China and the Second Space Age

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Introduction

The Chinese space program has not received significant review by the general population over the years. This is due in part because of the methodical approach the Chinese have used for its space program and the historical tendency of the Chinese government towards not publicizing its activities.

However, with the launch today of China's first human spaceflight mission, *Shenzhou 5*, China's space program has jumped onto the national headlines. Futron developed this White Paper to describe the China's past, current, and future space program. The information in this White Paper is based on publicly-available information.

China and The Second Space Age

A recent study conducted by Futron Corporation on behalf of NASA focused on worldwide government and commercial space activities over the next 20 years. While the intent of the study was to determine the market share effect of an RLV introduced into the worldwide launch market, the baseline analyses revealed some interesting trends in government space activities.

The United States is expected to continue its military and civil space programs in earnest; however, the overall trend in terms of annual U.S. launch events will remain essentially flat through 2021. The forecast showed a more pessimistic outlook for Russia. Russia's government space activities will amount to a substantial reduction in launches from previous decades due to a reduced space budget in recent years (estimated to be between $300 to 400 million per year). The Russian government has been forced to prioritize its spending on space programs, focusing on the International Space Station, while de-emphasizing communications, navigation, and certain remote sensing platforms.

In contrast to this "draw down" in space activity by the superpowers responsible for the Space Race of the 20th century, Futron projects that China's space activity will increase in the number of orbital launch events through 2021. China will be launching up to ten times a year - this represents an increase of 50 percent from previous years (see Figure 1).

This launch rate is still well below the U.S. launch rate; and, China's current annual spending on government space programs is about $2.2 billion, compared with $26 billion for the United States.[1] However, it nevertheless represents a major scaling up of Chinese space activity dedicated to human spaceflight and key satellite programs.

[1] Johnson, Tim, "China's launch of its first manned spaceship expected within days," *Knight Ridder*, October 7, 2003.

