grunt spacecraft fell in the Pacific Ocean three months later after launch. However, this experience did helped China in two ways. On the one hand, we have a real practice for a Mars mission during the design and manufacture. On the other hand, a Mars science team was built from almost zero.

In addition, as a main member of ESA, France is also a country with its own space programs. Space science is also one of its main activities. A joint space science mission called SVOM then became a symbol of close relationship between China and France. The cooperation was even written into the agreement signed by the presidents of the two countries. SVOM was an astronomical satellite that was successfully launched in June 2024.

Multi-lateral cooperation through international organizations is also an important aspect. China became a member of the Committee on Space Research (COSPAR), the only international organization in space science, in the beginning of the 1990s. In order to promote space research in China, CAS hosted a COSPAR scientific assembly in Beijing in 2006. After that, China's representative was elected as the bureau member, and later vice president of COSPAR. Since then, China has remained in the highest decision-making body of COSPAR.

In order to open up China's science program to all scientists around the world, CAS supported NSSC to establish a multi-lateral research platform, *i.e.* International Space Science Institute in Beijing (ISSI-BJ) in 2012. It was a cooperational project with the International Space Science Institute (ISSI) in Bern, Switzerland. ISSI-BJ and ISSI both are research platforms to organize cross institution studies in space science. They also share a common scientific advisory committee to select study proposals of international teams.

8. Conclusion

Chinese space science has been developing with the advancement of its space technology and its national science and technology development in general. In particular over the past 10 years, space astronomy, solar and terrestrial physics, fundamental physics, have benefited from the dedicated space science satellite missions, which became major activities in the overall space development. Together with China's manned space program and the deep space program, such as *Chang'e* and *Tianwen* series, micro-gravity, material and life sciences, planetary science also has a great number of fly opportunities.

For the future, the development of space science has entered a new era which needs more innovative technologies to acquire new data with new science payloads. Therefore, a new round of strategic study is going on and the new long-term planning has been released 15 Oct. 2024 (WANG Chi *et al*, 2024). For scientific satellite missions, they will focus on the origin and evolution of the universe, black holes, dark matter and dark energy, and also on the fundamental laws of matter and life in the solar system and space environment.

Chinese Space Station (CSS) will be a main experimental platform for research and application. *Tianwen* serial missions will go to Mars and beyond. A mission towards the edge of solar system is also under consideration. For our neighbor, the natural satellite of Earth, an International Lunar Research Station is proposed by China. The manned lunar landing program is also planned for 2030.

It is for sure that space science will continuously play an important role in breaking through on the frontiers of fundamental science and also as a driver for innovative technology. It will remain as one of the three major activities together with space technology and space application. CAS will certainly and continuously play a key role in it.

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