Chapter 10

Review of China's New Carrier Rockets and Solar Orbiters

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I. Introduction

The Chinese official data indicates that the 2021 national defense budget was approximately RMB 1.35 trillion,[1] up by 6.8% from 2020 and primarily for four prioritized areas: 1. assurance of initiation and implementation of major military engineering projects as scheduled in the 14th Five-Year Plan; 2. upgrade and replacement to enhance modernization of military weapons and equipment; 3. improvement of training conditions and construction of a talent development system for nurturing military professionals; 4. alignment of the military personnel's benefits and living standards with the country's economic and social conditions.

The military force modernization is mainly based on the two-pronged strategy of the Military-Civil Fusion (MCF) and Science and Technology (S&T) industrial innovations. First, the boundary between the military force and the livelihood economy is blurred so that economic and social development may be integrated into military development and national security requirements. The implementation measures include the fusion of military and private-sector industrial sites, the integration of military and civil technology and innovation, nurturing versatile talents for military and civil purposes, and mutual conversion of military and civil

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1 "Is China's Military Spending of RMB 1.35 Trillion High? Is it a Threat to the World Peace? In-depth Analysis from German Military Experts," *Storm Media*, March 6, 2021, https://www.storm.mg/article/3519423?page=1.

construction and development. The goal is to include all aspects of the society and the economy into the military system and build a holistic system and capabilities for national military strategy. Second, it is necessary to hunt for potential and critical technologies as the cornerstone of military modernization. Hence, China invests considerable resources in companies and research projects for technologies with strategic potential and proactively promotes the industry-government-academia cooperation in the development of new technologies, such as AI and advanced robotics, semiconductor and advanced computing, quantum technology, biotechnology, hypersonic and directed energy weapons (DEW), advanced materials, and alternative energies.

Based on the aforesaid military development strategy, China has made good progress in modernizing military equipment and important vehicles over the recent years. In its publication, "Military and Security Developments. Involving the People's Republic of China 2020", the U.S. Department of Defense openly says that China has reached the same level as the U.S. or even surpassed the U.S. in certain military areas (e.g., space vehicles). Below is a summary of the space developments internationally considered strategically critical.

II. Development of Key Space Vehicles

Given the high level of commonality in the manufacturing technology between missiles and space vehicles, such as rockets, and the high degree of complexity in space vehicle systems and components to drive the development of relevant industries, China believes that space development is essential to its national security, society, and economy and that "the wealth of the country and for the people does not equate to national power". Even in the past, when China was lagging in technology and poor in fiscal finance, it poured all the resources into its space industry. After more than 50 years, it has established a comprehensive plan for space development. Currently, the PLA Rocket Force manages all of China's space programs, including the development and deployment of ground-

based missiles and cruise missiles and the development of intercontinental ballistic missiles (ICBMs). The number is expected to increase to 200 within five years to create a substantial threat to the U.S. Meanwhile, China invests in a large number of resources on a variety of space projects, both military and civil (such as commercial launches, scientific research, and space exploration). This objective has critically driven the growth and development of China's aviation and space industry. Below is an introduction to a few of its important space vehicles.

1. Rockets

Provoked by the launch of satellites by Soviet Russia and the U.S. in 1958, China embarked on the planning for the launch of satellites (code name: 581 Plan) and started constructing its first spacecraft launch site. In 1959, China adjusted the research tasks for space technology and focused on the development of sounding rockets. In 1960, it successfully imitated the production of short-range missiles and surface-to-air missiles and designed its own medium- and short-range missiles. In 1964, the first biological rocket T-7A with white laboratory mice was launched from the Guangde Rocket Launch Site; this was China's first successful step in the exploration of space biology. Afterward, China began planning for the development of satellites. In the meantime, there has been a solid foundation for the research and production of rockets and the launch of guided missiles. China's extreme emphasis on the development of rocket science is primarily due to the significance of space warfare to its national development. It can be materialized through the development of politics, economy, society, military force, technology, and psychology. Most importantly, as a dual-use technology, rockets can effectively drive the development of the military industry and relevant sectors, such as metal processing, materials, machinery, electronics, electrical machinery, and information technology. For civil purposes, rockets can be used to develop multi-orbit satellite constellations, establish space stations, and conduct extraterrestrial exploration. For military purposes, rockets are directly related to the range of intercontinental missiles. Hence, China has been aggressively developing rockets since the 1950s. The year 2020 saw vibrant activities, with a total of 39 launches, although in global

space warfare, China is only second to the U.S. (with 44 launches during the year).[2]