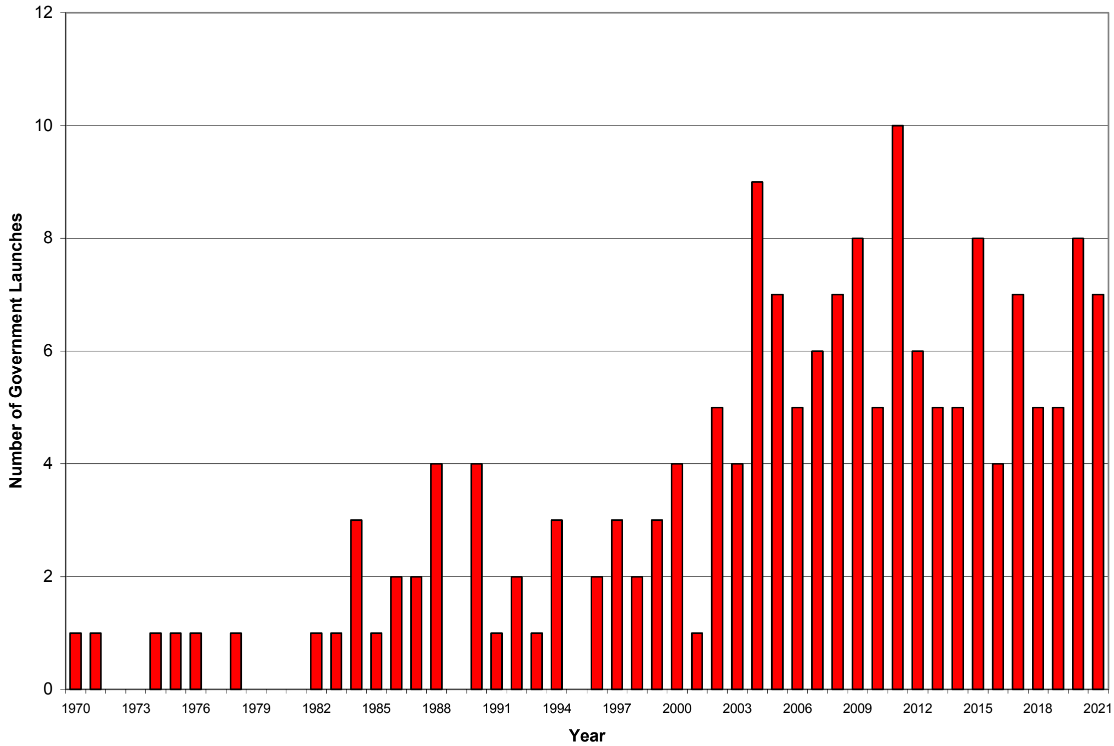

Figure 1: Chinese Government Launches (1970-2021).
Future Launch Projection from Futron's ASCENT Study

China's Space Activities in Context

China appears ready to enter space with a degree of ambition matching the Americans and Soviets during the 1960s, when sending humans into orbit and beyond became a method of demonstrating superior technical and economic competence. The capability to send humans into space is still seen as a pinnacle of achievement, a perception that may translate well in terms of attracting international investment, gaining additional respect among peers across the globe, and stoking domestic pride and inspiration.[2] China has recognized this for some time, but has taken a much more deliberate approach to sending people into space than the United States and the Soviet Union.

The United States and the Soviet Union, for example, sent humans into space within a few years of launching their first satellites. Perhaps even more remarkable, both nations directed plans almost immediately to send humans to the Moon, with the United States achieving this feat within ten years of launching its first astronaut. China, in contrast, launched its first satellite in 1970, capitalizing on the technical genius and leadership of Dr. Tsien Hsue-shen, considered the father of modern Chinese rocketry. It took the country over thirty years from the launch of that small satellite,

[2] There is some evidence to suggest that the general population of China is relatively unaware of its government's space program. It will be interesting to note how the Chinese will respond to the first flight of a Chinese astronaut.

Dongfanghong-1 (DFH-1, pictured in Figure 2), to the launch of *Shenzhou 5*, the first Chinese vehicle carrying a Chinese astronaut.

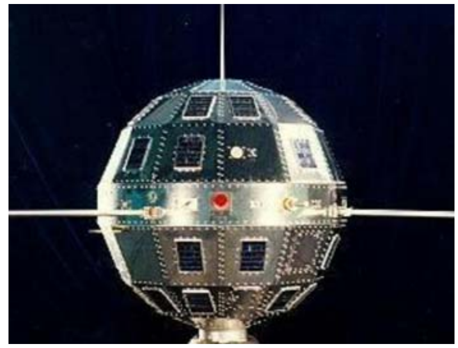

Figure 2: China's DFH-1 Satellite.

The Chinese government decided to pursue a more scaled down space program in the 1970s than that of the Americans and Soviets, dedicating its smaller economic and technological capability to pursuing more manageable projects like communication satellites and orbital remote sensing platforms.

It is interesting to note that the space programs of each country were established in no small part because of the influence and vision of three key individuals, each with special connections to their respective governments and a personal drive to see people live and work in space.

In the United States, Wernher von Braun used his training, charisma, and close associates to craft a master plan for Americans in space. The Soviets had as their champion, Sergei Korolev. Korolev was considered the center of Soviet space efforts until his death in 1966, an event which some experts think derailed the Soviet effort to land a man on the Moon. Likewise, Tsien, who earned his education and subsequent experience in rocket engineering in the United States, was an essential player in convincing the Chinese government that the country needed a space program.

Tsien Hsue-shen

Figure 3:
Tsien Hsue-shen.

Dr. Tsien Hsue-shen was born in Hangzhou, China in 1911. After what appears to be an ordinary childhood, he traveled to the United States in 1935 on a scholarship, ultimately becoming a protégé of Theodor von Karman at the California Institute of Technology.

Tsien applied to become an American citizen in 1949, but was isolated by accusations of being a communist sympathizer. In 1950, Tsien was accused by the United States of being a Communist Party member, an action that terminated his security clearance and his ability to conduct further research. He attempted to return to China; but, was detained under house arrest until 1955 when he was released and free to return to China.

