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# Executive Summary

China has had a space program since roughly the same time that the National Aeronautics and Space Administration (NASA) was created in 1958. Since the 1970s, China has launched increasingly complicated military, robotic, and human missions into space, making China a major spacefaring nation. Until recently, however, China has not had a *commercial* space sector in which firms vie to sell space products and services to state and private customers domestically and internationally.

Using original documents and first-hand Chinese-language interviews with Chinese companies and China's industry experts, this report provides a review of the current landscape of China's nascent but growing commercial space sector. The report addresses three questions:

- What factors are driving the development of China's emerging commercial space sector?
- What are the key characteristics of this sector?
- What are its strengths and weaknesses, and where do we expect Chinese commercial space companies to be in the next 5–10 years?

## Commercial Space Policies and Drivers in China

From the central government's perspective, China's preeminence in space will be achieved principally through government-directed efforts led by state-owned enterprises (SOEs). Official Chinese documents provide support to the commercial sector, but the commercial space sector is generally not seen by the bureaucracy as a central part of China's efforts in space. There is, however, a perception within the Chinese government that jumpstarting a commercial space sector may bring disruptive new technologies and efficiencies. Under this view, commercial space companies would support SOEs, and potentially reduce China's reliance on space-related systems and technologies from other countries. While it is not codified in law or policy, support for commercial activities also appears to be an experiment on the part of the government to spur entrepreneurship in a traditionally conservative space industry, and identify new sources of economic growth.

To support the growth of a commercial space sector, the Chinese government issued Document 60 (*Guiding Opinions of the State Council on Innovating the Investment and Financing Mechanisms in Key Areas and Encouraging Social Investment*) in 2014. Document 60 was followed by other policy documents that encouraged private and

international investment in space, a previously protected sector. The government has allowed commercial space companies to leverage the government's supply chains and other capabilities, such as the use of government launch sites and the facilities of space SOEs.

With the exception of direct central government support for a small number of commercial firms, central government funding for the commercial space sector in the form of research and development (R&D) funding or contracts for products and services has been less than funding from provincial governments eager for regional technology-based economic development. The central government appears to let private entities succeed or fail on their own merits. If a company is successful, the government may take greater interest in ensuring its continued success and growth, as the government has done in other sectors such as telecommunications or information technology (IT). In practice, while some collaborations have occurred, SOEs tend to dismiss most emerging space companies.

Commercial space companies and their investors are driven largely by the expectations of an economic payoff and interest in space, rather than a sense of patriotism, support for the government's goal of exercising space dominance as a form of soft power, or other such reasons. In public documents, these companies may appear committed to government initiatives—such as civil-military integration—as motivations for their endeavors, but these factors do not seem to drive the entrepreneurs with whom we spoke.

## Characteristics of the Emerging Space Sector

There are many different estimates of the number of commercial space companies in China. In some cases, the differences come from the definition of the term "commercial." To classify the companies examined, we evaluated each based on three questions: Does the company have some private parties taking risk (through ownership, investment or other means), even if the majority shareholder is an SOE? Do they sell their products to customers other than the Chinese government? Do they appear to demonstrate independence from their parent SOE or government agency?

Using this operational definition of commercial space, in a database developed by STPI, we identified 78 commercial companies in China. Of these, 29 focus on satellite manufacturing, 21 are part of the launch sector, 8 are remote sensing operators, 17 focus on communications, and 33 emphasize areas such as ground stations, downstream analytics, and other applications.[1] The entire sector focuses on the launch and use of small satellites (satellites under 500 kg). More than half were founded after 2014 (Figure ES-1), and most are headquartered in Beijing (Figure ES-2).

[1] The sum of these numbers exceeds 78 because some companies engage in multiple activities.


**Figure ES-1. Founding Dates of Companies in Database by Type of Commercial Category**

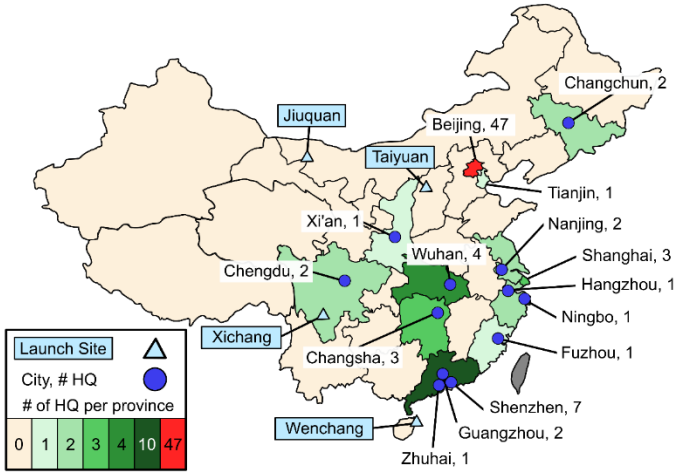


**Figure ES-2. Locations of Commercial Space Companies**

From an ownership perspective, these companies fell into four categories: (1) 14 are companies that are subsidiaries of SOEs that receive government funding but plan to sell to the government and other customers (e.g., launch provider Expace); (2) 9 are spin-offs from the Chinese Academy of Sciences (CAS) or other government organizations or SOEs that receive government support, including funding (e.g., commercial remote sensing company Chang Guang Satellite Technology); (3) 42 are start-ups with no known government funds (e.g., launch provider Landspace whose funding is primarily from venture capital [VC] firms); and (4) 13 are spin-offs from other private companies that have access to large sources of private funds (e.g., communications company CCT Satcom). Figure ES-3 illustrates these numbers.

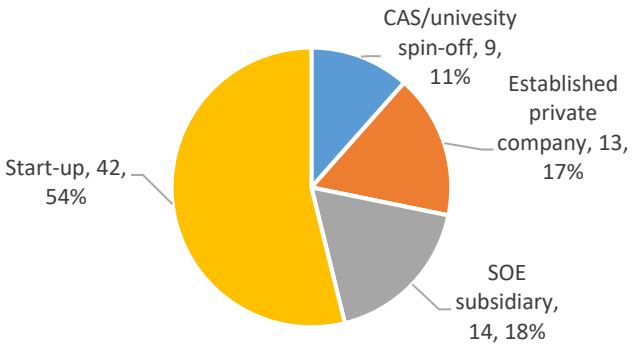


**Figure ES-3. Ownership of Chinese Commercial Space Companies**

Our best count of investment in the commercial space sector is between about $600–900 million in the years 2014–2018, with most of those investments made in the last 2 years (Figure ES-4). Most interviewees believe that VC will shrink in the coming years, or at least be concentrated in a smaller number of companies and sub-sectors.

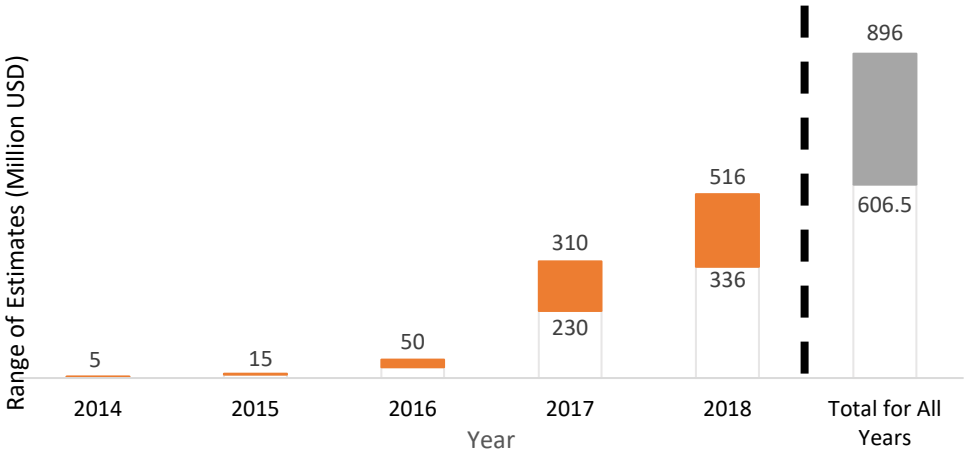


**Figure ES-4: Estimate of Total Funding of Chinese Commercial Space Companies**

Many of the companies in the database do not have profits yet. Most companies do not even have business plans or a strong sense of who their customers might eventually be. When queried about their future, the companies in the database indicated a desire to be Chinese versions of American space companies. They believe their customers will be those that American companies cannot serve or are not interested in serving (e.g., domestic Chinese customers, customers from Belt and Road Initiative [BRI] countries, and other customers that are price-sensitive). Neither the companies themselves nor the government experts interviewed expect Chinese commercial space companies to replace China's space SOEs in serving government needs, at least in the near-term. Most commercial space

companies are waiting and watching to see how U.S. companies perform before they pick specific directions for future products.

## Strengths and Weaknesses of the Emerging Commercial Space Sector

The emerging commercial space sector is nascent but shows some strengths. *First*, the central government has provided political support, and provincial governments have provided substantial financial support to the commercial sector. This support allows many commercial space companies to draw on state-owned space supply chains and manufacturing capabilities. In principle, it could allow them to develop unhindered and remain somewhat insulated from market forces, and sell (for example) in BRI countries, but we found no evidence of this. Government preference for traditional SOEs may limit the markets that commercial companies may enter and the share of those markets they may be able to capture. *Second*, the companies benefit from China's large, well-trained workforce, strong manufacturing sector, and an entrepreneurial culture that values hard work. The commercial space companies have focused on innovating on cost and leveraging second mover advantage by watching and learning from companies in the United States. *Third*, the companies benefit from the growing levels of private equity and VC funds in China, looking for investment opportunities outside the IT and telecommunications sectors. *Lastly*, U.S. and other countries' export control regimes are viewed as, and could well be, an initial challenge that ultimately results in a positive outcome by forcing the development of indigenous supply chains as well as domestic markets.

China's commercial space sector is also beset by several challenges. *First*, most companies are relatively unsophisticated from a business perspective, and do not have a clear idea of who their customers are. The Chinese VC ecosystem is also not as robust as that in the United States; Chinese VCs set shorter timelines for returns on investment than U.S. VC firms. Since most companies are watching the successes of American commercial sector, being a second mover, even as a fast follower, limits their opportunities. *Second*, while the companies have support from the central and provincial governments, some parts of the government bureaucracy and some SOEs are dismissive of the emerging space companies, which makes it difficult for them to become true competitors to the incumbent SOEs. *Third*, China has a "brand image" problem, which could hurt foreign sales, especially in countries that tend to be closely affiliated with the United States. *Fourth*, as with other high-tech sectors, Chinese commercial space companies are experiencing labor market pressures as salaries in the aerospace sector have risen sharply, and they face intense competition for trained staff, which may limit their ability to grow. *Lastly*, the lack of commercial space-specific regulations and policies may hurt the sector, as businesses would prefer the stability of rules, and the legitimacy they bring, rather than relying on one-off relationships with government officials.