Currently, China's most prominent launch vehicle is the "Chang Zeng" (CZ) rocket, developed by the Shanghai Academy of Spaceflight Technology (SAST) under the China Aerospace Science and Technology Corporation (CASC). The CZ Series carrier rockets started in the 1960s, and the research and production of four generations of space vehicles have been completed. CZ-1 and CZ-2 are first-generation space vehicles. The first successful launch of the DFH-1 satellite by CZ-1 was in the 1970s. This first-generation rocket was an improvement of strategic weapon models and contained the highly noticeable features of strategic weapon models. Although its creation resolved China's problem of not having a carrier rocket, its overall performance and launch capacity was relatively low, its maintainability poor, and the launch cycle for rocket tests was long. More so, it was controlled with an analogue system. The second-generation space vehicles, represented by CZ-2C, CZ-2D, CZ-3, and CZ-2E, still retained the characteristics of strategic weapon models. There were technical improvements on the foundation of the first-generation rockets. However, the adoption of toxic propellants made with dinitrogen tetroxide and unsymmetrical dimethylhydrazine (UDMH) was not environmentally friendly. The third generation consists of CZ-2F, CZ-3A, and CZ-4. Also built on the prior foundation, the third-generation space vehicles continued to enhance reliability and mission adaptability. In October 2003, the CZ-2F rocket sent China's first astronaut, Li-wei Yang, to space. This mission made China the third in the world to send humans into the orbits. The details of the first three generations of CZ rockets are shown in Figure 10-1.

[2] Bryce Briefing (2020). Global Orbital Space Launches. BRYCETECH.

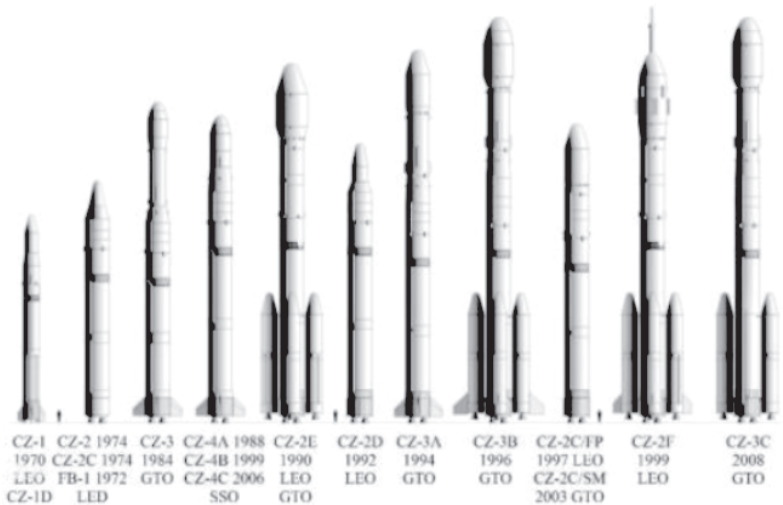

Figure 10-1 CZ Series the First-generation, Second-generation, and Third-generation Carrier Rockets

Source: China Aerospace Science and Technology Corporation (CASC) website.

The fourth-generation space vehicles include CZ-5, CZ-6, CZ-7, CZ-8, CZ-9, and CZ-11. This generation improved the flaws of the previous generations and significantly enhanced the launch capabilities. The CZ-6 with a small-capacity launcher took its first flight in 2015. Both the CZ-7 medium-sized rocket and the CZ-5 heavy rocket had their first flights in 2016. It is worth noting that the newest CZ-11 series rocket is 20.8 meters in length. The maximum diameter of the rocket body is 2.0 meters. It is 57.6 tons in weight and has a takeoff thrust of 120 tons. Its launch capacity is greater than 420 kilograms in the sun-synchronous orbit (SSO) at an altitude of 700 kilometers and 700 kilograms in the low-earth orbit (LEO). Meanwhile, this rocket adopts an international interface for satellites and rockets, can meet the varying mission and loading requirements, and launch in different orbits. CZ-11A is a larger and commercial solid carrier rocket developed and produced by the China Academy of Launch Vehicle Technology based on CZ-11. Its takeoff thrust is 115 tons, and its maximum diameter is 2.65 meters. There are three sizes of fairings available, at a diameter of 2.4, 2.7, or 2.9 meters. The launch