The Chinese government, with Tsien in the lead, negotiated a 1956 agreement with the Soviet Union for transfer of rocket and nuclear technology, including the training of Chinese students at Soviet universities. Sino-Soviet relations soured a few years later, and in 1960 the Soviet Union discontinued its cooperation with China. Tsien continued his work on the core technologies shared by the Soviets, and established the Space Flight Medical Research Center in 1968 to prepare for human space flights. In 1970 he successfully launched DFH-1, China's first satellite, using the Long March 1 launch vehicle, a modified intercontinental ballistic missile. Tsien then introduced his human spaceflight project, called Shuguang-1, aiming to put a Chinese man into space by 1973. Due to changing political conditions, the Chinese government cancelled the human spaceflight program and directed Tsien to develop a new line of Long March vehicles based on the Long March 1.

In 1974, China began its satellite remote sensing program with the successful launch of Fanhui Shei Weixing-1 (FSW-1), a satellite that used a reentry film capsule similar to the Corona system developed by the United States over ten years earlier. The FSW reentry capsule would prove to be integral part of China's future human spaceflight plans.

Figure 4: Early Chinese Spaceplace Concept.

Tsien continued to champion a human space program, and in 1978 he introduced a project with roots to his 1949 space plane concept. This vehicle system bore a striking resemblance to the X-20 Dyna Soar, a cancelled project the United States Air Force pursued in the mid- to late-1960s. But Tsien's spaceplane (pictured on the left) never made it off the drawing board. Instead, China decided in 1978 to pursue a method of sending astronauts into space using the more familiar FSW-derived ballistic reentry capsules. Two years later the Chinese government cancelled the program citing cost concerns.

The Chinese government directed Tsien to focus on more practical satellite programs. Additionally, the country decided to enter the international commercial launch market in 1985 and revisited an initiative to develop the Long March 2 series of launch vehicles to address these new priorities, ultimately introducing 12 launch vehicle variants. China also built three launch sites: Jiuquan, for launch to mid-inclination orbits, Xichang for launch to geosynchronous orbit, and Taiyuan for polar orbits.

Between 1985 and 2000, China conducted 18 commercial launches, usually at launch prices significantly lower than equivalent vehicles offered by American and European providers. During the late 1990s, an embargo on Chinese commercial launches was levied by the United States over improper technology transfers, and quotas were negotiated in an effort to moderate the effects of China's launch price undercutting. These measures, combined with the collapse of the low Earth orbit satellite communications market, have effectively ended commercial launch activity in China in the near-term.

While China continued to launch government missions, a human spaceflight program remained beyond China's funded priorities. In 1984, President Reagan offered to fly a

Chinese astronaut on the Space Shuttle, but the Chinese were not interested. Then, China began a five-year effort beginning in 1983 to sign various United Nations treaties on space and began participating in international space conferences. China appeared to be preparing for a new era in its space development effort. But Tsien was not going to play a major role. He retired in 1991, and currently lives just outside of Beijing.

Shenzhou is Born

In 1992, China decided that a human spaceflight program could be funded. The Chinese government directed that a human-tended spacecraft be launched before the new millennium in order to establish China's place as "one of the Great Powers." China's human spaceflight program was designated Project 921, to be executed according to three phases. Phase One was to be a crewed space capsule with first flight by October 1999. The second phase was to be a space station. The final phase was the development and fielding of a reusable launch vehicle (RLV) to be operational by 2020.

The international community received its first glimpse of China's Project 921 when its Phase One spacecraft was revealed on paper in 1992. The spacecraft resembled the Russian Soyuz, with a service module, a reentry capsule, and a forward orbital module. A new heavy launch vehicle capable of carrying the capsule was also on the drawing boards.