## China Commercial Space in the Next 5–10 Years

While China's emerging commercial companies are in an embryonic stage and often appear to be struggling, some are slowly gaining their footing. In the course of the next decade, a small number of them could enjoy substantial growth, especially if there is growth in markets that benefit from the launch and use of small satellites.

The size and composition of the commercial space sector in China in the coming 5–10 years depends not just on whether these companies can develop globally competitive products and services. They already have the scrappy entrepreneurialism, the talent, the technologies, and the funding, although some may be lacking business acumen. Their future also depends on four key external factors: Chinese government policies, which will affect their ability to compete for domestic and regional space markets; growth in the global space sector; international willingness to trade with China; and developments in adjacent sectors, which could improve China's competitiveness in the space sector, and increase the market share of Chinese commercial space companies.

As of this writing, most Chinese commercial space companies are only 2 to 3 years old. In the next decade, a small number of Chinese commercial space companies could grow to a point where they have critical mass, especially if markets that benefit from the launch and use of small satellites grow rapidly. If this is the case, the Chinese government is likely to take a greater role in ensuring the success—and contribution to the Chinese economy and national security—of the commercial space sector, as it has done in other sectors such as telecommunications and IT.

If future applications remain such that governments dominate the space sector, it would favor SOEs in China, especially the SOE subsidiaries focused on commercial business. If, on the other hand, applications of interest to businesses and households (rather than governments) emerge, China can leverage its capabilities in rapid mass production, its skilled space industry workforce, and its ability to rapidly develop products similar to other sectors. Commercial companies would likely fare better under this scenario, as there would be more opportunities for them to capture the market, domestically and internationally.

# Contents

# 1. Introduction

China has had an active, if at times small, space program since the mid-1950s. Today, China's space sector is one of the most robust in the world. China is the third nation to independently launch humans into space. In 2018, China led the world in the number of launches, attempting a total of 39, of which 38 were successful (Krebs 2019). As of December 2018, China had more than 280 operational satellites in orbit, which were providing communications and Earth observations, and supporting military missions (Union of Concerned Scientists 2018). On January 2, 2019, China became the first nation to soft-land a spacecraft on the far side of the moon (Jones 2019a). By 2020, China plans to complete the BeiDou Navigation Satellite System (BDS-3) so as to offer global coverage (China Satellite Navigation Office n.d.). Estimates of the total value of China's space activities in 2017 exceed $16 billion (Euroconsult 2018). The Chinese government's 13th Five-Year Plan (FYP) (2016–2020) not only named deep space as a strategic field and Earth observation systems as a strategic emerging industry, but also prioritized the development of next generation and heavy-lift launch vehicles, new types of satellites, and other space platforms and payloads.

To date, nearly all of China's accomplishments in space have been achieved by the Chinese government, state-owned enterprises (SOE), or their subsidiaries and suppliers. Historically, China's space industry has predominantly consisted of SOEs controlled by China's central or provincial governments. Since 1999, two SOEs, the China Aerospace Science and Technology Corporation (CASC, 中国航天科技集团) and the China Aerospace Science & Industry Corporation (CASIC, 中国航天科工集团),[2] have had a near duopoly on launch and space technology in China, with CASC serving as the primary SOE responsible for launch and space technologies.[3]

Chinese SOEs' historic dominance of the space sector may be changing. Today, private entities engage in research and development (R&D), manufacturing, launch, and operations of commercial satellites. State Council documents, such as the 2016 Space White Paper, have supported the development of the commercial space sector. Such policies and supporting documents appear to have dramatically shifted the landscape of China's space sector. Over the last 5 years, the number of start-up space companies in

[2] Both of these SOEs were created when the State Council split the China Aerospace Corporation in two to encourage competition in the aerospace and missile sector.

[3] A more extensive introduction to the major Chinese space organizations is available at: http://www.iafastro.org/wp-content/uploads/2018/06/MajorChineseSpaceCompanies.pdf

China has proliferated; industry insiders estimate that between 80 and 100 space companies had been founded in China as of the end of 2018 (Moss 2018; Chen 2018).

## A. Project Goals and Methodology

As China's commercial space sector expands, potentially into foreign markets, the U.S. Government will need to have a more accurate understanding of China's current commercial space sector and its future prospects. In this report, STPI examines China's burgeoning commercial space sector by surveying Chinese space companies, interviewing Chinese entrepreneurs, and investigating the broader Chinese space sector. The goal of this report is to provide insights into the role China's commercial space sector may play in the global space market, and whether this new commercial sector can drive innovation within China's space industry.

STPI evaluated the current landscape of China's nascent but growing commercial space sector by addressing three specific questions:

- What are the key characteristics of China's emerging commercial space sector?
- What factors are driving the development of China's commercial space sector?
- What are the strengths and weaknesses of the Chinese commercial space sector, and where do we expect the sector to be in the next 5–10 years?

To address these questions, STPI first developed a definition for commercial space, guided by our understanding of how the term is used in both China and the United States, as well as any notable differences between the two. The analysis that follows relies heavily on primary data collection, including non-attributional discussions with over 40 experts at 23 Chinese space companies at their offices, or at Chinese and international space conferences. Other sources of primary data include annual reports, public Chinese business records databases, and publicly available data on stocks listed on exchanges. STPI also reviewed and incorporated into the report academic and commercial literature on Chinese commercial space activities. Two reviewers with different areas of expertise in the Chinese space sector added further input. Research for this report was conducted between September 2018 and August 2019.

### 1. Definition of a Commercial Company

Prior to examining the commercial space industry, we first define what companies we include in our evaluation, as the boundary of what includes a commercial company in China varies depending on whom is asked. For example, many SOEs conduct commercial activities with the private sector, buying and selling goods and services from and to households and businesses. However, many of these SOEs prioritize state goals over profitability and do not face traditional market pressures (e.g., they may receive funding from the state to offset losses if costs exceed revenues). In China, therefore, a commercial

company is an enterprise that has a primary goal of pursuing profits, rather than meeting government policy goals.

Notably, this definition of *commercial* differs from the conception of commercial in the United States. The 2010 National Space Policy defined the term commercial as:

> space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential non-governmental customers.

Commercialization, under a U.S. perspective, has two dimensions:

1. risk-taking, especially financial, by entities other than the government. Generally, for a company's activities to be considered commercial, at least some private capital must be at risk or the company must sell to the private sector.
2. the breadth of the customer base, which includes both governmental and non-governmental customers

Although the above definition fits well with companies in the United States and Europe, ownership in China can be complex (Szamosszegi and Kyle 2011). For example, a majority state-owned company may sell services to households and businesses commercially and have some private investors. Many of the Chinese experts with whom we spoke would consider such a company to be commercial, despite being backed by the state, provided its primary purpose was to sell commercially in pursuit of profits. Alternatively, a company that is mostly privately-held that has some investment from provincial or municipal VC firms or from the Chinese Academy of Sciences (CAS) and sells solely to the government would also be considered commercial. As such, we use a different framework than one used in the United States for defining "commercial," as we believe it is more appropriate.

Although both these hypothetical companies would be considered commercial, they would be referred to differently in Chinese. Companies that are more privately-held are referred to as 民营企业 (mínyíng qǐyè), meaning a company operated by a civil entity. Companies that are majority-owned by the state fall under the label 国有企业 (guóyǒu qǐyè), meaning state-owned enterprise.

Interviews and a literature review revealed that Chinese nationals do not consider all SOEs that offer commercial services as commercial companies. This distinction was manifested in literature and news reports on China's commercial space industry, as authors often differentiate between commercial space (商业航天, shāngyè hángtiān) and space commercialization (航天商业化, hángtiān shāngyèhuà), with the latter referring to government-focused SOEs selling their space products and services in commercial markets

and the former referring to both commercially-focused state-owned companies and privately-held companies selling to commercial markets.

As ownership does not necessarily determine how a Chinese space company operates, for the purposes of this report we define a commercial company in China as an enterprise that is primarily operated in pursuit of profit, as opposed to an organization that conducts commercial activities primarily to meet public policy goals, which is characteristic of SOEs. Notably, this definition can include companies that are fully state-owned. We make a distinction between state-owned *enterprises*, which pursue the goals of the state, and state-owned *companies*, which pursue profits, rather than public policy goals, even though their shares are owned by state entities.

In classifying a company as commercial, we evaluated each company on the basis of three questions (the third question departs from the definition above):

- Does the company have some private parties taking risk (through ownership, investment or other means), even if the majority shareholder is an SOE? [4]
- If not, do they sell their products to customers other than the Chinese government, in domestic or foreign markets?
- Even when they are fully or partially state-owned, do they appear to demonstrate independence from their parent SOE or government agency?

These questions are meant to identify companies that have some separation from the Chinese government that could play a role in the global space market. Although we use an inclusive definition for what constitutes a commercial company, we do break these companies into three categories: state-owned, mixed-ownership, and privately-held, as ownership can affect other attributes of their businesses.

### a. State-owned

Most SOEs are owned and controlled by the State-owned Assets and Supervision and Administration Commission (SASAC) of the State Council or similar commissions organized by provincial, municipal, or county governments. SOEs in turn may fully or partially own subsidiaries. Partially owned SOE subsidiaries may be joint ventures with domestic or foreign private sector groups, funded by public or private VC, or publicly traded. As the goal of this report is to examine China's commercial space sector, we do not examine SOEs or their large subsidiaries that do not focus on making profits. They include CASC or its major subsidiaries such as the China Academy of Launch Vehicle Technology

[4] This assumes that private owners always have a profit perspective, which may not always be the case for all private companies. An example is Blue Origin in the United States, which, until recently, had operated more as a philanthropically-driven technology development company rather than a profit-driven commercial one.

(CALT), Shanghai Academy of Spaceflight Technology (SAST), or the China Great Wall Industry Corporation (CGWIC) that sells CASC's products and services, including those of the China Academy of Space Technology (CAST). In our statistics, we include some fully state-owned companies, such as Expace, as these companies are primarily focused on making profits and show some independence from their parent SOE.

### b. Mixed-ownership

A number of the commercial space companies we identified have a mix of public and private ownership. This does not mean that the government dictates how these companies operate or what they do. We find mixed-ownership companies fall into three categories.