capacity is 2 tons in the low orbits and 1.5 tons in the sun-synchronous orbit (SSO) at an altitude of 700 kilometers. It is on a hot launch system from a simple launch pad. The CZ-11A is China's first rocket designed, produced, and operated with a cost consideration. The launch cost is even the lowest, and the launch cycle is no more than 72 hours. The rocket is a single structure, with machinery and electrical units integrated. It can accommodate the launch requirements for most low-orbit satellites. This rocket is currently under research and production and is scheduled to take its first flight in 2022. The CZ Series carrier rockets currently in service are detailed in Figure 10-2. In addition to the well-known Chang Zeng, the China Aerospace Science and Technology Corporation (CASC) also has carrier rockets, such as Ceres, ZQ-1, and KZ-11, for different tasks.

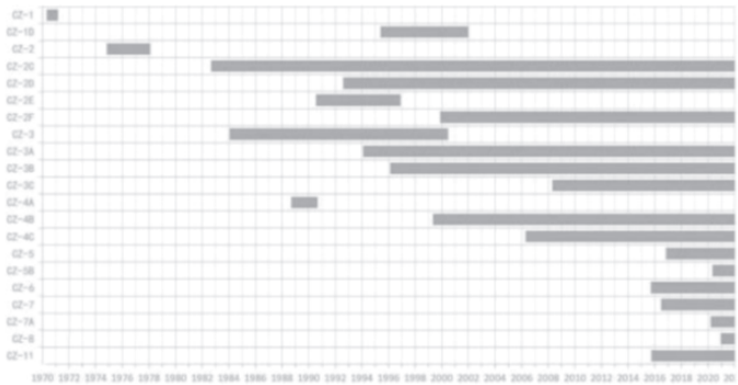

Figure 10-2 CZ Series Carrier Rockets Currently in Service

Source: China Aerospace Science and Technology Corporation (CASC) website.

At present, China's orbital launches are from four launch sites—Taiyuan Satellite Launch Center (TSLC), Xichang Satellite Launch Center (XSLC), Jiuquan Satellite Launch Center (JSLC), and Wenchang Satellite Launch Center (WSLC). China is working on the modernization and remodeling of space launch systems and the design and introduction of environmentally friendly rockets. In the past, Chinese launchers often used toxic hypergolic propellants. However, new designs are starting to use kerosene or hydrogen as fuels for RP-1 and RP-2 motors. It is

worth noting that KZ and CZ-11 on solid propellants are improvements from the Dongfeng intercontinental missiles. In addition to state-owned enterprises, there are also private companies, such as the i-Space, China Rocket, and LinkSpace. The latter has been developing reusable rockets in recent years.

2. Space Station

The International Space Station is located in the low-earth orbit (LEO), operated jointly by the National Aeronautics and Space Administration (NASA), Russian Federal Space Agency (RKA), Japan Aerospace Exploration Agency (JAXA), Canadian Space Agency (CSA), and European Space Agency (ESA). It is a microgravity laboratory for developing biology, medicine, and manufacturing technology. The biological statistics (e.g., bone density and muscle mass) of astronauts are also important data for human migration to space in the future. China's space station project kicked off in 1992 by China Manned Space (CMS). It was a three-stage project: launch of crewed vehicles with space for experiments; activity of astronauts in the space environment; and construction of space stations. After China lost the right in 2011 to use the International Space Station, it launched the space laboratory Tiangong-2 and the crewed vehicle Shenzhou-9 to complete a series of scientific experiments before returning to the earth. This year, China launched Tiangong Space Station's Tianhe core cabin module[3] and will send astronauts and a space station module into orbits for docking. The planned completion of the space station will be in 2022. If the International Space Station is not extended its service life and then decommissioned in 2024,[4] there will be just one space station from China. The space competition has been considered a showcase of national strengths. It is unclear whether China has surpassed the U.S. and Russia in space technology, but its ambition is evident.

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[3] Jones, A., "China Launches Tianhe Space Station Core Module into Orbit," *SPACENEWS*, April 29, 2021.

[4] Xiaoci, D., et al., "China Successfully Launches Core Module for Its Space Station, Kicking off Intense Construction Phase," *Global Times*, April 29, 2021.

3. Other Space Vehicles

In addition to the relative maturity in the development and the utilization of space vehicles, China is also proactively developing vehicles for new requirements, such as space humanoid robots and exploration vehicles for space resources, introduced below.