In 1994, Russia sold some of its advanced aviation and space technology to the Chinese. In 1995 a deal was signed between the two countries for the transfer of Russian Soyuz spacecraft technology to China. Included in the agreement was training, provision of Soyuz capsules, life support systems, docking systems, and space suits. In 1996 two Chinese astronauts, Wu Jie and Li Qinglong, began training at the Yuri Gagarin Cosmonaut Training Center in Russia. After training, these men returned to China and proceeded to train other Chinese astronauts at sites near Beijing and Jiuquan. The hardware and information sold by the Russians led to modifications of the original Phase One spacecraft, eventually called *Shenzhou*, which loosely translated means "divine vessel." New launch facilities were built at the Jiuquan launch site in Inner Mongolia, and in the spring of 1998 a mock-up of the Long March 2F launch vehicle with *Shenzhou* spacecraft was rolled out for integration and facility tests.

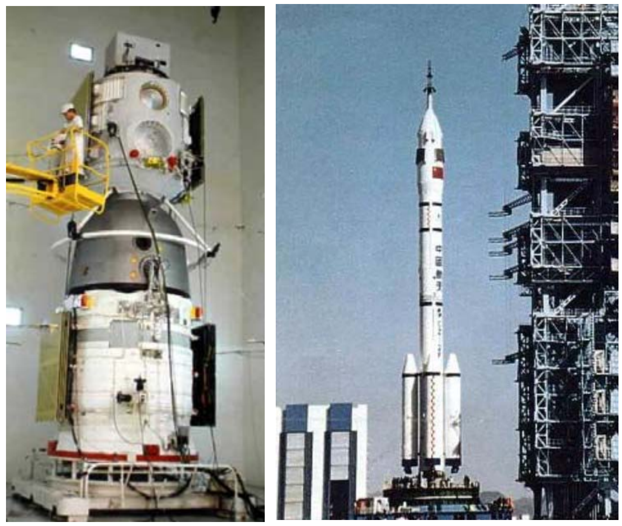

Figure 5: The Shenzhou and the Long March 2F at Jiuquan.
(credit: Mark Wade)

Figure 6:
Col. Yang Liwei.

In February 1999, the Chinese government authorized funding for Phase Two of Project 921 - the development and eventual operation of a “Salyut-type” space station. Facilities were built to test station components soon afterward. In July of that same year, the last of China’s tracking and telemetry ships was built, completing a fleet of three ships. China then successfully tested the Long March 2F with an uncrewed *Shenzhou* aboard on November 20, 1999. This flight was followed by *Shenzhou 2* in January 10, 2001, *Shenzhou 3* on March 25, 2002, and *Shenzhou 4* on December 30, 2002. *Shenzhou 5*, carrying the first Chinese astronaut, Lieutenant Colonel Yang Liwei, was successfully launched today, October 15, 2003.

During the earlier *Shenzhou* flight tests, the Chinese government introduced a follow-on plan to launch a large “Skylab-type” space station in 2010. This station will be launched by a Long March 5, China’s next generation heavy-lift booster. In the meantime, *Shenzhou* capsules are planned to dock with “Salyut-type” space station modules launched by Long March 2E or Long March 2F vehicles. In addition to the *Shenzhou*-station missions, China intends to conduct a mission to circumnavigate the Moon in a similar manner as was carried out by Apollo 8 in 1968. This mission will apparently involve a modified *Shenzhou* spacecraft and will be launched around 2006.

Who's Doing What in China's Space Programs

The organizational structure and evolution of China's space program is complicated and constantly undergoing change. Today, the management and operation of China's space activities are carried out by the China National Space Administration (CNSA), established in June 1993. CNSA is roughly the equivalent of the National Aeronautics and Space Administration (NASA).

Because China's public and "private industries" are very intertwined, a separate group of organizations is charged with providing the hardware, software, and research and development for the CNSA (see Figure 3), all under the auspices of the China Aerospace Corporation (CASC).