- The first group is SOE-backed companies that have large percentages of private ownership, such as APT Satellite. These companies demonstrate a large degree of independence from their parent SOE, but may rely on it for certain services (e.g., satellite manufacturing).
- The second group of mixed-ownership space companies are spin-offs from CAS institutes and universities, such as Chang Guang Satellite. Spin-offs from CAS often give CAS a minority stake, in exchange for in-kind subsidies, such as use of CAS facilities or researchers. The remainder of the shares is divided among the founder, members of the board, some employees, and public and private VC firms.
- The third group of mixed-ownership companies are otherwise privately-held companies that have received some investment from a provincial or municipal VC firm. Provincial and municipal governments offer this investment to attract high technology businesses and jobs to their areas. Beyond influencing where a business locates itself, this investment does not appear to affect business decisions.

### c. Privately-held

Non-state-owned space companies we identified can be divided into four (somewhat overlapping) categories.

- Perhaps most important for this report are China's space start-ups, which are much like the start-up space companies elsewhere in the world. In general, these companies have existed since 2014 and have business plans similar to those of other New Space companies in the West. The largest of these companies have over $100 million in VC funding and several hundred employees; the smallest are still PowerPoint companies with little funding and few employees, but big goals.

- The second group of companies are small, privately-held companies that have had time to become established. Many of these companies were founded to act as component suppliers to SOEs. Today, they still supply SOEs but may also supply other private companies.
- The third group of companies are older, more established companies that initially supplied SOEs, but are publicly traded (e.g., Zhuhai Orbita). Several of these companies have pivoted in recent years to owning and operating their own satellites.
- The last group of companies include large, publicly traded non-space companies that have acquired small space companies or expanded into space markets (e.g., Tatwah Smartech).

Chapter 3 begins with these categories but collapses them somewhat given the sometimes limited information about the companies.

## B. Methodology

### 1. Initial Data Collection

To analyze trends in the Chinese space sector, using the filters above, we first identified as many Chinese companies as we could learn about. Using the three-part definition of a Chinese commercial company (discussed in the report), we winnowed down to 78 companies that we could reasonably claim as being commercial.

For each company, we attempted to collect information on their basic business operations (e.g., Chinese and English names of the company; company websites and WeChat handles; locations; year of establishment; number of employees; subsidiaries; and investments), commercial operations (e.g., services and products, patents, customer base), financing (e.g., funding and investors), and other notable information (e.g., the professional backgrounds of their CEOs and other leadership). Our data sources fell into two categories:

- Primary sources, which include the company's website and WeChat pages; interviews with companies and other Chinese commercial space experts
- Secondary sources, which include the Chinese language enterprise information search platform Qichacha[5] and Chinese government business statistical

[5] Qichacha.com (企查查) is a Chinese business data analytics company. Qichacha compiles data on all public and private Chinese companies by scraping public Chinese government databases for business registration data and other sources of public information (e.g., stock market filings, patent filings, websites). Because Chinese businesses are required to maintain accurate business registration information in government databases—including addresses, board of executives, shareholders and registered capital, business scope (i.e., what activities a business can legally engage in), subsidiaries,

databases; Chinese government news sources such as Xinhua, and CCTV; websites such as China Aerospace Blog, Go Taikonauts, 36kr.com and iyiou.com interviews; other native sources such as Baidu Baike (comparable to Wikipedia); Chinese spaceflight forums; website databases on Chinese companies (such as zhipin.com, zhaopin.com, and ITjuzi.com); and other networking sites such as LinkedIn.

### 2. Interviews

To research Chinese language material, and arrange and conduct the site visits, the STPI team included three Chinese language speakers, and had access to two local experts in China. We promised interviewees that their responses would be confidential and anonymous. We draw on our interviews throughout this report, but do not reveal with whom we spoke. For our site visit interviews, we created a semi-structured interview protocol beforehand to address gaps in our understanding of the specific companies and the general commercial space industry. Interviews were conducted in Chinese with company representatives and subject matter experts.

The subjects of our discussions included:

- company founder motivations
- products and customers,
- company workforce, financing and technological capabilities
- commercial space policies and regulations
- government support, and
- challenges and opportunities in the commercial sector.

Altogether, we interviewed representatives of 23 Chinese commercial space companies that span the gambit of space activities, including launch, satellite operations, satellite and component manufacturing, and ground system operations. We also interviewed 15 experts (both Chinese and American) in Chinese space law and China's space sector.

### 3. Limitations

We attempted to use as much original information as feasible, whether by talking to Chinese experts directly or reviewing Chinese language documents and databases. But use of original sources has its own set of limitations:

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and investments—Qichacha lists this information along with a company's patents, stock prices, and more.

- ***Quality and completeness of databases***. We found information on Chinese organizations that was lacking from these organizations' English language materials—both from an accuracy, timeliness, and completeness perspective. Chinese language materials were more complete and updated (and presumably more accurate, although that cannot be fully ascertained). However, they had limitations as well. For example, business records (on Qichacha) contain only certain types of financial information, such as investors, but may not contain the amount invested.
- ***Challenges related to working with Chinese documents***. Working with Chinese language documents is challenging. The Chinese language material did not always match the English language material. In some cases we found companies had several names in Chinese and in English. Many companies do not have websites, only WeChat handles (which may be a good indicator that their initial customers or stakeholders are domestic rather than foreign).
- ***Challenges related to talking with Chinese companies***. Many commercial space companies were unable to speak with a U.S. research organization, especially the state-owned subsidiaries, because they could not attain official approval. Some businesses could not reveal their full business plans or discuss some of their products' capabilities. Last, sometimes what was said during the interviews did not fully comport with what we found in written documents and websites. This was likely not an attempt by the interviewees to mislead us; rather it was their lack of knowledge about fast-moving developments in China.

## C. Organization of the Report

The report is organized into five chapters. In Chapter 2, we examine the drivers—both private sector and government—of the commercial space sector in China. In Chapter 3, we provide a high-level overview of the 78 commercial space companies identified in our research, including a deep dive into topics such as their financing and ownership structures. In Chapter 4, we examine these companies by sector, and describe trends in each of eight sectors in China's space industry. Finally, in Chapter 5, we assess the strengths of and challenges facing the emerging Chinese commercial space sector. We conclude by looking at the major factors that will affect how the Chinese commercial space sector might develop over the next 5 years and beyond. Appendix A contains a brief summary of the 78 companies STPI identified as commercial. A more complete database is available on request.

# 2. Commercial Space Policies and Drivers in China

In this chapter, we discuss specific government actions and policies that guide and affect commercial space activities in China. These are split into policies and regulations at both central and provincial levels. Next, we describe the factors that drive the development of such activities. We divide these factors into two parts: those that motivate the private sector to participate and invest in commercial space, and those that may motivate the government to support commercial space development.

## A. Government Policies that Affect Commercial Space Activities

China's industrial policies are based on the notion of "guidance planning," with central plans and 5-year planning cycles for specific sectors (Heilmann 2013; Kenderdine 2017). These policies are usually drafted by the National Development and Reform Commission (NDRC), formerly known as the State Planning Commission, and then implemented by the State Council through its various ministries (Breznitz 2014). The NDRC is responsible for China's macroeconomic planning; it sets "social and developmental goals for [each] industry" (Breznitz 2014) through guidance and policy documents. The State Council makes and enforces the policies. Since its establishment in 2008, the Ministry of Industry and Information Technology (MIIT) under the State Council has been responsible for the coordination of China's industrial and technological advancement (Heilmann 2013).

These official institutions provide the 'guidance planning' to the economic development aspects of the space industry, dictating the priorities in the commercial space industry. In this section, we provide an overview of the key policies and documents of these institutions that affect the commercial space sector in China. While these official documents are often interpreted as symbols of policy support for the commercial space sector, many commercial space companies we spoke to found them to not be supportive enough, and expressed frustration with the lack of tangible government support for the commercial space sector. Table 1 summarizes government policies that affect commercial space.

### 1. Evolution of China's Policies on Commercial Space

#### a. State Council White Papers on Space Activities (2000, 2006, 2011)

China first entered the commercial market in the 1990s by providing commercial launch services with its Long March rockets, launching nearly 30 satellites for customers outside of

mainland China.[7] The Chinese government has promoted other commercial space activities over the last few decades. However, until recently China's commercial space industry has primarily consisted of several large SOEs and their subsidiaries.

The State Council's White Papers on Space Activities track how commercial space policy has evolved over the past two decades. Starting in 2000, the State Council has published a white paper on the country's space activities about once every 5 years. Similar to Five-Year Plans, these white papers provide an update on the major accomplishments of the space industry over the previous 5 years, and lay out the main goals and policies for future developments in the space industry for the next 5 years (China Net 2016). These white papers are published in over eight languages, functioning as major outward-facing policy documents for the international community. This is a departure from the norm as most policy documents from the State Council are only published in Chinese (China Net 2016).

All the white papers acknowledge certain commercial space activities and encourage international space commercial cooperation. In the more recent white papers, however, commercial space has become a much greater priority, especially in the 2016 White Paper (discussed in Section 2.1.c). Each white paper builds on the last and introduces more commercial space activities and goals. The 2000, 2006, and 2011 White Papers do not, however, acknowledge *private* investment or private companies. They encourage participation in commercial space activities from SOEs, but do not expressly support private companies.

The original 2000 White Paper emphasized China's achievement in commercial launch services in the 1990s with the Long March rockets, encouraging further participation in the international commercial launch industry. The 2006 White Paper encouraged participation in the commercial launch and telecommunications industries; it also mentioned as major accomplishments two commercial contracts with Nigeria and Venezuela to provide communications satellites.

The 2011 White Paper built upon previous commercial space policies and goals. China had considerably increased its international commercial space activity between the publication of the 2006 and 2011 White Papers. The 2011 White Paper commends China's commercial activities and references sales of its commercial satellite, launch, and ground system products and services to Nigeria, Venezuela, Pakistan, Indonesia, and other developing countries. The 2011 White Paper introduces a few new policies regarding commercial space. The State Council now "actively promotes" the SOEs to commercialize their products and services and to participate in international commercial space activities (2011 White Paper). As a major policy goal, the 2011 White Paper also called for the establishment of a "diverse multi-channel space funding system," implying that the central government should not be the only investor in space activities.

[7] Technically, China provided launch services for its own subsidiary companies located in Hong Kong (Asiasat) (The Telegraph 2011).

To encourage the development of a more diverse funding system for space, the State Council began encouraging private investment in the commercial space industry. We also observe an increase in provincial support for the space industry around this time.

