Chapter 9

The Development of Aerospace Science and Technology and Industry in China

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I. Introduction

China's aerospace science and technology[1] made significant progress in 2021. First, China's space station construction kicked off this year. On April 29, the launch vehicle "Long March 5B" sent China's Tiangong space station core module, Tianhe, into Earth's orbit. On June 17, the Shenzhou 12 spacecraft delivered three astronauts to the core module of Tianhe, where they stayed for three months and carried out robotic arm operations, extravehicular work, space experiments and various critical technology verification before returning to Earth on September 17. Secondly, the Chinese Mars probe Tianwen-1 on May 15 successfully landed on the southern Utopia Planitia of Mars after entering orbit around Mars in February. The Zhurong Mars rover, carried by Tianwen-1, has spent more than 140 days on the planet by mid-October, with the goal of exploring the terrain and climatic features of the planet and looking for signs of the presence of water or ice.

These are major breakthroughs in Chinese aerospace science and technology in the very short term, following the successful launch of the Long March 5B launch vehicle, the return of lunar soil samples by Chang'e 5 and the activation of the

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1 The term "hang-tian" (航天 , aerospace) used in China refers to the interplanetary flight of man-made satellites and spacecraft around the Earth or within the solar system, and is somewhat different from the terms "hang-tai" (航太 , space flight) and "tai-kong" (太空 , space) used in Taiwan. In order to retain the original meaning, the term "hang-tian" (航天) is used hereinafter.

BeiDou-3 global satellite navigation system in 2020. In particular, the Tiangong space station is scheduled for completion in 2022 and is likely to replace the International Space Station (ISS), which will be decommissioned in 2024, as the only space station in low-Earth orbit. Moreover, China has become the second country after the United States to successfully land on Mars in its first exploration of the planet. In 2018, China ranked first in the world in terms of the number of spacecraft launches, and from 2020 onwards, it has scheduled even more launches in preparation for the gradual realization of the Chinese "space dream."

China's primary objective in developing aerospace science and technology is to dominate space. Large-scale projects such as missile/rocket launches, satellite networks, planetary exploration and manned spaceflight were initially developed for military purposes, and only later for economic and social development purposes. Aerospace science and technology is itself a dual-use technology, and China's military-civilian integration policy gives top priority to military applications. However, the economic benefits of aerospace science and technology are far greater than the Chinese military could ever have imagined, even when combined with emerging technologies such as 5G, artificial intelligence (AI) and big data to drive a range of innovative activities from basic research to human resources cultivation. Particularly, Satellite Internet was included in April 2020 as one of China's "new infrastructure construction" projects, which means that satellite networks would constitute one of China's national infrastructure priorities during the 14th Five-Year Period, and its military and commercial applications are worthy of continued attention.

The Chinese government is making every effort to build a strong aerospace nation, with the aim of achieving the goal of establishing a modern and strong socialist country by 2049, the 100th anniversary of the founding of the People's Republic of China. How is China developing its aerospace science and technology? Through what mechanism? What capabilities and foundations are in place for military and commercial applications? What are the future trends? This chapter will attempt to address these issues.

II. The Development of Aerospace Science and Technology in China

The "space dream" is at the heart of Xi Jinping's "China Dream." The importance of aerospace construction in China's development can be seen from the 13th Five-Year Plan's "building of an major space player" to the 14th Five-Year Plan's "building of an major space power."[2] The specific contents of the "building of an major space power" include: human spaceflight, lunar exploration, Mars exploration, asteroid exploration, BeiDou navigation, high-resolution earth observation system(i.e. the "Gaofen satellite project"), heavy-lift launch vehicles, spacecraft in-orbit services, and a space-ground integrated communication network system. The ultimate goal is to make China a space power through aerospace science and technology.

As a matter of fact, China's initial development of aerospace science and technology was for national defense purposes. Immediately after Qian Xuesen's 1956 "Position Paper on the Establishment of China's National Defense and Aviation Industry," China set up the Aviation Industry Commission, the Missile Management Bureau of the Ministry of National Defense, and the first missile research institute, the Fifth Research Institute of the Ministry of National Defense,[3] to actively develop rocket/missile and satellite technologies. In 1966, China completed the combination of a nuclear warhead and a missile. In 1970, China launched its first artificial satellite, Dongfanghong 1, fulfilling the goal of developing "two bombs and one satellite" (missile, nuclear bomb and artificial satellite). The U.S. Congress has also pointed out that China may develop a number of counterspace systems that will pose a growing threat to U.S. national security.[4]

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[2] At first, China drew the vision and roadmap to major space power by 2030 in " China's Space Activities in 2016".

[3] It was founded in Beijing and its first director was Qian Xuesen.

[4] See *China's Space and Counterspace Capabilities and Activities*, The U.S.-China Economic and Security Review Commission, May 11, 2020, https://www.uscc.gov/sites/default/files/2020-05/ China_Space_and_Counterspace_Activities.pdf.

1. Roadmap of China Aerospace Science and Technology Development

The Three-Step Development Strategy is a strategy for the development of important technologies and industries in China. In addition to setting short-, medium- and long-term development targets, it is also effective in terms of investment and allocation of resources. For example, the Three-Step Development Strategy for the manned spaceflight project was formulated in 1992. The first step was to launch a manned spacecraft to accomplish experimental human spaceflight and space applications; the second step was to complete astronaut extravehicular activities, spacecraft rendezvous and docking, and launch a space laboratory to achieve short-term manned space applications; and the third step was to build a space station to realize long-term space applications with a larger number of crew members stationed. Other major aerospace science and technology projects such as planetary exploration, BeiDou navigation and carrier rockets also have their own "Three-Step Development Strategy" (Table 9-1).

2. The Main Content of China's Aerospace Science and Technology

Since the development of the "Two Bombs and One Satellite" in the 1950s, China's aerospace science and technology has seen a steady advancement in rocket and satellite applications. The highlights of this development can be briefly described as follows:

(1) Planetary exploration: The main missions are lunar exploration ("Lunar Exploration Program"), Mars exploration and other planetary explorations. China had successfully landed on the back of the Moon in 2019 and returned to Earth in 2020 with nearly two kilograms of lunar soil samples collected by robotic arms. Following the experience of the Lunar Exploration Program, China is currently conducting Mars exploration and planning future projects such as Mars sampling, Jupiter exploration and solar exploration. However, the technical key to planetary exploration lies not only in the successful launch of the launch vehicle, but also in the acquisition of energy for the long-range flight of the probe, the ability to communicate and remotely control from space, and the ability of the spacecraft to autonomously identify and respond

to environmental conditions (e.g. slowing down during landing, releasing Mars rovers or drones).

Table 9-1 The Three-Step Development Strategy for China's Major Aerospace Projects

	Name	Step 1	Step 2	Step 3
1	Human Spaceflight	1992-2003: Launched a manned spacecraft, built an experimental crewed spacecraft project and started experiments in space applications. • In 2003, China became the third country in the world, after the U.S. and the former Soviet Union, to conduct manned spaceflight on its own.	2005-2017: Achieved astronaut extravehicular activities, spacecraft rendezvous and docking, launched space laboratories, and solved the problem of short-term manned space applications of a certain scale.	From 2020 onwards: Building a space station to address the issue of larger scale, long-term manned space applications.
2	Lunar Exploration	"Orbiting": 2007- 2012 • Launched a lunar probe to orbit the Moon at an altitude of 2,000 km above the lunar surface. • Conducted integrated surveys of the lunar terrain, some elements and material composition, lunar soil properties, etc. • Set up a preliminary system for lunar exploration projects.	"Landings": 2013-2018 • Launched soft landers and rovers, landed on the lunar surface and released lunar rovers. • Performed surveys of terrain, geomorphology, geological structure and material composition of the landing zone. • Carried out lunar-based astronomical observations.	"Return": 2019 - 2020 • Launched an automated lunar sampling return vehicle. • Collected lunar soil and rock samples by robotic arm. • Brought lunar soil samples back to Earth.
3	Mars Exploration	Robotic exploration of Mars • Mars Sample Return, Mars base site survey, in-situ resource utilization system construction, etc.	Primary exploration • Manned orbit around Mars, orbital surveys, manned Mars landing surveys, Mars base construction, etc.	Flight-based exploration • Large-scale Earth-Mars transport fleet, establishment of an Earth-Mars economic circle, large-scale development and applications, etc.