(1) *Space Humanoid Robot*[5]

In early 2021, the Centre for Advanced Mechanisms and Robotics (CAMAR), Tianjin University released its developed humanoid robot. It looks like an octopus, with soft, thin, long, and stretchable arms. Once launched into an orbit on a satellite, this robot can grab and remove space junks out of the orbit. However, space experts indicate that it is necessary to predict the path of movements for trash cleaning. Otherwise, the robot will lose control due to external forces and cause damages to other satellites. Based on its appearance, it is difficult not to associate it with the possibility of changing paths of the enemy's satellite as an anti-satellite (ASAT) weapon.

(2) *Exploration Vehicles for Space Resources*

China sees the exploration of space resources as one of the important means to global dominance and a major way to demonstrate its economic strengths and technological development. Since its 13th Five-Year Plan, China has conducted multiple space exploration missions, including the exploration and the collection of rare earth on the moon (Yutu lunar rover and Chang'e lunar lander) and the exploration of Mars (Zhurong Mars rover, Tianwen-1).[6] China is likely to leverage its Tiangong Space Station, along with the development of its space resource exploration vehicles and probes, to provide space laboratory resources and connect with countries other than the U.S. This avenue for joint technological breakthroughs is a way to achieve global supremacy.

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[5] Harrison, T., Johnson, K., and Young, M., "Space Threat Assessment 2021," *Center for Strategic &International Studies*, 2021.

[6] "Tianwen-1 and Zhurong, China's Mars Orbiter and Rover," *The Planetary Society*, https://www.planetary.org/space-missions/tianwen-1.

III. Possible Bottlenecks and Challenges

The above summary indicates China's emphasis on the space domain and ambition to compete with the U.S. for global leadership. With the emergence of a plethora of new technologies and materials, the breakthrough of the current capabilities of space vehicles will become the key to space dominance. Given its technological development and international status in politics to date, China is faced with two potential bottlenecks and challenges, as discussed in the following sections.

1. Reliance on Other Countries for Semiconductors

China is expecting to complete the "basic" goals of military modernization in 2035. Its current major technological breakthroughs are achieved with Military-Civil Fusion and industrial innovations in science and technology. However, China still relies on other countries for leading-edge semiconductors in the short term. The development of its hypersonic cruise missile (HCM) is a case in point.[7] It is believed that China obtained the chips designed by the U.S. and manufactured by the Taiwan Semiconductor Manufacturing Company for use in the supercomputer developed by Phytium Technology Co., Ltd. in order to simulate the heat and resistance of passing through the atmosphere. In other words, China still needs to enhance its semiconductor tech prowess. In the short term, it uses Military-Civil Fusion to secretly transfer civil technology for military purposes by concealing private companies' connection with the PLA. In this way, China has obtained key technological breakthroughs in space vehicles.

2. Military-Civil Fusion under International Scrutiny

China deems Military-Civil Fusion as an important strategy to accomplish military modernization to use the civil market in accelerating technological innovations and achieving breakthroughs in military technology. However, China's

[7] "U.S. Failed in Hypersonic Cruise Missile (HCM) Test, but China Achieved Breakthrough by Using U.S. Chips," *Central News Agency*, April 8, 2021, https://www.cna.com.tw/news/aopl/202104080173.aspx.

political status is sensitive in the international community. Many Chinese tech companies are related to the PLA. As a result, the U.S. Department of Commerce and the U.S. Department of Defense have become stricter in naming companies for the entity list, squeezing the profitability of other Chinese firms in the U.S. market. In other words, Military-Civil Fusion constraints China in the international political arena and loses the energy of developing generic technologies for both military and civil use. Huawei and DII are high-profile examples.

IV. Conclusion

China has become a formidable participant in the world's space race after more than 50 years of effort. Starting from the construction of the first launch site for carrier rockets in 1958, China is now accomplishing over 30 launches each year. On top of the foundation built with the Military-Civil Fusion strategy in national defense, China has achieved multiple significant and influential developments in space vehicles over the last 20 years. These developments include the famous CZ Series rockets, carrier rockets for different tasks, the space station, the space humanoid robot, and exploration vehicles for space resources. China's ambition does not end at an equal footing with global powers, such as the U.S. and Russia. It seeks to reobtain the global leadership under the banner of "revival of the Chinese people". The development of space vehicles and relevant technologies effectively enhance physical and non-physical military strengths. Moreover, this advantage is an important means of winning other countries over as a leader. Hence, the technology race between China and the U.S. will continue. With Chinese companies developing at a vibrant pace and stretching reach without constraints, the Military-Civil Fusion for military modernization will remain one of China's essential strategies in military development.