### b. 2015-2025 Medium- and Long-term Development Plan for National Civil Space Infrastructure

The 2015–2025 Medium- and Long-term Development Plan for National Civil Space Infrastructure (国家民用空间基础设施中长期发展规划[2015–2025]) was released in late October 2015 by the State Council (National Development and Reform Commission 2015). Written in part by the NDRC, the Plan lays out specific priorities for the civil space industry in China. It highlights the value and importance of China's space industry as a high-technology industry and a means to promote indigenous innovation. The plan also promotes commercialization of space products and a more diversified system of funding the space industry. The Plan prioritizes industrial and business-oriented applications rather than experimental and scientific applications, specifically calling out in section 7 the need for the space industry to generate mass consumer services. The Plan does not acknowledge the role of private space companies, implying that SOEs will lead the development of commercial products by the space industry.

### c. 2016 State Council White Paper on Space Activity

The 2016 White Paper identified major tasks for the next 5 years aimed at expanding China's space infrastructure (State Council 2016). One task focuses on improving space applications such as developing comprehensive satellite applications to assist in regional urban planning; natural disaster prevention, reduction, and emergency response; food security; smart cities and smart transport applications; and providing public services. The report notes that China is determined to advance the industrialization of space applications to foster economic growth.

The 2016 White Paper is also the first space white paper to acknowledge private investment and private companies in the space industry. This White Paper calls for increased cooperation between the government and private investors in the space industry, and encourages social capital, which usually consists of nongovernmental and private capital, to participate in space-related activities, including scientific research and production, space infrastructure, and space information products and services. Notably, the White Paper includes a section on "diverse funding" (Section 6 of Chapter 4), which includes several references to increasing commercialization of space through private funding. It is the first white paper to explicitly mention a private commercial company, praising Changguang, a commercial company that manufactures remote sensing satellites. The White Paper discusses several other important policies, including defining the scope and management practices of government investments in space, improving procurement processes for aerospace products, and improving how the government may access and withdraw from commercial markets.

Section 5.2.3 on commercial activities in other countries in the 2016 White Paper states that China encourages and supports the participation of Chinese private companies in international commercial activities in the space field. For example, China has exported satellites and made in-orbit delivery of Nigeria's communications satellite, Venezuela's remote-sensing Satellite-1, Bolivia's communications satellite, Laos' communications Satellite-1 and Belarus' communications Satellite-1. In addition, China has provided commercial launch services for Turkey's Gokturk-2 earth observation satellite. It has provided launch sharing services—launching small satellites for Ecuador, Argentina, Poland, Luxembourg, and other countries—when launching its own satellites. China has also offered business services concerning space information.

## 2. National Policy regarding Private Investment in the Space Industry

The following sections detail the various policies and drafts of the NDRC and State Council regarding the role of private entities in the space industry and provide details on Chinese government support for private Chinese space companies.

### a. Document 60

On November 26, 2014, the State Council issued Document 60 or *Guiding Opinions of the State Council on Innovating the Investment and Financing Mechanisms in Key Areas and Encouraging Social Investment*（国务院关于创新重点领域投融资机制鼓励社会投资的指导意见）(State Council 2014). Drafted by the NDRC, Document 60 aims to restructure financial institutions and propose new policy measures to allow for more strategic (and private) investments and growth in seven broad areas of interest: environmental sustainability, agriculture, local infrastructure, transportation, energy facilities, information technology (IT) and civil space infrastructure, and public institutions (NDRC 2014). Only one sub-section in Document 60 (Section 7.24) explicitly mentions the space industry, specifically calling for private capital to develop, launch, and operate commercial remote sensing satellites and provide commercial services.

Many Chinese space industry watchers credit Document 60 for officially opening up the space industry to private investment and actively encouraging participation of private companies in a historically state-dominated industry (Huang 2019; Astropreneurs n.d.; Shiong 2019; Lingye Mao 2017; Chen and Xin 2018). Although Document 60 is the first policy document issued by the Chinese government explicitly encouraging private individuals and companies to conduct space activities, the actual impact of Document 60 may not be particularly large. It only opens up the remote sensing and launch sectors, and does not open up historically more profitable sectors such as satellite communications. Many company representatives with whom we spoke said that they were either unaware of or did not pay attention to Document 60 when their companies were established. Some Chinese space policy and law experts were also unaware (or professed lack of awareness) of Document 60 at the time of our interviews.

### b. Industrial Catalogue Encouraging Foreign Investment

The NDRC issued an updated industrial catalogue (**全国鼓励外商投**资产业目录) to be implemented in July 2019 to promote foreign investment in a number of previously closed or semi-closed industries. These industries include, among others: civil satellite design and manufacturing, civil satellite payload manufacturing, civil satellite component manufacturing, on-board testing equipment manufacturing, satellite communication system equipment, and civil satellite application development (NDRC 2019). According to interviews, this new policy opens the door for commercial space companies in China to contact foreign investors and will likely help these new companies with securing investments.

## 3. Space Regulations: Launch, Re-entry, and Spectrum

Although the Chinese government has not passed a comprehensive space law, it has issued regulations concerning launch and re-entry. It also has a process for allocating spectrum, including to private companies. These regulations were created for China's space industry at a time when the commercial space sector was not as prominent. They were written for CASC, until recently the only entity in China's civil space industry. Consequently, commercial space companies must adapt to policies that are not tailored to them. These licensing processes may pose a challenge to commercial space companies: two commercial companies expressed in interviews that the lack of regulation hindered their business activity and growth. Experts also noted that a lack of specific regulations for commercial entities signals that the government is not fully supportive of the commercial space sector.

### a. Launch and Re-entry

Until recently, the launch approval and licensing process was only defined in the *Interim Measures on the Administration of Permits for Civil Space Launch Projects* (**民用航天**发射项目许可证管理暂行办法), which took effect on December 21, 2002 (State Council 2012). This regulation only applied to CASC Long March launches until commercial launch companies began to proactively adopt the policy for themselves in order to launch their own rockets in the late 2010s.

On June 10, 2019, the State Administration of Science, Technology and Industry for National Defense (SASTIND) and Equipment Development Department of the Central Military Commission issued *Notice on Promoting the Orderly Launch of Commercial Vehicles* (国家国防科技工业局中央军委装备发展部关于促进商业运载火箭规范有序发展的通知), the launch approval and licensing process for commercial entities. This new regulation codifies the previous Interim Measures for commercial launch companies, stating that companies funded by social or private capital must apply for launch licenses in accordance with the Interim Measures. The policy begins with a declaration of support for commercial launch vehicles for China's space industry and international competitiveness. The policy also lists the major activities of commercial launch companies, including R&D, development, manufacturing, and testing of system-level and sub-

system-level launch vehicles, reusable launch vehicles, and launch and re-entry vehicles (State Council 2019).

The regulatory body for licensing launch is SASTIND. The major space launch sites are all military launch sites, which are controlled by the People's Liberation Army (PLA). Many companies have articulated the need for a civil or commercial launch site in order to facilitate commercial launches and reduce launch congestion.

### b. Spectrum

The spectrum licensing process is regulated by the *People's Republic of China Radio Regulations* (中华人民共和国无线电管理条例), which took effect on December 1, 2016 with the Bureau of Radio Regulation under MIIT as the regulatory body. This spectrum licensing process follows International Telecommunication Union (ITU) Radio Regulations. During our interviews, a few satellite communications companies noted that spectrum allocation is not well-regulated by the spectrum licensing process. Companies are not very aware of the public regulations on spectrum licensing; obtaining spectrum often involves negotiations with many different agencies and entities. Our interviews indicated that spectrum licensing is a major challenge for the satellite communications industry.

### c. Remote Sensing

According to interviews, there are no specific policies regulating remote sensing activities. However, remote sensing satellites can be regulated through the launch licensing process, as companies need to provide all the technical information regarding their remote sensing satellites in the application for a permit to launch. Through this means, the government regulates remote sensing activities, limiting the resolution for commercial imagery to 0.5 meters and forbidding imagery of sensitive areas (CCTV 2018a).

### d. Future Regulations

As of July 2019, China has not passed a comprehensive law on space, which many experts and companies note is a major issue for the development of China's overall space industry. According to one subject matter expert, the Chinese government first promised to release a comprehensive space law in 2013, and has promised to release such a law every year since 2013. Another expert indicated that a comprehensive space law will probably be released within 5 years. At the 13$^{th}$ National People's Congress, Chinese legislators advocated a space law that would provide guidance for private companies on utilizing space resources (Cao 2019). To the best of our understanding, there is a comprehensive space law in the works, but it is unclear when it will be promulgated.

## 4. Other Government Policies Affecting Commercial Space

The space industry has become an important priority for the Chinese government, especially in the past few years under President and General Secretary Xi Jinping (Bowe 2019). Many major policy initiatives by the State Council lay out specific plans for the space industry. Although these policies do not address the commercial space sector, commercial space companies have the potential to benefit from these policies. This section provides an overview of such policies with observations on how they could benefit the commercial space sector.

The Belt and Road Initiative (BRI), announced in 2013, is aimed at promoting foreign trade and investment and investing in large infrastructure projects in countries in Africa, Asia, and Europe. Over 130 countries have signed cooperation documents (memoranda of understanding [MOUs] or cooperation agreements) for BRI; over 60 countries have contracted for BRI projects (Chatzky and McBride 2019). BRI mostly consists of large infrastructure projects such as railroads, energy pipelines, highways, and dams. BRI projects also encompass digital infrastructure and space infrastructure through the Belt and Road Spatial Information Corridor (Hui 2018). As part of the Spatial Information Corridor, China plans to build a network of communications, navigation, and remote-sensing satellites to connect all the BRI countries (NDRC 2016).

Many satellite launches and other space-related investments for African and Southeast Asian countries are currently branded as BRI projects (Huang 2018). Several BRI-participatory countries have purchased satellites from China for Earth observation and weather forecasting; such satellites are important for tracking urban development and for preventing disasters. However, it is unclear whether such investments are official state-sanctioned BRI projects, because the Chinese government has never provided a list of official BRI projects, or defined what constitutes a BRI project (Ang 2019). Several commercial space companies refer to BRI countries as opportunities for future sales in their business plans; they may brand their own business deals with foreign countries as BRI projects (Zhu 2017). The implications of BRI on the potential growth for commercial space are elaborated on in Chapter 5 Section A.

Civil-military integration (CMI) or 军民融合 [8] has been described as "the catch-all term for China's two-decade-long push to enlist private enterprises to upgrade China's defense industrial base through developing scale and efficiency in dual-use sectors such as IT, robotics, and aerospace" (Laskai 2019). CMI is targeting the space industry; President Xi has called for promoting and innovating space infrastructure to better connect the military and civilian businesses (Xinhua 2018c). Commercial space companies could indirectly benefit from CMI because CMI elevates the space industry and will likely boost the space economy in China.