	Name	Step 1	Step 2	Step 3
4	BeiDou Navigation Satellite System	A pilot system was developed since 1994, and the BeiDou-1 system (1st gen BeiDou system) for navigation within China was set up in 2000 until Dec 2012.	Since Nov 2012, the "BeiDou 2 System" (2nd gen BeiDou system) was rolled out to provide regional positioning services to customers in the Asia Pacific region.	The global positioning service of the "BeiDou-3 System" (3 gen BeiDou system) was rolled out in 2018 and was fully operational by the end of July 2020.
5	Heavy-lift Launch Vehicle	Developing the Long March series of launch vehicles, which can be launched into low, medium and high Earth orbits and carry various types of satellites with different loads, etc.	Completion of autonomous manned launch capability.	Completion of high density launch capability.

Source: Compiled by the author from various publicly available information.

(2) Manned spaceflight: The main tasks are crewed spaceflight, spacecraft docking and space station construction. As stated earlier, the construction of China's Tiangong space station is slated for completion in 2022 and it could be the only space station in near-Earth orbit in the foreseeable future. During its construction, China will launch several cargo and manned spacecraft to deliver other modules, supplies and astronauts to the station.[5] Meanwhile, China is also planning human missions to the moon and even a manned landing on Mars, but has yet to surmount numerous technical hurdles. The space suits worn by astronauts for extravehicular activities, the manufacture and operation of extravehicular robotic arms, and the remote communication with the Earth control center all require a high level of technology in the fields of materials, robotics, communications and AI. A robotic arm on a space station,

[5] "China Space Station: Tiangong Core Module 'Tianhe' Launched, First Step Towards Permanent Chinese Space Station," *BBC News Chinese*, April 29, 2021, https://www.bbc.com/zhongwen/trad/science-56926554.

for instance, must be equipped with visual recognition and autonomous AI capabilities in order to observe, monitor, capture and push space targets.

(3) Heavy-lift launch vehicle: This refers mainly to the capability to launch satellites or manned spacecraft in low, medium and high Earth orbits, and the key technology is the engines. China's Long March-11 rocket took off in 2019 from an offshore platform in the Yellow Sea, marking the first sea launch of a launch vehicle, and the country will follow up with commercial rocket launches at sea. On the other hand, rocket technology has also contributed to China's development of supersonic weapons for direct attacks on terrestrial targets from orbit through the atmosphere, such as the completion of the world's first supersonic gliding missile—the Dongfeng-17 ballistic missile[6] — in 2018 and the testing of a hypersonic missile fitted with a nuclear warhead in August 2021.[7] China is currently developing a new generation of super heavy-lift launch vehicle with a payload of 70,000 kg, capable of carrying a men to the moon.[8]

(4) Satellite Internet: It refers to the use of a certain number of communication satellites to form a worldwide, real-time, low-cost satellite broadband communication system. The BeiDou satellite system, which was fully operational at the end of July 2020, can already perform positioning, navigation, remote sensing (i.e. "telemetry") and communication functions. The ultimate goal of the Satellite Internet is to create a space-ground integrated system, enabling accurate and clear communications in mobile vehicles on land, at sea and in the air, or in remote areas where 5G base stations cannot be easily built. In April 2021, the Chinese Academy of Sciences unveiled a database of global satellite images targeting more than one million objects

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6 "China Successfully Tests DF17 Missile, 2500 km Radius to be Off-limits to U.S. Military," *Sina Military*, January 1, 2018, http://mil.news.sina.com.cn/jssd/2018-01-01/doc-ifyqefvw8169842.shtml.

7 "China Tested Hypersonic Missiles in Aug, Experts: a Step Towards Global Nuclear Attack from Space," *udn.com*, October 17, 2021, https://udn.com/news/story/6809/5823405.

8 "China Continues to Push Forward the Development of Two 'Heavyweight' Rockets in 14th Five-Year Plan," *People's Daily Online*, March 3, 2021, http://finance.people.com.cn/BIG5/n1/2021/0303/c1004-32040948.html.

that could enhance AI's ability to identify objects from space, and in August, China's Xinhua News Agency released a video of its satellite surveillance of more than 200 U.S. bio-lab sites around the world, providing a glimpse into the latest advances in Chinese satellite technology.[9] In addition, China is currently developing a light detection and ranging (LiDAR) satellite that will enable it to detect foreign submarines under the sea directly from space.[10]

(5) Reusable Earth to orbit transportation system: In September 2020, China announced the successful launch of its reusable spacecraft when it launched the Long March 2F launch vehicle to send an experimental reusable spacecraft to Earth orbit, returning to its intended landing site two days later.[11]

3. China's Counterspace Capabilities

What concerns the U.S. most, however, is China's integration of various aerospace science and technology to develop counterspace capabilities (or "counterspace weapons"). As the U.S. military relies heavily on satellites for communications, global positioning and surveillance functions to maintain global operations, satellites have become a source of vulnerability for U.S. military deployments.[12] According to relevant studies, "counterspace weapons" can be broadly categorized as follows:[13]

(1) Physical kinetic attack: A direct attack on a satellite or ground station or detonation in the vicinity. The main types are anti-satellite missiles launched directly from the ground, co-orbital anti-satellite weapons (e.g. killer satellites)

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[9] "Overseas Netizens Gasp as Space Angle Locates U.S. Biochemical Lab," *Xinhua News Agency*, August 11, 2021, http://www.xinhuanet.com/world/2021-08/11/c_1211327482.htm.

[10] "Turning the Ocean Transparent! China Develops Laser Satellites that Could Become Submarine Killers," *China Times*, October 1, 2018, https://www.chinatimes.com/realtimenews/20181001001180-260417?chdtv.

[11] Chloe (Tomorrow's Science Editorial Group), "Higher Technology than SpaceX Uses? China Launches First 'Reusable Rocket'," *The News Lens*, September 10, 2020, https://www.thenewslens.com/article/140297.

[12] Hiroyuki Akita, "China's Space Ambitions Target Satellites, a U.S. Vulnerability," *Nikkei Asia*, May 26, 2021, https://reurl.cc/mvYxLY.

[13] See Harrison, Todd et al., "Space Threat Assessment 2021," *CSIS*, April 2021, https://www.csis. org/analysis/space-threat-assessment-2021; Weeden, B. and Samson, V, "Global Counterspace Capabilities," *Secure World Foundation*, May 17, 2021, https://reurl.cc/kLonLK.

and direct attacks on ground stations.

(2) Non-physical kinetic attacks: These are attacks that do not require direct physical contact to achieve their effectiveness. Examples include blinding satellite sensors with lasers or overheating of electronic components, high powered microwave (HPM weapons), detonation of nuclear devices in space to create a highly radioactive environment, and electromagnetic pulses. Laser and HPM weapons can be launched from the ground, ships, airborne platforms or other satellites to mount multi-angle attacks and are not easily detected, while nuclear detonations from space can cause long-term radioactive contamination of the Earth's orbit and damage to satellite components.