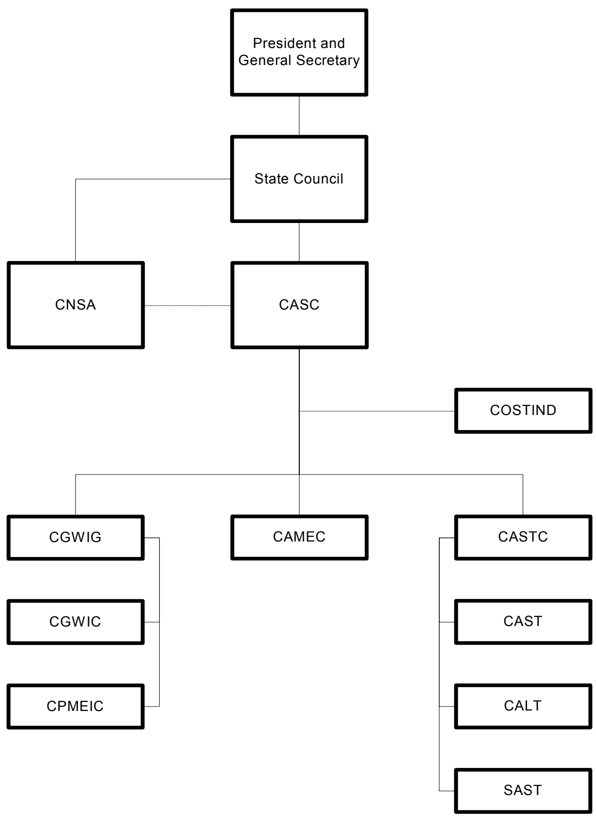

Figure 7: General Organizational Structure of the Chinese Government Space Program

CASC is divided into two large organizations: China Aerospace Machinery and Electronics Corporation (CAMEC), and China Aerospace Science and Technology Corporation (CASTC). The administration and management of facilities, payroll, and other similar functions fall to State Commission of Science, Technology, and Industry for National Defense (COSTIND). CASC headquarters is in Beijing, and the organization oversees the activities of 250,000 employees.

The majority of space-related industrial activity is conducted by CASTC. Space projects are mostly divided among three key organizations under CASTC. China

Academy of Space Technology (CAST) oversees institutes and factories related to research, development, and production of communications, space-based military systems, navigation satellites, data relay satellites, and weather satellites. It also conducts research and development on space station and RLV technology. China Academy of Launch Technology (CALT) conducts research, development, and production of launch vehicles, liquid-fueled surface-to-surface missiles, and solid-fueled surface-to-surface and submarine-launched missiles, among which is the Long March family of space launch vehicles. Shanghai Academy of Spaceflight Technology (SAST) is responsible for tactical air defense missiles and carrier rockets. The organization originally developed the Long March 1, 2, and 3 series of vehicles, including the guidance systems.

A third grouping of organizations also falls under CASC. Commercial launch campaigns are contracted through the China Great Wall Industry Corporation (CGWIC). CGWIC is managed under a conglomerate called the China Great Wall Industry Group (CGWIG), which also oversees the China Precision Machinery Import and Export Corporation (CPMEIC).

Future Chinese Space Activities

In 1999, the Chinese government directed the CNSA to follow a ten-year space plan. CNSA was tasked with building up an integrated military and civilian Earth observation system using meteorological, Earth resource, oceanic, and disaster monitoring satellites, all coordinated for receiving, processing, and distributing data to both civilian and military users.

This effort was begun with launch of the Ziyuan-2 satellite in 2000. The Chinese government also directed CNSA to establish an indigenously built geosynchronous satellite broadcasting and telecommunications system using partnerships made with Western companies to increase the level of Chinese technology. Sinosat-1, launched in 1998, was the first such cooperative project between the Chinese and European aerospace industries. The technology would be used to develop new FH-1 military and DFH-4 civilian communications satellites to form a command-and-control network designed to link Chinese combat forces. Deployment of the new constellation began with Zhongxing 22, launched in January 2000.