[8] 军民融合 is translated as civil-military integration by some and military-civil fusion by others. Although some experts differentiate between the two concepts, both concepts refer to the same Chinese term. STPI uses civil-military integration, because that is how official Chinese media translates 军民融合 into English (Liu 2015).

The State Council issued *Made in China 2025* in 2015, a 10-year action plan oriented toward increasing domestic production of high technology goods (State Council 2015). The goal is to boost China's manufacturing capabilities in 10 key industrial sectors, including the aerospace sector. *Made in China 2025* sets specific policies to promote these sectors, such as providing direct subsidies, encouraging foreign investment and acquisitions, and mobilizing SOEs (McBride and Chatzky 2019). For the aerospace sector, "Made in China" focuses on aviation infrastructure; however, the boost in domestic manufacturing capabilities could benefit commercial space companies, especially manufacturing companies (Wubbeke et al. 2016).

The State Council designated the civil space industry as a Strategic Emerging Industry (SEI) in 2016 with the 13th Five-Year Plan (Central Committee of the Communist Party of China 2016). The Strategic Emerging Industries policy highlights a few major industries and lays out specific actions to promote them. This creates a supportive environment for these industries (Kenderdine 2017).

Commercial space companies could take advantage of these policies to receive further support from the media, private investors, provincial governments, and the general public by demonstrating how their business activities support these national policies. These policies may also facilitate funding for commercial space companies as government and private VCs may be more willing to fund commercial space activities.

## 5. Provincial Support for the Commercial Space Industry

While central government pronouncements "signal" government interest and guidance, most government investment and support for commercial space companies has come from provincial and local governments. Several provinces and municipalities such as Xi'an and Wuhan boast of substantial publicly backed aerospace industrial bases (Zhao 2016a). Wuhan, in particular, is facilitating the construction of supporting infrastructure, so as to satisfy enterprises' needs (Huifang Mao 2017). Hubei province is providing a fund of 10 billion Renminbi (RMB) ($1.6 billion USD) to "boost aerospace industries" (Myrrhe 2018).

Some municipalities have worked to build space industry clusters, such as Jilin, which helped develop the Changguang Aerospace Information Industry Park (长光航天信息产业园). This industrial park is planned to have an annual capacity of 30 satellites and 200 drones, and will gradually form an industrial cluster that will develop and produce satellite and unmanned aerial vehicles (UAVs) for remote sensing information processing and applications. Other cities with aerospace strategies include Chongqing, Shenzhen, and Changsha.

**Table 1. Chinese National Government Policies Regarding Commercial Space**

| Date | Official Government Document (Chinese) | Official Government Document (English) | Relevance to Commercial Space |
|---|---|---|---|
| 12/21/2002 | 民用航天发射项目许可证管理暂行办法 | Interim Measures on the Administration of Permits for Civil Space Launch Projects | Policy regulates all civil space launches, laying out the process for licensing and approval of civil space launches. |
| 2000, 2006, 2011, 2016 | | State Council White Papers on Space Activities | These White Papers recount major accomplishments and lay out future goals for the civil space industry every five years. They have shown increasing levels of support for commercialization of space goods and services. The 2016 White Paper also promotes diverse funding structures in the space industry. |
| 11/26/2014 | 国务院关于创新重点领域投融资机制鼓励社会投资的指导意见 | Guiding Opinions on Innovating Investment and Financing Mechanisms (Document 60) | Document 60 is a financial document encouraging private investment in certain key industries, including the satellite industry. The media (Chinese and English) often credits Document 60 for opening up the space industry to private investment. |
| 10/1/2015 | 国家民用空间基础设施中长期发展规划[2015–2025] | 2015-2025 Medium- and Long-term Development Plan for National Civil Space Infrastructure | The Plan lays out the priorities for the civil space industry, including support for commercial applications of space goods and services. |
| 12/1/2016 | 中华人民共和国无线电管理条例 | People's Republic of China Radio Regulations | Policy regulates spectrum licensing for all entities, including commercial space companies. |
| 6/1/2019 | 国家国防科技工业局 中央军委装备发展部关于促进商业运载火箭规范有序发展的通知 | Notice on Promoting the Orderly Launch of Commercial Vehicles | Policy codifies the regulations for the 2002 Interim Measures for private commercial space launches. |
| 7/30/2019 | 鼓励外商投资产业目录 | Industry Catalogue Encouraging Foreign Investment | Policy promotes foreign investment in a number of previously closed or semi-closed industries, including many related to satellite manufacturing and satellite communications. |
| -- | 军民融合 | Civil-Military Integration | Policy does not address commercial space, but commercial space companies have the potential to benefit from this policy. |
| 2015 | 中国制造 2025 | Made in China 2025 | Policy prioritizes the space industry, but does not address the commercial space sector. |

| Date | Official Government Document (Chinese) | Official Government Document (English) | Relevance to Commercial Space |
|---|---|---|---|
| 2013 | 一带一路 | Belt and Road Initiative | Policy does not address commercial space, but commercial space companies could benefit from this policy when interacting with BRI countries as potential customers. |
| 2016 | 战略性新兴产业 | Strategic Emerging Industries | Policy prioritizes the space industry, but does not address the commercial space sector. |

## B. Factors Motivating the Development of Commercial Space in China

Several factors are driving global trends in commercial space, increasing private and governmental interest, as well as investment (Lal et al. 2015). China is no exception to these trends; many of the drivers of commercial space in other countries also apply to China. The first section below will discuss the factors that motivate the private sector to engage and invest in commercial space activities in China. The second section will discuss the factors that likely motivate the Chinese government to support commercial space activities.

### 1. Private Sector Drivers

STPI identified the following motivations for founders to establish commercial space start-ups in China and for private investors (including the VC firms) to fund these commercial space start-ups. Most of the information came from interviews with the founders of newly established space start-ups and with VC experts in China.

#### a. Economic Potential of Commercial Space

Capital markets, venture capitalists, and individual companies in China see potential profits from space-based activities. Interviewees noted that the potential for profits emerges not just from the sale of imagery or communication services from space, but also their fusion with other data sources, to sell business analytic products to private customers. Interviewees confirmed that the satellite manufacturing and launch sectors have recently experienced a surge in investment, undergoing a "hot period" (热点), when these sectors were considered the "hottest investments" (Zhou 2018).

This surge of investment in the private sector (especially from the VC community) emerges partly from a sense that there are now fewer opportunities in the IT sector. A few experts mentioned that VCs are looking into other high-technology sectors; naturally space activities have been the recipient of large investments. Not only is space a top government priority as illustrated by the various aforementioned State Council policies, but there is also growing interest in "hard-tech" sectors: sectors that require a higher tolerance for risk and large investments in R&D and technology maturation (Zhou 2018).

In a recent interview, Wang Xinhe of the Chinese VC firm Essential Capital (元航资本) noted several criteria for evaluating start-up investments, including: whether the start-up is a technological priority of the Chinese government; whether the technology faces high competition with foreign counterparts; the level of advancement of the technology; and the level of maturity of the technology—that is, has the technology reached the prototyping stage (Zhou 2018).

Space start-ups fulfill most of these evaluation criteria: the space industry is a government priority; there are not many countries in the world as advanced in space activities as China; and most space start-ups have been founded by experienced aerospace engineers, so their technologies are quite advanced and have reached the prototyping stage.

### b. Freedom for Founders

Most founders and executives of these start-ups are former employees of CASC or CAS institutes with extensive academic and professional backgrounds in aerospace engineering. When asked why they chose to leave the traditional space industry and establish their own companies, most founders cited their desire for freedom to be more innovative. Many wanted to work on different space projects than what they had pursued for the government. With their own companies, these individuals have the freedom to pursue their own research and develop their own technologies without constraints found in the traditional SOEs. One expert noted that quite a few of the founders had studied or spent time abroad, which exposed them to many more possibilities in the space industry and might have inspired their entrepreneurial spirit.

### c. Inspiration from Western counterparts.

The publicity around Western space start-ups such as SpaceX and OneWeb has encouraged many individuals in China to establish their own companies. Many founders of Chinese space companies cite these Western companies as sources of inspiration; they strive to emulate founders like Elon Musk and Jeff Bezos. According to Yang Feng, the CEO of satellite start-up Spacety, "We wanted to be the Chinese SpaceX, the Chinese Elon Musk. At the time, it was based on dreams." (de Selding 2019).

These Western companies demonstrate the large potential of the commercial space market. Their successes have made it easier for Chinese start-ups to obtain funding. According to interviewees, investors are more willing to provide funding for Chinese space start-ups that are modeled after some Western counterpart, lessening the burden on the start-ups to develop their own business models. Without the exemplar Western companies, it would be more difficult for many of these founders to leave their traditional SOE positions and find support in the start-up and VC community.

## 2. Government Drivers

STPI identified the following factors for why the Chinese government supports the commercial space sector.[9] Because STPI did not interview many Chinese government

[9] Not all government interest favors commercial space. For example, in recent years, at least four provincial leaders in China have come from the aerospace sector: https://www.scmp.com/news/china/policies-politics/article/2092940/how-leaders-chinas-space-programme-entered-political. Because of their backgrounds, one would suspect that the governments of

officials, these factors are based on a review of the literature, and not confirmed by interviews with government sources.

### a. Economic Development

A major motivation for the Chinese government to support commercial space activities is the potential for domestic economic development. Chinese aspirations with respect to investments in space are being driven by slowing economic growth, and a sense that China needs to encourage the growth of new high-value-added industrial sectors. This has resulted in ambitious intentions in the space industry outlined in the policy documents. The central government prioritizes strategic emerging industries, which include the space sector, in an effort to create more jobs and stimulate economic activity (Kenderine 2017).

Globally, space activities are becoming increasingly attractive because of advances in technologies and decreases in costs. China would benefit greatly if it could leverage its space capabilities to provide space-based services in Earth observations, satellite broadband services, telemedicine, and tele-education, among other services. Commercialization of space capabilities into downstream services would be key to tapping into the economic potential of the space sector.

Provincial governments are also trying to use the space sector to foster regional economic development. In recent years, at least four provincial leaders in China have come from the government aerospace sector (Mai 2017). Because of their backgrounds, these provinces are likely to favor aerospace investments when trying to accelerate economic growth. One industry insider with whom STPI spoke concurred with this view. However, he noted that these governors are more likely to direct provincial aerospace investments to SOEs than commercial space start-ups as they came from state organizations, and SOEs are seen as safer investments than start-ups.