(3) Electronic attacks: Electromagnetic spectrum that interferes with satellite data transmission. For example, the creation of electronic noise in the form of radio waves in the same frequency to interfere with satellite communications, or the inclusion of false signals in the transmission of a signal to deceive the receiver. Such attacks can be launched from satellites or ground-based mobile vehicles.

(4) Cyberattack: An attack on satellite data and data streams by users that can create "grey zone conflicts" without directly harming people, such as monitoring the flow of satellite data, intercepting data or inserting fake messages into it, or even controlling the satellite through the satellite control system.

As regards China's counterspace capabilities, some U.S. studies suggest that China already has significant capabilities in the areas of direct liftoff attack on low-Earth-orbit (LEO) satellites, electronic warfare and space situational awareness, as well as partial capabilities in co-orbital attacks (including low- and medium-orbit and geosynchronous orbits), direct liftoff attacks on medium- and geosynchronous-orbit satellites, and directed energy weapons.[14]

Specifically, the U.S. believes that China has the capability to deploy an anti-

[14] Weeden, B. & Samson, V, "Global Counterspace Capabilities," *Secure World Foundation*, May 17, 2021, https://swfound.org/counterspace/.

satellite ground-based laser weapon system that can blind U.S. satellites with direct laser fire from ground stations. The U.S. also predicts that China will be able to deploy a ground-based directed energy weapons system in five years to directly disrupt U.S. satellite operations. Moreover, China may also develop a mobile-staged laser weapon to destroy a large number of U.S. low-Earth-orbit (LEO) satellites, or use the robotic arm of a killer satellite to capture or push a U.S. satellite out of orbit.[15]

Actually, since the first collision of artificial satellites in near-Earth orbit in 2009, both space debris and scrapped spacecraft can become ultra-low-cost space weapons. Not only can space junk such as satellite debris damage the robotic arms of the International Space Station (ISS), but even Russian experimental capsules can knock the ISS out of its rotation.[16] Further, China is currently developing space capabilities such as in-orbit satellite repair, space debris removal, and special spacecraft technologies that can be readily converted into military weapons under the civil-military integration policy. Some U.S. officials even hold the view that if there is a war between the U.S. and China in the Taiwan Strait, it will most likely start with a satellite attack.[17] Space warfare will undoubtedly be another major battlefield of technological warfare between the U.S. and China.

4. The Major R&D Institutions of China's Aerospace Science and Technology

China Aerospace Science and Technology Corp (CASTC) and China Aerospace Science and Industry Corp (CASIC), two major central state-owned military enterprises, are the cornerstones of China's R&D in aerospace science and

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[15] "China and Russia Accused by U.S. of Developing Ground and Orbital Anti-satellite Weapons," *BBC News Chinese*, December 20, 2020, https://www.bbc.com/zhongwen/trad/world-55385518; "Expert: China's space program poses direct military threat," *The Epoch Times*, August 11, 2021, https://www.epochtimes.com/b5/21/8/10/n13153236.htm; Si-fu Ou, "China's Robotic Arm Practices Satellite 17," *National Defense Security Commentary*, June 17, 2021; ODNI, *Annual Threat Assessment*, April 9, 2021, pp. 7-8; Joe Gould, "China Aims to Weaponize Space, Says Intel Community Report," *Defense News*, April 14, 2021, https://reurl.cc/AR3Myj.

[16] "International Space Station Briefly Loses Control After New Russian Module Misfires," *CNN*, July 29, 2021, https://edition.cnn.com/2021/07/29/tech/nasa-iss-russian-space-module-misfire-scn/index. html.

[17] Hiroyuki Akita, "China's Space Ambitions Target Satellites, a U.S. Vulnerability," *Nikkei Asia*, May 26, 2021, https://reurl.cc/mvYxLY.

technology.[18]

CASTC is tasked with the R&D, design, production, testing and launch of missile weapon systems, aerospace technology applications, aerospace products and aerospace services, and is the sole manufacturer of China's intercontinental strategic nuclear missiles. Its performance is the highest among China's central state-owned enterprises (SOE) and it has been ranked among the world's top 500 enterprises since 2015. The division of work in CASTC is shown in Table 9-2.

As regards CASIC, apart from the production of missiles, it is also responsible for the launch of various space vehicles, satellite networks and the development of reusable spacecraft. The division of work in CASIC is listed by Table 9-3.

Table 9-2 CASTC Division of Work

		Primary Secondary Units	Principal Business
Large research and production consortia/ institutes	1	China Academy of Launch Vehicle Technology (CALT) (CASTC 1st Research Institute)	R&D of launch vehicle technology, satellite application technology, and computer hardware and software technology.
	2	Academy of Aerospace Solid Propulsion Technology (AASPT) (CASTC 4th Research Institute)	R&D of aerospace power technology, development of aerospace products and civil products, related professional training and technical services.
	3	China Academy of Space Technology (CAST) (CASTC 5th Research Institute)	Development of outer space technology, satellites, spacecraft and other space vehicles.
	4	Academy of Aerospace Liquid Propulsion Technology (AALPT) (CASTC 6th Research Institute)	R&D of space rocket propulsion technology and aerospace inertial device technology.
	5	Sichuan Academy of Aerospace Technology (SAAT) (CASTC 7th Research Institute)	Research, development and production of a wide range of aerospace products and development of the Guardian series of multiple launch rocket weapon systems.

[18] In addition, the Chinese Academy of Sciences' National Space Science Center and Space Environment Prediction Center are also involved in China's space science and satellite projects.

		Primary Secondary Units	Principal Business
	6	Shanghai Academy of Spaceflight Technology (SAST) (CASTC 8th Research Institute)	R&D of satellite application equipment and communication equipment.
	7	China Academy of Aerospace Electronics Technology (CAAET) (CASTC 9th Research Institute)	R&D of products such as for inertial navigation, measurement and control communications, and specialized electronics.
	8	China Academy of Aerospace Aerodynamics (CAAA) (CASTC 11th Research Institute)	Research into integrated aircraft aerodynamics, aerodynamic technology applications and testing, related equipment manufacturing, and the overall design and manufacture of specialized aircraft.
Directly affiliated units	1	China Aerospace Academy of Systems Science and Engineering (CASTC 12th Research Institute)	One of the founding units of China's manned aerospace project, with the aim of continuing Qian Xuesen's theory.
	2	China Academy of Aerospace Standardization and Product Assurance	Formerly the China Aerospace Standardization Research Institute (708 Institute), it provides aerospace product standardization and product assurance.
Specialized enterprises	1	China Satellite Communications Co	Responsible for satellite operation services, it is the only satellite communications enterprise in China that owns communication satellite resources and is a listed company.
	2	China Lucky Group Corp	China's largest manufacturer of video message recording and photographic materials.
	3	China Great Wall Industry Corp	The only commercial organization authorized by the Chinese government to launch and provide satellites for commercial use and to engage in international space technology cooperation.
	4	China Siwei Surveying & Mapping Technology Co	A benchmark industry in China's geographic information sector, it is mainly engaged in electronic maps, satellite navigation and positioning, remote sensing, aerial photography and surveying, and vehicle monitoring and dispatching.