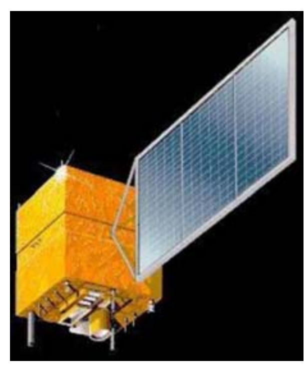

Figure 9: Ziyuan-2.

Establishing a geosynchronous satellite navigation and positioning system and maturing the industry for providing value-added services constitutes another of CNSA’s directives. In the early 1980s, China began to utilize the American Navstar and Russian Glonass systems to develop the application technology of satellite navigation and positioning. After joining the COSPAS-SARSAT search and rescue system in 1992, China established the Chinese Mission Control Center, now used to operate China's Beidou navigation satellites, the first of which was launched in 2000. The development of a new generation of scientific research and technological experiment satellites also falls under the purview of the CNSA. These would conduct studies in microgravity, materials science, life sciences, space environment, astronomy, and preliminary studies for human exploration of the Moon.

CNSA is currently upgrading China's launch vehicles in an effort to improve the performance and reliability of the Long March family, while simultaneously developing a new generation of expendable launch vehicles (the Long March 5 series) using non-toxic, high-performance propellants with lower operating costs. Work has also been under way to provide a commercially available small launch vehicle called Kaitouzhe. This new solid propellant vehicle has been launched twice, failing both times for undisclosed reasons.

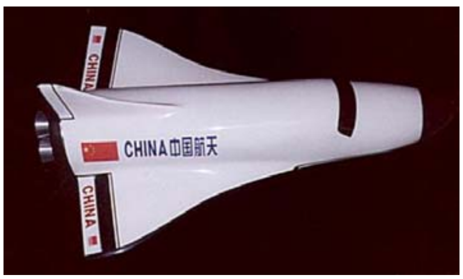

Figure 10: Project 921 RLV.

Regarding human spaceflight initiatives, CNSA is to continue pursuing the *Shenzhou* program and complete research and development for future human space projects (Phase Two "Skylab-type" space station and *Shenzhou* Circumlunar Mission). This responsibility is extended in China's 20-year plan, which directs CNSA to establish some sort of orbital space laboratory, and a research base on the Moon. The Project 921 Phase Three RLV was not mentioned as a realistic development project beyond 2000, with some speculating that difficulties experienced with the development of an RLV in the United States may have caused the Chinese to abandon such plans.

CNSA's 20-year plan goes a bit further, concentrating more on maturing the industrial base necessary for sustaining government space operations. This includes modernizing the aerospace industrialization process, marketing of space technology and applications, and establishing an integrated space infrastructure and a satellite ground application system integrating spacecraft and ground equipment.

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Corporate Overview

Futron Corporation is a technology management consulting firm. Futron applies analytically rigorous decision-support methods to transform data into information. We collaborate closely with clients to relate decisions to future outcomes and measures of value. Our aerospace consulting services include market and industry analyses, safety and risk management, remote sensing, and communications and information management. Futron was founded in 1986 and is headquartered in Bethesda, Maryland with a branch office in Houston, Texas.

Futron's headquarters in Bethesda, Maryland

Summary of Capabilities

Futron's Space and Telecommunications Division is the industry leader in researching, analyzing, and forecasting space and telecommunications markets and programs. Futron offers our commercial and government clients a suite of proprietary, leading-edge analytic methodologies. Our world-class team of market and policy analysts, economists, and engineers bring unparalleled skills and expertise to each account.

- We have surveyed hundreds of aerospace firms to develop a unique revenue, employment, and productivity profile of the industry.

- We have developed country-by-country models of demand for telecommunication services that aggregate a global forecast up from the individual household PC or business network; these models have accurately predicted future launch levels and business changes in the satellite industry.

- Futron helps clients win competitions, analyze competitors, estimate costs and prices, and track opportunities.

- Futron also performs cost estimates and economic analyses. Futron generates bottoms up, parametric, and analogous cost estimates for commercial satellite and launch vehicle programs.

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