### b. National Pride and Geopolitical Standing

Similar to many other countries, China regards its government space program as an important expression of national power. Prestige and national pride are strong motivations for the Chinese government, especially because of China's experiences with foreign imperialism during the 19th Century (Kaufman 2010). Advances in space would demonstrate how far China has come since that time. In recent years, China has made great progress across a broad range of space technologies, including launch vehicles, satellites, lunar exploration, human spaceflight, and counterspace technologies.

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these provinces would favor aerospace investments when trying to foster economic development. One industry insider with whom we spoke concurred with this view, but noted that as these governors came from state organizations, any provincial investments in aerospace companies are more likely to be directed at SOEs due to personal connections, and as SOEs are seen as safer investments than start-up space companies.

As demonstrated in the 2015–2025 Medium- and Long-Term Plan for National Civil Space Infrastructure and other national policies, China places a premium on indigenous innovation, especially in high-technology industries. Not only are advances in high technology sectors a strategy for economic growth, they are also an opportunity for China to redefine its place in the international order to catch up with other world powers.

The role of the commercial space sector in China's national strategies is currently unclear. However, successful commercial space companies would contribute to national pride, demonstrating China's indigenous innovation capabilities. The Chinese government's desire for international prestige partially explains why investors are trying to find the "Chinese SpaceX" and are willing to fund Chinese counterparts of Western commercial space companies.

### c. Spin-off Companies: Commercialization of State Technologies and Access to Global Markets

Another factor that may drive government interest in a commercial space sector is the potential for spin-off companies from government-led enterprises. A commercial space sector gives state-owned institutions, including research and academic institutions, opportunities to transfer ideas and technologies and develop them into profitable private companies. Spin-offs have been found to be better at diffusing ideas than transfers of intellectual property (IP). Many of the founders and principal engineers of space start-ups were previously employed at CASC, CASIC, or CAS. More mature companies, including some visited by STPI, often receive technical support from SOEs and research institutions, especially CAS. We identified the following reasons why SOEs have been amenable to sharing or transferring technologies:

- To access open and shared space launch sites and aerospace measurement and control systems
- To share support infrastructure such as testing facilities
- To assist in the construction of research clusters
- To increase competition among suppliers and system integrators to reduce prices
- To promote the transfer of military dual-use technologies to civilian industries
- To actively guide the development of satellites and application industries to promote application service innovations and scale applications

Private commercial companies may also find it easier to sell space-based services to non-Chinese customers. SOEs often have a brand image problem given China's failures to protect foreign intellectual property and concerns about its military capabilities. A China-based project advisor suggested that it might be easier for private companies to sell their services on foreign markets compared to SOEs doing so.

### d. Spin-in Commercial Developments: Accelerate Innovation in the State Sector

Several experts interviewed for this study acknowledged that Chinese space SOEs and other state-driven organizations are bureaucratic, slow, and, in some instances, falling behind cutting-edge space companies in other nations. Recent testimony in Congress described Chinese government officials' reaction to the launch of SpaceX's Falcon Heavy: "Our country finds itself in a surprising position where it must desperately catch up with a private company" (Laskai 2019).

Many government official believe that the growth of a commercial sector may inject more innovation into China's space sector, as it has done in the United States. Tian Yulong, Secretary General of the China National Space Administration (CNSA), has been quoted as having said that the development of the commercial space industry will help improve China's competitiveness in the international market (Xinhua 2018e). It is expected that spin-in commercial developments would be streamlined with policies such as CMI, which has encouraged both the spin-off of dual-use technologies and excess military goods production capacity to civilian markets (军转民), and the spin-in of technologies developed by the commercial sector and the increased participation of commercial enterprise in defense development and production (**民参**军) (Laskai 2019).

# 3. Overview of Commercial Space Companies in China

China's space industry includes a variety of participants, from large SOE subsidiaries to small, privately-owned start-ups. Some of these organizations—in particular, CASC, CASIC, and their subsidiaries—engage in commercial activities, buying and selling goods and services with the private sector. However, many of the organizations that engage in commercial activities, such as CAS institutes, are not commercial companies.

As discussed above, in this report we define a commercial company as an enterprise that is primarily operated in pursuit of profit, as opposed to an organization that prioritizes public policy goals over profits, even though it conducts commercial activities. Notably, this definition can include companies that are fully state-owned. In classifying a company as commercial, we evaluated the selection of each company as to whether it is commercial on the basis of three questions:

- Does the company have some private parties taking risk (through ownership, investment or other means), even if the majority shareholder is an SOE?
- If not, do they sell their products to customers other than the Chinese government, in domestic or foreign markets?
- Even when they are fully or partially state-owned, do they appear to demonstrate independence from their parent SOE or government agency?

These questions are meant to identify companies that could play a role in the global space market and that have at least some separation from the Chinese government. Using these questions and through a review of the open literature and publicly available databases, we identified 78 companies that generally meet these criteria. Basic information about the companies is listed in Appendix A, and the full database is available on request.

As a benchmark, we looked at other inventories of commercial space companies in China. Industry insiders in China estimate that between 80 and 100 space companies have been founded in China between 2014 and 2018 (Moss 2018; Chen 2018). Other sources note even larger numbers. For example, the Future Aerospace Research Institute, a Chinese think tank focused on China's space industry, found that as of May 2019 there were 141 "registered" [10] commercial space firms distributed across four sectors: 36 satellite

[10] Registered refers to a company that has submitted incorporation documents to the government. Within these documents, companies must disclose the sectors in which they plan to operate, their address, board of directors, investors, registered capital and several other pieces of information. Whenever a

manufacturing enterprises, 22 satellite launching companies, 39 satellite operating companies, and 44 satellite application enterprises (Future Aerospace Research Institute 2019b). We find our numbers to be more reliable.

In this chapter, we describe trends in China's commercial space industry by examining 78 prominent Chinese space companies that fit our definition of commercial space and are actively developing or selling products.[11] A full list of these companies by their English and Chinese names is included in Appendix A. These companies include established enterprises and start-up companies, state-owned, mixed-ownership and privately-held companies, government suppliers, and companies targeting private markets. Our data are drawn from over 40 interviews with company representatives and industry insiders, company websites and social media pages, company registration and operations information from government and business databases, presentations at space conferences, news articles, and the business literature on the Chinese commercial space sector.

## A. Founding Dates

Of the 78 commercial space companies we identified in our database, 45 were founded in 2015 or later, or an average of about 10 companies per year since 2015 (Figure 1).[12] Although Figure 1 shows only six companies were founded in 2018, the actual number is likely higher. Our primary method of identifying new companies was through online searches. If a company does not have a web presence or has not attracted attention from the media, we were unlikely to capture it in our survey. Consequently, years that are more recent probably undercount the number of commercial space companies that were founded. Despite this gap, companies that have a web or media presence are more likely to be active companies with funding and customers, meaning that our numbers may actually reflect legitimate companies, rather than companies that only exist on paper.

company has a change in one or more of these fields, they must update their filing. All Chinese companies are subject to these disclosures. Notably, just because a company has registered does not mean it has any investors or products to sell. As such, some fraction of these 141 commercial space companies likely do not have a physical presence.

[11] East Dawn is the only commercial Chinese start-up that we identified that no longer exists. The company was founded in 2001, backed by angel investment funds, did some business with the U.S. firm GeoEye, and went out of business in 2007. We do not include it in our statistics. Source: Pitchbook

[12] In comparison, Bryce Space and Technology reports that an average of four space companies globally were founded and funded by angel and VC investors per year (Bryce 2019). It is unclear if any of the Chinese companies in Figure 1 are included in these statistics, as only some received VC funding.

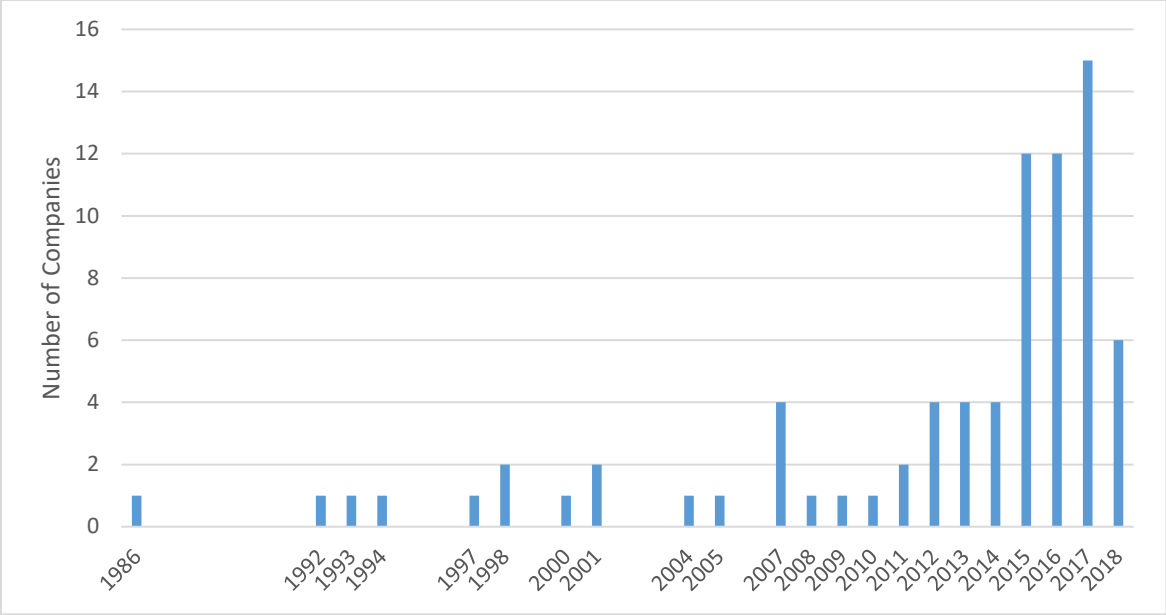
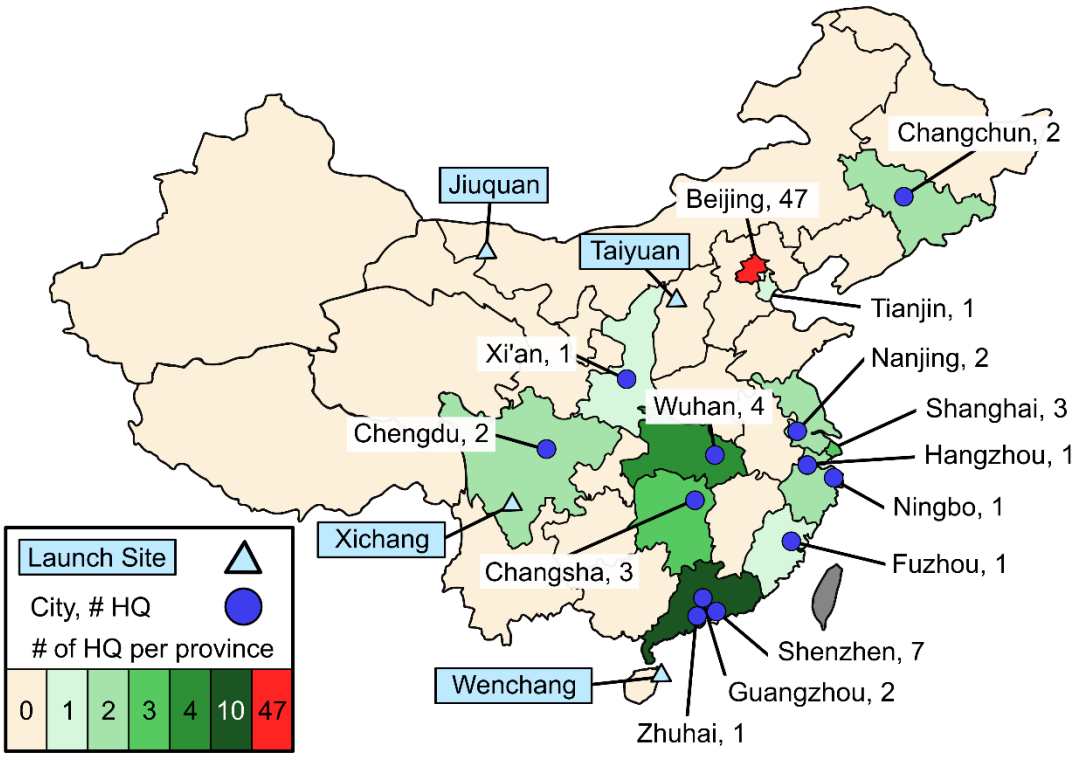