		Primary Secondary Units	Principal Business
	5	Aerospace Science & Technology Finance Co	Responsible for the centralized management and use of CASTC funds, providing financial management and support to CASTC's member organizations.
	6	China Aerospace Investment Holdings Ltd	An investment management, capital operation and strategic cooperation platform authorized by CASTC.
	7	China Aerospace International Holdings Limited	China Aerospace International Holdings Limited is a listed company in Hong Kong. Its main businesses are manufacturing of injection molding, LCD monitors, audio-visual products, circuit boards printing, telecommunication products, smart charging and security systems; property investment and trading of electronic products.
	8	Beijing Shenzhou Aerospace Software Technology Co., Ltd.	Combining cloud computing, big data, "Internet +" and other emerging technologies, providing four major services such as industrial software, big data, e-gov, intelligent management system, to military and government customers.
	9	Shenzhen Academy of Aerospace Technology	Focus on the research development and industrialization of technologies in four areas: power electronics and power transmission, mobile computing and communication technologies, composite materials, and microelectronics. Specifically in four fields, including new enegry, new materials, IoT, energy conservation and environmental protection.
	10	Aerospace International Long-march Trade Co., Ltd.	Import and export of defense equipment, technology and services; anti-terrorism, riot control equipment and technology export; international exchange and cooperation in related technologies; aerospace technology industry and related investment, the company is also engaged in overseas project contracting.

		Primary Secondary Units	Principal Business
	11	Macro Co., Ltd. Net Communication	One of China's ISP and LEO operator, in charge on China's first LEO system "Hong yan constellation".

Source: Official website of China Aerospace Science and Technology Corp (CASTC) at http://www.spacechina.com/n25/n142/n152/n12989/index.html; official websites of its subsidiary companies and other publicly available information, etc.

Table 9-3 CASIC Division of Work

	Name of Company	Primary Service
1	China Aerospace Systems Engineering Corp	Founded in 1993 under the direction of Qian Xuesen, it is affiliated with the Academy of Information Research of CASIC (CASIC 1st Academy) and is principally engaged in the research of civil-military information technology, product development and system integration, specializing in large-scale aerospace system engineering and advanced aerospace technology. It is currently developing emerging technologies and applications such as BeiDou navigation, big data and Internet of Things, focusing on national defense and security, satellite applications, smart city, smart transportation and smart tourism.
2	CASIC Defense Technology Academy (CASIC 2nd Academy)	Formerly known as the Institute of Aerospace Science and Technology of the Fifth Research Institute of China, it was responsible for the development of ground-to-ground missile control systems and ground/ship-to-air missile weapon systems, as well as the production of China's first solid submarine strategic missiles and solid land-based tactical missiles. Specializing in microelectronics, optoelectronics and electro-mechanical technologies in the areas of weapon system integration, missile integration, precision guidance, radar detection, target features and target identification, simulation technology, military computers and common software, ground equipment and launch technology and advanced manufacturing technology.

	Name of Company	Primary Service
3	CASIC Aviation Technology Academy (CASIC 3rd Academy)	China's only aerospace missile research and production base that integrates research, design, testing and production.
4	China Space Sanjiang Group Corp (CASIC 4th Academy and 9th Academy)	A merger and restructuring of the former CASIC Academy IV and Academy IX, it is in charge of the R&D of China's solid carrier rockets, special off-road vehicles and chassis, specializing in commercial aerospace, laser industry, special vehicles and heavy equipment, energy equipment industry.
5	CASIC Academy for Drive Technology (CASIC 6th academy)	Originally the Research Institute for Solid Propulsion Systems of the Ministry of National Defense of the PRC, it is capable of developing, designing, producing and testing solid propulsion systems and has supplied more than 80 types of solid rocket propulsion systems to China's strategic tactical missile and aerospace industries.
6	China Aerospace Construction Group Co (CASIC 7th Academy)	Responsible for the consultation, design, survey and construction of large-scale aerospace projects in China, and having made significant contributions to manned spaceflight, lunar exploration and BeiDou navigation, with business areas covering aerospace, chemical engineering, petrochemicals, pharmaceuticals, oil and gas, power, metallurgy, railway, highway, electronic communication, radio and television, civil aviation, municipal engineering, building materials, etc., and dealings with 20 countries including the U.S., Germany, France, the UK, Australia, Russia and Japan.
7	Aerospace Jiangnan Group Co	R&D, production and sales of tactical missile weapon systems, aerospace products, ground equipment, satellite applications, radar, special batteries, small & special electrical machines, electronic components and other related products, automotive parts and accessories, petroleum equipment and instruments, agricultural machinery, industrial infrastructure, special encrypted 2D code anti-counterfeit data terminals, and other electronic information products; aerospace technology development and consulting.

	Name of Company	Primary Service
8	Hunan Aerospace Ltd	Aerospace products, magnetic materials and devices, computer hardware and software products, etc.
9	Aisino Co	Engaged in information security for the Chinese government and enterprises, and responsible for key projects such as the "Golden Tax," "Golden Card" and "Golden Shield" in China, specializing in cryptography, blockchain, big data and AI.
10	China Huateng Industrial Co	The main platform for CASIC's international operations and the main conduit for its international trade development.
11	Shenzhen Aerospace Industry Technology Research Institute Co	R&D and testing platforms for aerospace/airborne products; R&D in smart manufacturing, laser radar, optoelectronic information and AI technology; computer software development and technology transfer; and incubation of cutting-edge emerging technology enterprises.
12	Aerospace Communications Holdings Group Co	Formerly known as Zhejiang Zhonghui (Group) Co, it is a re-invested enterprise with CASIC as its largest shareholder, covering a wide range of fields such as communications, textiles, construction and security.
13	Aerosun Corp	Originated from the Qing Empire's Jinling Machinery Manufacturing Bureau, it is now a large-scale integrated machinery manufacturer directly under CASIC, and is also the biggest research and production base for metallic hoses and corrugated compensators in Asia and the fifth manufacturer of RTP pipes in the world. It applies aerospace technology in a wide range of fields such as special vehicles, engineering machinery, flexible pipe fittings and pressure vessels.
14	China Aviation Automotive Co	With a focus on civilian use, the company develops automobiles (including sedans), engines, scooters and spare parts, and is an integrated civil-military industry in the fields of automotive power, automotive parts, new energy vehicles and logistical support equipment.

	Name of Company	Primary Service
15	CASICloud-Tech Co	It is responsible for building the "Aerospace Cloud Network" industrial Internet public service platform, which is based on "Internet + Smart Manufacturing" and aims to create a secure and controlled environment for Industrial Internet (IIoT) in China and build a "Cloud Manufacturing" industrial cluster ecosystem to establish a new Internet economy. It has taken the lead in formulating the "Integration Requirements for Manufacturing Resources/Capabilities Access for Smart Manufacturing Service Platform," which is the first international standard on smart manufacturing service platform in the world.
16	Addsino Co	Formerly the state-owned Fuzhou Power Equipment Factory in China, the company is currently responsible for military and civilian communications technologies, with its main businesses encompassing five major areas: digital blue army and blue force gear, 5G communications and command-control equipment, cyberspace security, microsystems, and marine information gear.
17	Honghua Group Limited	The only overseas listed company under CASIC, it is a world-renowned manufacturer of land drilling equipment and an exporter of large-scale land-based oil rigs in China, positioning itself as the primary platform for the development of aerospace industry energy equipment. Its products are sold to major oil-producing regions in the world, such as North America and the Middle East, as well as emerging markets such as South America, India, Russia and Africa.
18	Henan Aerospace Industry Co	One hundred percent owned by CASIC, the company is engaged in the following activities: aviation and spacecraft related ancillary products, pumps, valves, pipes and fittings, pressure vessels, test and inspection instruments and equipment, compressors and mechanical equipment, industrial automatic control system devices, electronic components and electrical and mechanical component equipment, general components, automotive components, technology development, etc.

	Name of Company	Primary Service
19	Aerospace Precision Products Inc	Responsible for the R&D, production and sales of high-end fasteners in the aviation and aerospace fields, with primary business lines including: mechanical parts and components, rubber and plastic products, various standard parts and fasteners for military and civilian use, and import and export thereof.
20	Aerospace Science & Industry Finance Co	A non-banking financial institution jointly invested by CASIC and its 15 subsidiaries, it offers a wide range of financial services to CASIC and its affiliated enterprises.
21	Aerospace Science & Industry Asset Management Co	A platform for the incubation of new and innovative industries and equity investments by CASIC, it is engaged in capital management and asset management.