**Figure 1. Founding Dates of Chinese Commercial Companies**

## B. Locations

Although commercial space companies can be found across China, most are headquartered in a small number of cities and provinces (See Figure 2). Beijing hosts the largest number of commercial space company headquarters. Other major host cities include Shenzhen, Wuhan, Shanghai, and Changsha. Although company headquarters are primarily grouped in several cities, we found that companies had offices and subsidiaries in many other cities. In addition to the above five cities, other important space industry cities (e.g., cities with multiple space industry manufacturing or design facilities) include Xi'an, Nanjing, Guangzhou, Chengdu, and Changchun. Throughout our interviews, companies cited several major reasons for choosing these cities: access to suppliers, access to manufacturing facilities and laboratories, access to talent, access to customers (especially the government), and reduced price or free land in aerospace or high-technology industrial bases sponsored by the city or province.




Note: The Chinese government announced that it would open a spaceport in Haiyang, Shandong for sea-based launches, following the successful sea launch of a Long March 11 (Xinhua 2019c). It is unclear if commercial companies will be able to use this facility.

**Figure 2. Locations of Space Company Facilities**

## C. Financing

Precise data on many of the investments in Chinese space companies are not publicly available, especially for investments prior to 2017. Consequently, estimating the total amount of capital invested in Chinese commercial space companies since the State Council sanctioned private sector investments in China's space industry in 2014 is difficult. Several groups, however, provide estimates on investments in recent years.

Space Angels, a U.S. VC firm that invests in the space industry and tracks global space investments, has estimated that total Chinese investment in commercial space was $336 million in 2018 (Space Angels 2019). The Future Aerospace Research Institute found Chinese space companies raised 2.1 billion RMB (approximately $310 million) in investments during 2018 across 34 rounds from seed to Series C capital for non-listed companies (Future Aerospace Research Institute 2019a). [13] Future Aerospace notes that

[13] For purposes of comparison, the global start-up space sector in its early years (2000-2006) raised about $1.3 billion, averaging about $220 million annually (Bryce, 2019). In 2018, the start-up space sector raised almost $3 billion (Bryce, 2019). A large fraction of this investment went to just two companies –

two older space companies listed on Chinese stock exchanges sought further funding, raising another 1.4 billion RMB (approximately $206 million) together, resulting in over $500 million raised in 2018.

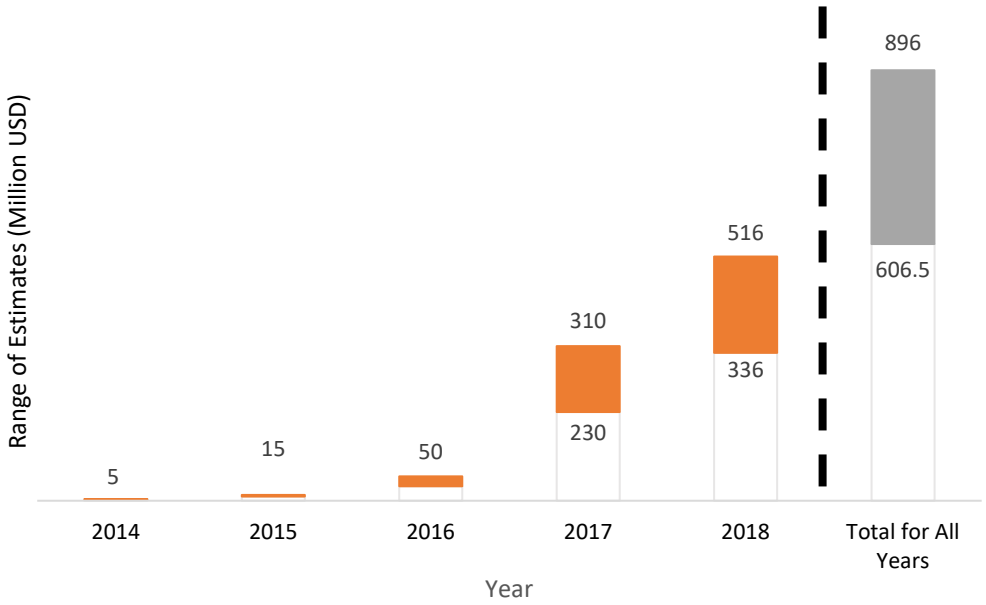
The numbers have grown over the years. In 2017, Space Angels reported that Chinese space companies raised $230 million (Sheetz 2018), whereas the Aerospace Engineering Technology Research Institute (2018) found that the Chinese commercial space sector raised 2.1 billion RMB (approximately $310 million) for 17 space companies in 2017.

Space Angels notes that the vast majority of the investments in Chinese space companies were made between 2016 and 2018 (Sheetz 2018). Although we were unable to find comprehensive information on the amount of investment in Chinese commercial space companies prior to 2017, of the 78 companies for which data are available, we found that 8 received investments between the publication of Document 60 in November 2014 and the end of December 2016. They include: OneSpace, LandSpace, Spacety, Space Wisdom, Jiahe Info, Chuang Guang, GAGO Inc., and Space Star Technology Corporation.

Altogether, between November 2014 and the end of 2018, Chinese commercial space companies have likely raised between $600 million and $900 million. Angel investor Niu Wen, who has invested in LandSpace and MinoSpace, among other companies, is quoted to have estimated around 6–7 billion RMB (approximately $870 million to $1 billion USD, representing the upper range of our estimate) in total investment in Chinese commercial space (Chen 2018).[14] During this time period, Chinese investment has represented a growing share of global investment in space companies. Space Angels estimated that between 2009 and 2018, investments in Chinese space companies comprised 5 percent of global investments in space (Space Angels 2019). As noted above, most of this investment has come since 2016, and thus the actual percentage of global investment made in China is higher. In 2018, for example, Space Angels calculated that Chinese investments comprised 11 percent of global investments in space (Space Angels 2019). Figure 3 is STPI's best estimate of the funding of the commercial space sector in China. The figure showcases the dramatic rise in funding in 2016.

SpaceX and Blue Origin. Also, 9 of the companies in the Bryce database (out of 35 outside the United States) are based in China.

[14] In contrast, in about the same time period, U.S .companies raised about $13 billion (Bryce 2019).




Source: Space Angels Network, Future Aerospace Research Institute, STPI Estimates

Note: STPI estimated the high and low ranges for 2014–2016 by using known investment figures for the eight companies listed above and extrapolating those figures to other commercial space companies that existed concurrently.

**Figure 3. Range of Total Funding of Chinese Commercial Space Companies**

## 1. Sources of Finance

By examining Chinese business records using Qichacha.com, we were able to identify all direct investors in the 78 commercial space companies in the database, for a total of 531 unique investors. Of these entities, 324 were organizations and 209 were people. Data in this section were gathered at the end of April 2019, and is therefore only accurate through that date. Financing for Chinese commercial companies comes from several groups:

### a. Private venture capital firms

As discussed in Chapter 2, one of the major motivations for the Chinese government to open commercial space to private activity was to leverage private capital. We identified investment in Chinese start-up space companies from some of China's top VC firms, including Matrix Partners China, Shunwei Capital, K2VC, and Legend Capital. Altogether, we found nine private investment partnerships that had directly invested in more than one space company[15] along with a few dozen private VC groups that have invested in one space

[15] Two private investment groups, Essential Capital and Galaxy Holdings Group, have each invested in three space companies; Shunwei capital has invested in two. Many investments in Chinese space companies are made by holding companies and funds-of-funds. There may be other private investors that have invested in more than one space company through other investment partnerships, but are not directly listed as shareholders.

company.[16] Some Chinese VC firms, such as Tencent Holdings, have invested in foreign space companies, like Satellogic, Planetary Resources, and Moon Express (Bryce Space and Technology 2018).

Several interviewees indicated that Chinese VC timelines are significantly shorter than those of American VC, with some as short as 3 years with the option to extend for 1 year. Shorter turnaround times may inhibit companies from taking a longer-term outlook.

### b. Private individuals

In examining public business records, STPI found that a significant share of the ownership of many of the start-up commercial companies was held by individuals. Of the 78 commercial companies we identified, all but six had at least one individual directly named as an investor.[17] Altogether, we found over 200 individuals who have directly invested in space companies; several hundred more individuals have invested in space companies by owning shares in a holding company. Although some of these individuals are angel investors, most seem to be founders and early company employees. Many are also members of the boards of directors of these companies. Founders of companies often are directly invested in the company, whereas other important individuals (e.g., board members and key employees) are more likely to own stock through a holding company. Of the 78 companies we identified, 12 were fully owned by people. Such companies are more likely to be in earlier stages of development, as they have not yet attracted VC financing.