Source: Official website of CASIC at http://www.casic.com.cn/n12377654/n12378699/n12379906/index.html; official websites of affiliated enterprises; other publicly available information, etc.

As shown by the above two tables, there is a distinct division of work within China's two major military aerospace industry groups, which are gradually expanding the commercial application of their software and hardware technologies in a variety of fields, in addition to their main business of developing missile weapon systems.[19] This tendency is associated with the reform of China's central SOE, which can also dilute the military dimension of their military research and production organizations and facilitate international cooperation and technology transfer in the form of enterprises or through their affiliated enterprises that are close to relevant foreign high-tech sources.

Secondly, the key technologies in the aerospace field, ranging from launch vehicle power technology, satellite application technology, spacecraft power and propulsion technology, inertia-related technology, measurement and control communication technology, etc., to satellite launch, map surveying and mapping,

[19] The missile weapon systems developed and produced by China's two major aerospace and defense groups include the Falcon, Flying Leopard and Flying Eagle anti-aircraft missile systems, the M20 ground tactical missile system, the Super Patrol supersonic cruise missile systems, the Rainbow drones, the Fei Teng precision-guided bombs, the East Wind 5B and East Wind 15B missiles, etc.

and even software development, satellite networking, and the application of aerospace technology to automobiles and oil excavation, etc., are all in the hands of the major research institutes of the two military aerospace industry groups. This underlines the aforementioned priority given to military applications in China's aerospace science and technology, with commercial applications being promoted and operated by enterprises under the two leading military aerospace industry groups. As regards the incubation of new industries and equity investment in private enterprises, it is convenient to draw in advanced technology from private enterprises or foreign countries.

5. Technology Transfer from Other Advanced Countries

It is noteworthy that while China's aerospace science and technology boasts long-established R&D capabilities, it has suddenly taken a leap forward in recent years. In terms of global aerospace technology patents from 2016 to 2021, the top three are all Chinese companies, with Boeing only in fourth place.[20] Breakthroughs in critical Chinese aerospace technologies are largely transferred from other advanced countries by way of overseas trade, corporate mergers and acquisitions or international cooperation. For example:

(1) Ukraine: China has taken advantage of Ukraine's political corruption and economic downturn to introduce key space technologies such as liquid rocket engines, spacecraft power systems and space capsule systems. Ukraine was a prime site for the development of military and aerospace science and technology in the former Soviet Union, and the Yuzhnoye State Design Office, a leading company, developed a variety of weapons such as intercontinental missiles, medium-range ballistic missiles and spacecraft in the former Soviet era. The Yuzhnoye State Design Office has been assisting China in its lunar exploration project since 2014. On top of duplicating the engine for the lunar module and assisting China in developing the power system for the lunar

[20] "China Once Said It Couldn't Put a Potato in Space. Now It's Eyeing Mars," *CNBC*, June 29, 2021, https://www.cnbc.com/2021/06/30/china-space-goals-ccp-100th-anniversary.html.

spacecraft, the two countries are also working together on projects such as developing a cargo spacecraft system and setting up a colony on the Moon.[21]

(2) Russia: China has picked up a lot of space equipment and technology, either explicitly or implicitly, from Russia, which has a lot of experience in space development but a stagnant economy. China has bought equipment from Russia to build its Tiangong space station, modelled its space suits and launch vehicles on Russian products, provided substantial funding for technical cooperation in satellite technology, planetary exploration and materials for drones, and is scheduled to establish a permanent research base with Russia on the south pole of the Moon in 2030. China also acquired the latest Russian heavy-lift rocket engine technology through academic exchanges, resulting in the conviction of a Russian rocket expert who leaked the secrets.[22]

(3) Israel: China has secured advanced technologies or high-end semiconductor chips from Israel through affiliated companies of its central SOE. For example, the Changchun Institute of Optics, Fine Mechanics and Physics under the Chinese Academy of Sciences is responsible for the overall design and R&D of satellites, and its subsidiary Changguang Yuanchen Microelectronic Technology Co has acquired the complete technology for chip design and production through a collaboration with Tower Jazz, an Israeli semiconductor company, and has leveraged Tower Jazz's collaborative platform to develop the world's highest resolution full-frame image sensor and set up related production lines. Not to mention the fact that China has also acquired from

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[21] Li-ling Chiu, "Revealed: The Key to China's Aerospace and Defense Technology Surge: Beijing's Pal Ukraine," *CredereMedia*, February 20, 2019, https://reurl.cc/YOqzRL; "Ukraine Increases Cooperation with China in Aerospace Technology," *Voice of America*, April 10, 2016, https://www.voachinese.com/a/voa-news-ukraine-china-space-cooperation-20160410/3278359.html.

[22] Andrew E. Kramer and Steven Lee Myers, "Russia, Once a Space Superpower, Turns to China for Missions," *New York Times*, July 29,2021, https://www.nytimes.com/2021/06/15/world/asia/china- russia-space.html; "Representative of China's Ministry of Aerospace Industry Discusses Vision of Russian-Chinese Military-technical Cooperation in Space," *Sputnik*, September 17, 2016, https://big5.sputniknews.cn/opinion/201609071020697665/; "China Seeks New Rocket Engine Technology, Russia Charges Scientists," *Voice of America*, August 5, 2021, https:// reurl.cc/zW5q5y.

Israel advanced technologies such as missiles, chips, communications and AI.[23] Despite the tightening of technology export controls by the U.S. and the EU, China is still looking for ways to bring in critical technologies from other countries that are integral to the creation of an "aerospace powerhouse".

III. The Development of China's Aerospace Industry

The world's aerospace industry is currently dominated by the manufacture of hardware equipment such as missiles, rockets, satellites, spacecraft and space probes, but in the foreseeable future it will develop towards the provision of various aerospace services such as commercial rocket launches and commercial satellite applications (communications, navigation, positioning, remote sensing). Aerospace products are considered to be one of the key industries of next generation, as they can be applied in a wide range of fields beyond military, such as communications, navigation, positioning, traffic management, meteorological forecasting, underground mining, marine observation, disaster monitoring and rescue, etc., and can play a role in economic growth and social development.

China has long recognized the potential of the aerospace industry and has been promoting it with vigor since 2014, focusing on commercial applications such as rocket launches and satellite manufacturing, positioning, navigation and remote sensing. Its aerospace products include the Long March rockets, satellites of various types and applications, the Shenzhou manned spacecraft, cargo spacecraft, the Chang'e planet probes, the Tiangong space station, as well as satellite application services and advanced materials, etc. It is now aggressively developing the Dragon-series commercial rocket launch program, such as the Jie Dragon and Teng Dragon. The market size of China's aerospace industry has reached 1 trillion yuan RMB by 2020 and is projected to surpass US$210 billion by 2025, in which the total output value of the satellite navigation and positioning services

[23] "Exclusive: Documents Leak Secrets of China's Theft of Israeli Tech," *The Epoch Times*, August 4, 2021, https://www.epochtimes.com/b5/21/8/3/n13134887.htm.

industry has hit 403.3 billion yuan RMB by 2020, which holds great potential for development.[24] Furthermore, with the "One Belt, One Road" initiative in place, China is stepping up its efforts to promote China-led commercial aerospace applications, such as commercial launches, piggyback services and export of whole satellites, to countries in the Near East, Southeast Asia, Africa and Central America, in order to realize its "Space Silk Road" idea.[25]

The development blueprint of China's aerospace industry lies in the establishment of the "Five Clouds and One Vehicle" service and Industrial Internet Platform. The "Five Clouds and One Vehicle" refers to the following five projects: the "Flying Cloud" project for drone-borne regional cloud networks, the "Fast Cloud" project for near-Earth spacecraft-borne local cloud networks, the "Traveling Cloud" project for satellites-borne narrowband global mobile Internet, the "Rainbow Cloud" project for satellites-borne broadband global mobile Internet, the "Turn Cloud" project for flights between space and high altitude on Earth, and the "High-Speed Flying Train" project for supersonic trains using superconducting magnetic suspension technology and vacuum tubes. The Industrial Internet Platform refers to CASICloud, the first industrial Internet platform in China.[26]

The basic structure of China's aerospace industry is dominated by state-owned enterprises and complemented by private companies. It consists of CASTC, CASIC and the Chinese Academy of Sciences, together with relevant military research institutes, universities and other higher research institutions, as well as about 160

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[24] VentureBond Research Center, "Ready to Take off: China Commercial Aerospace Research Report 2021," *VZKOO*, June 2, 2021, https://reurl.cc/Gb5v8p; "Total Output Value of China's Satellite Navigation and Location Services Industry Reaches 403.3bn Yuan," *Xinhuanet.com,* May 18, 2021, http://www.xinhuanet.com/2021-05/18/c_1127460035. Htm.

[25] By Sept 2020, China had made 49 commercial launches, exported 14 whole satellites for 21 countries and international organizations, and exported various space products to all continents. AVIC Securities Finance Research Institute, *China Aerospace in the New Era* (Beijing: AVIC Securities, September 8, 2020), p. 16. For more information on the geopolitical deployment of China's BeiDou system, see: Hsiu-wen Wang, "The Recent Status of China's BeiDou System and its Geopolitical Deployment," *Defense Security Biweekly*, No. 30, October 15, 2021, pp. 11-17.

[26] "CASIC's 'Five Clouds, One Vehicle' Project Makes Series of Important Progress," *xinhuanet.com,* October 20, 2020, http://big5.xinhuanet.com/gate/big5/www.hb.xinhuanet.com/2020-10/20/c_1126631811.htm; "CASICloud 5th Anniv: Deepening the Industrial Internet to Seize the Frontier of the Times," *Xinhuanet.com,* June 16, 2020, http://www.xinhuanet.com/2020-06/16/c_1126120249.htm.

small and medium-sized private enterprises and numerous start-ups. The aerospace clusters are concentrated in Beijing, which is home to aerospace research institutes in China, and the Zhongguancun Science Park, where a wide range of start-ups are clustered, followed by Xi'an, China's main aerospace base, and Changchun, Tianjin and Wuhan.[27]

China's commercial aerospace industry is classified into five main categories: missiles, launch vehicles, satellites, spacecraft and space probes, with rocket manufacturing/launching and satellite manufacturing being the dominant ones. A brief overview of each industry can be found below.

1. Missile Industry

The global missile market is growing at an accelerated rate due to geopolitical uncertainty. Major international events such as the uncontrollable COVID-19 pandemic in 2021, the unstable situation in the Middle East due to the withdrawal of U.S. troops from Afghanistan, and the frequent movements of Chinese and European and U.S. warships in the South China Sea have led to a significant increase in global demand for missiles, which is estimated to reach a production value of over US$130 billion from 2019 to 2027.[28] China's domestic demand for missiles has also grown as a result of its military strengthening policy, and its missile supply chain is shown below (Table 9-4).

As can be found in Table 9-4, the military-industrial complex plays a leading role in the design and manufacture of missiles, while only some systems such as electronic components, guidance, navigation, and control systems and composite materials allow for the participation of private companies. This also demonstrates the relationship between the private enterprises involved in the supply chain of missile manufacturing and the Chinese military, and possibly even the equity investment by the military industrial group. However, are these Chinese private

[27] VentureBond Research Center, "Ready to Take off: China Commercial Aerospace Research Report 2021," *VZKOO*, June 2, 2021, https://reurl.cc/Gb5v8p.

[28] AVIC Securities Finance Research Institute, *China Aerospace in the New Era* (Beijing: AVIC Securities, September 8, 2020), p. 31.

enterprises listed overseas to raise funds? Is there any foreign capital invested?[29] It may be worthwhile for the governments of the countries concerned to look into this matter.

2. Launch Vehicle Industry

As China has been building up its aerospace infrastructure, the market for launch vehicles, which are capable of delivering various space vehicles to Earth orbit, is extremely promising, with the launch vehicle supply chain tabulated as follows (Table 9-5).

Table 9-4 China's Missile Supply Chain

Phase	Task	Related Listed Companies			
Planning	Design	Addsino, Zhongtian Rocket, Tian'ao Electronics, DongHua Testing, Xinguang Optoelectronics, Watertek Information, Beetech, Up Optotech			
Manufacture	Prototype validation, finalization and mass production	Components	Spare parts	Forged parts, thermal protection, sealing materials	Avic Heavy Machinery, Zhongtian Rocket, Anhui Truchum Advanced Materials, Shanghai Hugong Electric, Fushun Special Steel, Kuang-Chi Technologies, Baoji Titanium, Guangwei Composites, Loncin Motor, Guangyunda Optoelectronics, Beijing Cisri-Gaona Materials & Technology, NCS Testing Technology, Xinjiang Machinery, PRET Composites, Hunan Boyun New Materials, Kingstrong Technology, Tongda, Qinchuan Machine Tool, Pengqi Technology, Tianjian Tech, Zhongjian Technology

[29] In Taiwan, there are around 30 mutual funds holding stocks of Chinese military companies such as Hikvision Co, AVIC Aviation High-Tech Co and Shenyang Aircraft Corp. See Kuo-chiang Cheng, "Investors Become Accomplices in China's Aircraft Harassing Taiwan? List of 28 Taiwan Funds Buying China's Military Industry Revealed," *Yahoo! Stock Market*, August 11, 2021, https://reurl.cc/6Dl82M.

Phase	Task	Related Listed Companies			
			Electronic components	Electronic components, Semiconductor devices	Space Appliance, Long March Launch Vehicle Technology, CASTC, Glarun Technology, GCI Science and Technology, Zhenhua Science & Technology, AVIC Jonhon Optronic Technology, Sai MicroElectronics, Hangjin Technology, Wantong Technology, HTC, Hongyuan Electronic, Quanxin Cable, Tellhow Sci-Tech, Red Phase, Shenzhen H&T Intelligent Control, Kingstrong Technology, DongHua Testing, Guide Infrared, Haige Communications, Jingjia Micro, Torch Electron, Zhejiang Dali Technology, YaGuang Technology, Shenglu Telecommunication
			Others	Propellants, pyrotechnic devices, optical devices	Haohua Chemical Science, Shaanxi Xinghua Chemistry, Xinyu Guoke Technology, Fujian Forecam Optics, Sichuan Tianyi Science & Technology
		Subsystems/ components	Projectile structure		Aerospace Communications
			Power system		Zhongtian Rocket
			Guidance and control systems		Long March Launch Vehicle Technology, North Electro-Optic, Glarun Technology, Aerosun, North Navigation Control, Kangtuo Infrared, Jiuzhiyang Infrared, Uroica Precision Information, Sai MicroElectronics, Huaxun Ark System Technology, Chenxi Aviation, Changshu Tianyin Electromechanical, Gaode Infrared, StarNeto Technology Development, Harbin New Optoelectronics, Weixing Industrial Development, Leike Defense, Shenzhen SDG Information, Toyou Feiji Electronics, Zhejiang Dali Technology, Red Phase
			Combat systems		North Industries Group Red Arrow, GreatWall Military Industry, Guangdong Ganhua Science & Industry
			Others		Aerospace Changfeng, CASTC, Shenyu Communication, Quanxin Cable, Kangda New Materials, Guangdong Ganhua Science & Industry, Beijing Relpow Technology, TongHe Technology
Maintenance	Life extension		Harbin New Optoelectronics, Watertek Information		

Source: AVIC Securities Finance Research Institute, *China Aerospace in the New Era* (Beijing: AVIC Securities, September 8, 2020), p. 46.

According to the "Aerospace Transportation System Development Roadmap 2017-2045" released by CASTC in 2017, the development progress of China's launch vehicles (i.e. the aforementioned "aerospace transportation system") is as follows: by 2020, the mainstream launch vehicles of the Long March series will reach international first-class standards, and the low-cost medium-sized launch vehicle Long March 8 will complete its maiden flight; by 2025, the development of a reusable launch vehicle will be completed and suborbital space tourism will be realized; by 2030, the inaugural flight of a heavy-lift launch vehicle will be achieved and a manned lunar landing will be prepared; by 2035, the launch vehicle will be fully reusable, the first flight of a new-generation launch vehicles will be accomplished, and intelligent space transportation systems will be widely used; by 2040, a new-generation launch vehicles will be in use, a combined power two-stage reusable vehicle will be developed, a major breakthrough will be made in nuclear-powered space shuttles, and asteroid mining and solar power stations in space will be realized; and by 2045, access to space and space transportation will have undergone a revolutionary change, and it is hoped that the construction of sky ladders, Earth stations and space stations will be implemented.[30] This provides a glimpse of China's long-term plans for the development of launch vehicle technology and commercial applications, with a view to capturing a share of the global launch vehicle market.

[30] "China Releases Roadmap for Future Aerospace Transport System," *Chinese government portal*, November 17, 2017, http://www.gov.cn/xinwen/2017-11/17/content_5240308.htm.

Table 9-5 China's Launch Vehicle Supply Chain

Phase	Task	Related Listed Companies			
Planning	Design	Zhongtian Rocket, China Electric Power Research Institute, DongHua Testing			
Manufacture	Prototype, production, assembly	Components	Spare parts	Forged parts, thermal protection, sealing materials	Zhongtian Rocket, Avic Heavy Machinery, Anhui Shenjian New Materials, Fushun Special Steel, Shanghai Hugong Electric, Xinjiang Machinery, Beijing Cisri-Gaona Materials & Technology, Bichamp Cutting Technology (Hunan), Wuhan Huazhong Numerical Control, Zhejiang Dayuan Pumps Industry, Western Superconducting Technologies, Hunan Boyun New Materials, Anhui Truchum Advanced Materials, Luoyang Bearing Science & Technology, Anhui Antai Technology, Xi'an Bright Laser Technologies, Baoji Titanium, China Molybdenum, Nancal Technology, Zhejiang XCC Group, Fujian Longxi Bearing, Hubei Feilihua Quartz Glass, Xining Special Steel, Kuang-Chi Technologies, Harbin Electric Corporation Jiamusi Electric Machine, Haohua Chemical Science, Zhongjian Technology, Guangwei Composites, Sichuan Sunny Seal
			Electronic components	Electronic components, Semiconductor devices	Addsino, Long March Launch Vehicle Technology, Space Appliance, Zhenhua Science & Technology, AVIC Jonhon Optronic Technology, China Marine Information Electronics, YaGuang Technology, Galaxy Biomedical Investment, Sai MicroElectronics, Torch Electron, DongHua Testing, Zhuhai Orbita Aerospace, Hongyuan Electronic, Quanxin Cable, Shenzhen H&T Intelligent Control
			Others	Propellants, pyrotechnic devices, optical devices	Chongqing Sanxia Paints, Fujian Forecam Optics, Haohua Chemical Science, Shaanxi Xinghua Chemistry, Sichuan Tianyi Science & Technology, Xinyu Guoke Technology
		Subsystems/ components		Rocket body structure	N/A
				Propulsion system	Avic Heavy Machinery, Zhongtian Rocket
				Control system	Long March Launch Vehicle Technology, Xinguang Optoelectronics

Phase	Task	Related Listed Companies		
			Flight measurement safety system	Long March Launch Vehicle Technology, YaGuang Technology
			Other systems	Long March Launch Vehicle Technology, Zhongtian Rocket, Beijing Relpow Technology, Quanxin Cable, Guangzhou Hi-Target Navigation Tech, Harbin Electric Corporation Jiamusi Electric Machine
Launch	Launch		N/A	

Source: AVIC Securities Finance Research Institute, *China Aerospace in the New Era* (Beijing: AVIC Securities, September 8, 2020), p. 53.

3. Satellite Industry

The satellite industry is the largest aerospace industry in terms of number of products and market size, and can be divided into low-Earth-orbit (LEO) satellites, medium-Earth-orbit (MEO) satellites, geostationary-orbit (GEO) satellites and sun-synchronous-orbit (SSO) satellites, depending on their orbital altitude. Additionally, they can be categorized into communication satellites, navigation satellites, remote sensing satellites that use electromagnetic waves to observe the Earth, and other satellites for scientific experiments, technical verification and military surveillance.

China has launched the BeiDou global navigation system for navigation satellites and the Gaofen and Fengyun series for remote sensing satellites. Particularly in 2018, China has significantly increased the number of launches of various satellites in order to catch up with the satellite network deployments by advanced countries, making it the world's largest launcher. Further, China's constellation of remote sensing satellites and communication satellites was being deployed from 2020 onwards, and the inclusion of the "Satellite Internet" in the "New Infrastructure Construction" program has led to a very promising outlook for China's satellite industry, with an estimated market size of over 315 billion yuan RMB from 2020 to 2025 and 80 percent of these satellites being small low-orbit

communication satellites and navigation microsatellites.[31] The Chinese satellite supply chain is listed below (Table 9-6).

As the missile industry and the launch vehicle industry, the key technologies in satellite hardware manufacturing are mostly in the hands of the two major aerospace and military conglomerates and the Chinese Academy of Sciences, with private enterprises only allowed to supply a small proportion of spare parts and electronic components. Compared to the missile and launch vehicle supply chain, nevertheless, the satellite supply chain has seen more participation from small and medium-sized private enterprises in downstream applications and operations such as ground-based measurement and control, data processing, communications, navigation, remote sensing and other sectors.

Table 9-6 China Satellite Supply Chain

Phase	Task	Related Listed Companies			
Planning	Design etc.	China Spacesat, Shenzhen SDG Information, Hwa Create			
Manufacture	Prototype, assembly, mass production	Components	Spare parts	Forged parts, thermal protection, sealing materials	China Spacesat, Anhui Truchum Advanced Materials, Anhui Yingliu Electromechanical, Pengqi Technology, Sinoseal Holding, Zhejiang XCC, Haohua Chemical Science, TDG Holding, Grinm Advanced Materials, Xinjiang Machinery, Guangwei Composites, Zhongjian Technology
			Electronic components	Electronic components, Semiconductor devices	Long March Launch Vehicle Technology, Addsino, Zhenhua Science & Technology, Hongyuan Electronic, Shanghai Hugong Electric, HC SemiTek, Sichuan Haite High-Tech, Torch Electron, Leike Defense, YaGuang Technology, Sanan Optoelectronics, Maxscend Microelectronics, Quanxin Cable, Shenzhen H&T Intelligent Control, Shenglu Telecommunication, Zhuhai Orbita Aerospace, Hwa Create
			Others	Electric machinery, optics,	Shanghai Moons' Electric, Haohua Chemical Science, Uroica Precision Information, Fujian Forecam Optics, Zhejiang Dali Technology

[31] Source: AVIC Securities Finance Research Institute, *China Aerospace in the New Era* (Beijing: AVIC Securities, September 8, 2020), p. 79.

Phase	Task	Related Listed Companies		
		Subsystems/ components	Communication satellite	Aerospace Communications, Long March Launch Vehicle Technology, Hwa Create
			Navigation satellite	Long March Launch Vehicle Technology, Tian'ao Electronics
			Remote sensing satellite	Long March Launch Vehicle Technology
			Structural system	N/A
			Survey and control system	Long March Launch Vehicle Technology, Aerosun, CASTC, Leike Defense, Hangzhou Prevail Optoelectronic Equipment
			Attitude and orbit control	Long March Launch Vehicle Technology, Changshu Tianyin Electromechanical
			Thermal control system	Long March Launch Vehicle Technology, Shanghai Hugong Electric
			Power supply systems	China Spacesat, CETC Energy, Aerospace Changfeng, Shanghai Hugong Electric, Quanxin Cable, Beijing Relpow Technology
			Other: ground side control network, data processing, etc.	Long March Launch Vehicle Technology, CETC Energy, Aerospace Communications, Glarun Technology, China Spacesat, Piesat Information Technology, Unigroup Guoxin Microelectronics, Daheng New Epoch Technology, Shanghai Hugong Electric, Sichuan Zhongguang Lightning Protection Technologies, Toyou Feiji Electronics, Leike Defense, Up Optotech, Kaile Science and Technology, Zhuhai Orbita Aerospace
Operation	In-orbit testing, operations management	Satellite remote sensing		China Spacesat, Long March Launch Vehicle Technology, Piesat Information Technology, Tianjin 712 Communication & Broadcasting, Leike Defense, Zhuhai Orbita Aerospace, Donghua Remote Sensing, Geovis Technology

Phase	Task	Related Listed Companies	
		Satellite navigation	China Spacesat, Long March Launch Vehicle Technology, Sun-create Electronics, China Greatwall Technology, CASTC, Tian'ao Electronics, Ningbo Joyson Electronic, Hunan Copote Science and Technology, TKD Science and Technology, Tsinghua Tongfang, Shanghai Huace Navigation Technology, Quectel Wireless Solutions, Nanjing Doron Technology, Tianjin 712 Communication & Broadcasting, Sai MicroElectronics, Huizhou Speed Wireless Technology, Chengdu Corpro Technology, Hwa Create, Beijing Jiaxun Feihong Electrical, Guangzhou Hi-Target Navigation Tech, Wuhan Yangtze Communication, Jiangsu Xinning Modern Logistics, Guangzhou Haige Communications, Leike Defense, Beijing UniStrong Science and Technology, NavInfo, Anhui Shenjian New Materials, Beijing BDStar Navigation, Sichuan Jiuzhou Electronic, Shenzhen Neoway Technology, Zhejiang Weixing Industrial Development, Hangjin Technology, Shaanxi Fenghuo Electronics, Zhejiang Dali Technology

Source: AVIC Securities Finance Research Institute, *China Aerospace in the New Era* (Beijing: AVIC Securities, September 8, 2020), p. 94.

Secondly, as noted above, one of China's main objectives in developing its aerospace industry is to advance the "Belt and Road Spatial Information Corridor" in an effort to fulfill its vision of a "Space Silk Road." China is capitalizing on the BeiDou system, various satellite applications and space station diplomacy in the hope of partnering with countries along the "Belt and Road" route in the fields of communication, navigation, remote sensing and space research.

At present, China has over 200 satellites in orbit, including meteorological satellites, resource satellites, ocean satellites, high-resolution Earth observation satellites, navigation and communication satellites, etc. Regarding satellite communications, in addition to launching Asia Pacific communication satellites, China has succeeded in establishing a beachhead in the ASEAN member states

by providing Laos with a "whole-satellite export" model ranging from satellite launching, in-orbit delivery, operation and maintenance, to ground station infrastructure. Meanwhile, by assisting Belarus in launching its communications satellites, China has for the first time rendered a "whole-satellite in-orbit delivery" service to a European customer. With regard to satellite remote sensing services, China has set up permanent bases in South America and Africa to provide remote sensing services on a global scale. With respect to satellite navigation, China has forged partnerships with Russia, the Arab League, Pakistan and ASEAN countries via the BeiDou navigation system. As regards international cooperation on the space station, China has decided to conduct 9 space science experiments with 17 countries and 23 institutions by means of open recruitment and competition.[32]

It is envisaged that the Chinese commercial space market will see a swift growth with the intensive launch of various spacecraft, the conclusion of several satellite constellation projects and the mass production of reusable rockets.

IV. Conclusion

By summing up the above analysis, preliminary conclusions are drawn as follows:

First, the initial and primary purpose of China's development of aerospace science and technology is for military applications. Notwithstanding China's repeated statements that its development of aerospace science and technology is for the sake of world peace, its "original intent" of military applications should not be overlooked. Since the inception of the "Two Bombs and One Satellite" project, China has laid down the "Three-Step Development Strategy" for aerospace science and technology under the direction of the government, and has committed and allocated funds, manpower and other relevant resources to inspect and accept the results of each stage along the way. While lagging behind the U.S. in some areas of

[32] "CASTC: Partnering with the Aerospace World for Win-win," The State Council State-owned Assets Supervision and Administration Commission, January 8, 2021, https://reurl.cc/ZjZg0p.

expertise, China's space military capability, developed through the integration of various technologies, poses a definite threat to the U.S.

Second, China has developed aerospace science and technology primarily with the aid of the aerospace and military–industrial complex and the Chinese Academy of Sciences. As can be noted from Tables 9-2 and 9-3, the development of China's aerospace science and technology rests on the two major military aerospace industry groups, with clear internal divisions of work in place. Everything ranging from the development of key technologies such as power and inertia, to satellite launching and mapping, to software development, satellite networking, and the application of space technology to automobiles and oil exploration is all spearheaded by the two leading military aerospace industry groups. In addition, under the policy of civil-military integration, China has also strived to acquire advanced technologies from private enterprises and through its affiliated enterprises from Ukraine, Russia, Israel and other countries.

Third, China's aerospace science and technology, by leveraging its strengths in emerging technologies like AI, has developed considerable space capabilities, such as the BeiDou satellite navigation system, Gaofen Earth observation systems, space station docking and Mars landing. For the U.S., the progress of China's counterspace capabilities such as space situational awareness, physical kinetic attacks, electronic attacks, and directed energy weapons warrants close attention. As far as our country is concerned, has China's approach to warfare against Taiwan changed as a result of its advancements in space capabilities, such as by waging intelligent warfare, using satellites to direct unmanned weapons for precision attacks, or using laser and electromagnetic pulse weapons to strike at our critical infrastructure, rather than physically destroying it? Perhaps this could serve as a reference for our military simulations.

Fourth, China is capitalizing on BeiDou navigation and satellite applications to swell its geopolitical sphere of influence. Laos has embraced the "export of whole satellites" model, in which all satellites are manufactured, launched and managed by China, effectively putting it in China's aerospace sphere of influence. Will this model be duplicated in Central and South America, Africa, the Middle East and

other regions? In the future, if the satellite Internet and space stations are put in place, China's "Space Silk Road" may be completed sooner than the ground-based infrastructure under the Belt and Road Initiative.

Fifth, in terms of the space confrontation between the U.S. and China, the U.S. government has not only created a space force, but also tightened export controls on Chinese related technologies and products, and added a number of Chinese aerospace enterprises to its Entity List. But the fight for space technology must be backed by strong economic and financial support. Will the two countries be able to sustain the race for R&D and investment in space technology? Whether China's huge national budget dedicated to the realization of its space dreams by the 100th anniversary of the founding of the PRC would repeat the mistakes of the former Soviet Union, which collapsed in the end due to an economic meltdown in the wake of a space race with the U.S. warrants further attention.