### c. Provincial and municipal venture capital firms

In efforts to spur development and attract high technology jobs, many Chinese provinces and cities operate government-owned VC firms. Some of these firms have taken minority stakes in space companies. For example, Beijing E-town, the VC firm of the city of Beijing, has invested in several of the commercial space companies that have established their headquarters in that city (China Knowledge 2018). Other provinces, such as Jilin, have also used state-owned VC firms to support local high technology industries. The Jilin Provincial Government's 2019 work report noted that it would support small launch vehicles manufacturing in order to enable a key strategic emerging industry (Jilin Daily 2019). While the extent of this support is unclear, according to business records, two provincial and municipal VC firms have taken minority stakes in Enterspace, a launch

[16] We identified 301 organizations that invested in only one space company. Most of these groups are holding companies, public VC firms, corporate strategic investment funds, or CAS or university investment funds. As the ultimate ownership of investment funds in China can be difficult and time-consuming to determine, we do not know the exact number of privately-held VC firms that have invested in only one space company, but we estimate the number to be somewhere between 25 and 75 firms.

[17] Data from scraping Qichacha database of companies. Many companies also had holding companies that controlled stock on behalf of key company employees and board members.

company founded in Changchun, Jilin in September 2018. According to its business records, Chang Guang Satellite received an investment from Jilin province's fund for small and medium enterprise development in 2014. Altogether, we found several dozen investors in space companies that appear to be provincial or municipal VC firms.[18]

### d. Corporate strategic investment organizations

In principle, the key Chinese SOEs support commercialization of their space technologies. Large corporations, in particular SOEs, have invested in commercial space companies through subsidiaries that make strategic investments. The two most notable groups for space investments are CASIC's Sanjiang Space Group and CASC's Aerospace Investment Holdings Company (Global Times 2017).[19] In general, the companies that have received funding from these organizations are subsidiaries of SOEs, but are somewhat independent in their business decisions, such as DFH Satellite, APT Satellite, Expace, or CASIC Xingyun. We did not identify any investments from SOEs into any company that was not spun-out of the SOE nor otherwise associated with the SOE.

CASC and other major SOEs have established several national innovation funds, which, although not explicitly space-focused, have made investments in space companies. These funds generally target specific industries or seek to promote national policies through strategic investments. For example, CASC, along with several Chinese banks, established the 150 billion RMB (approximately $22 billion) Guochuang Investment Guidance Fund (国创投资引导基金, short for "national innovation fund") to foster developing industries, support civil-military integration, and help SOEs to become more innovative (Chen 2017). Like other funds established by SOEs, this fund targets SOE subsidiaries. As of March 2019, it had invested in DFH Satellite Mobile Communications and a number of other funds focused on aerospace. The fund's management company also runs Guohua Satellite Application Industry Fund Management Company, which was established in late 2018. As of the end of March 2019, this group had yet to make any investments. Looking through investment records of these funds, STPI did not identify any companies that received investments from these funds that were not subsidiaries of SOEs.

The ownership structure of these funds and strategic investment organizations can be complicated. By examining investment records listed in Qichacha, we observed that these funds often do not invest directly in companies, but distribute their money through funds that are more targeted to specific regions or industries, which often in turn distribute money to smaller funds. These smaller funds may be co-owned by provincial or municipal VC

[18] As noted above, it is difficult and time-consuming to deduce whether a VC firm is publicly or privately held. As such, we do not know how many public VC firms have invested in the space sector. However, of the 324 organizational investors we identified, we estimate that between 25 and 75 are likely public VC firms.

[19] Both of these organizations also invest in many non-space companies.

funds or funds that are managed by industry groups. Occasionally, these funds will also invest in each other.

A few publicly traded or private companies have invested in space. Huaxun Fangzhou, a communication technology company, owns a stake in ZeroG Lab, a satellite manufacturer. It plans to use this manufacturer to build a remote sensing satellite constellation consisting of 378 satellites, which Huaxun Fangzhou plans to finance and operate (China National Administration of GNSS [Global Navigation Satellite System] and Applications 2018). Other listed companies, such as Tatwah Smartech, have acquired space companies to enter space markets. In 2017 and 2018, Tatwah Smartech acquired a 49 percent ownership stake in Sri Lanka's SupremeSat and Malaysia's ASN Satellites (Reuters 2017; 2018). At least two start-up space companies have invested in other start-ups: Spacety holds minority shares in both LaserFleet and AerospaceMaker; LandSpace has indirect minority investments in both MinoSpace and Space Wisdom through an investment partnership with several other technology companies and several CAS VC funds.

### e. CAS institutes and universities

Another prominent investment group is CAS, its institutes, and Chinese universities. Investments in space companies from these groups are limited to companies that emerge from their own institute or university. For example, according to their business records, available online, one of the earliest and largest investors in Chang Guang Satellite is the CAS Changchun Institute of Optics, Fine Mechanics, and Physics. As of March 2019, Spacety's largest shareholder has been the CAS Center for Space Applications on Engineering and Technology through a series of holding companies. We identified five CAS-backed investment funds that have invested in several commercial space companies. Several universities or university-affiliated groups have also invested in space companies. The Harbin Institute of Technology Robot Group has invested in OneSpace and S-motor; Tsinghua University is a minority investor in TYSpace, Laserfleet, and UCAS through a series of holding companies.

### f. Banks

Chinese banks have provided loans to a subset of commercial space companies, primarily ones that are associated with SOEs. In interviews with bank representatives that work with space companies, the representatives stated they had never provided loans to start-up space companies and that these companies would likely be unable to obtain bank loans. As these companies grow and show signs of success, or become better politically connected, banks may become more willing to lend to them. For example, in an interview with SpaceNews, when asked whether the government has supported their company,

OneSpace noted that the government has supported them by helping it secure bank loans (Jones 2019d).

### g. Stock markets

Several Chinese commercial space companies offer stocks on public markets, including Zhuhai Orbita and APT Sat. In July 2019, PIESAT, a Beijing-based Earth observations and satellite navigation software developer, conducted its initial public offering (IPO) on the Shanghai Stock Exchange Sci-Tech Innovation Board (Platonov 2019). Many of the companies we spoke with hoped to eventually issue an IPO but had no plans to do so in the near future.

## 2. Subsidies

STPI found no evidence that the Chinese central government directly subsidizes commercial space companies, especially private companies. The central government has instead published a series of guiding policies that provincial and municipal governments, SOEs, and other public organizations have cited when making decisions to subsidize commercial space activities. These subsidies from provincial and municipal governments come in many forms. Local governments may give land subsidies to companies to build manufacturing facilities or build industrial parks to attract high technology businesses to their cities. Huzhou City provided LandSpace 200 million RMB of funds dedicated to civil-military integration (LandSpace 2018), which are likely related to LandSpace building its production facility in Huzhou, although the purpose of these funds has not been publicly stated. The Chongqing government provided subsidies to OneSpace for its facilities in the Chongqing Liangjiang New District in exchange for OneSpace establishing a subsidiary in Chongqing. It tied its financing plan to the development of OneSpace (Hualong Net 2018).

Although SOEs often do not directly invest in private companies, they have provided support through other means. For example, CASIC "supports more than 6,000 private innovative, entrepreneurial programs that have attracted more than 1.7 billion yuan ($250 million) in total funds…It has also set up eight innovation incubators across the country, covering a total of 483,000 square meters. Last year, the output of businesses in those incubators surpassed 40 billion yuan" (Li 2017). SOEs and CAS institutes have also made engineering support available and provided facilities for some of these companies. For example, S-motor uses technical consultants from CASC, CASIC, and Norinco for its projects (Shi 2018).[20] As will be discussed in Section 4.A, several private launch companies have been able to use CASC facilities to integrate payloads with their rockets.

[20] It is unclear from this interview whether this is an in-kind subsidy or S-motor pays for these consulting services. Regardless, that these SOEs are willing to provide technical support to a potential future competitor suggests that the SOEs view S-motor as potential supplier that they should support rather than a future competitor.

During interviews, we also heard that CAS will provide technical support and laboratory space for companies that it has spun-off.

### 3. Trends in Financing

Throughout research for this report, STPI observed a notable change in community views of VC. In September 2018, at a commercial space conference in Wuhan, many presenters mentioned "winter of capital," referring to the inability of many space companies to attract VC, in an apparent sharp departure from preceding years. In interviews conducted in March 2019, when asked about this trend, company representatives stated that during the first half of 2018, VC firms had been hesitant to invest, but since that time companies with strong business plans have been able to attract VC. Chinese venture capitalists and reports on VC in China have noted that funding has begun to concentrate around a few categories such as launch (Future Aerospace Research Institute 2019a; Zhou 2018). This suggests that although VC may have initially saturated the market when private investment in space was first allowed, VC firms have since become more cautious when investing in space companies, and are conducting more due diligence on companies' market prospects.

## D. Ownership Structures

A scrape of the Qichacha database showed that of the 78 companies in our database, 72 identified some degree of private ownership (anywhere from less than 1 percent to 100 percent privately owned). However this number is difficult to interpret, so we also explored the issue of ownership more qualitatively. Some Chinese space industry experts divide the space sector into four categories: SOE commercial subsidiaries, mixed-ownership corporations spin-off and backed by CAS/universities, privately-held start-ups, and established private companies and their subsidiaries. We use these categories in the discussion of ownership structures below.

In general, companies that are majority privately owned are more independent from government influence on business decisions than those with a minority of privately owned shares. However, some degree of government ownership does not mean that the government controls business decisions. Rather, how much the government influences a business depends on what part of the government holds a stake in the company. For example, an SOE-backed company is much more heavily influenced by government decisions than one backed by CAS or a public VC firm.

Conversely, private ownership in and of itself does not necessarily mean a company is independent. Although SOEs may own controlling stakes in some of these companies, others are privately held or publicly traded on the Hong Kong and Shenzhen stock exchanges. Such companies are somewhat akin to "old space" companies in Western nations, as these companies primarily sell to national, provincial, or municipal

governments or SOEs. As with older space companies in China, these commercial companies cross the spectrum of state-owned to privately held.

### 1. SOE Commercial Subsidiaries

As discussed in Chapter 1, we differentiate between SOEs and their more commercial subsidiaries. Interviews with SOE subsidiaries and industry insiders revealed several unique characteristics about state-owned commercial companies' ownership structures. In comparison to SOE subsidiaries that do not sell commercially, commercial subsidiaries report that they had more independence in business operations, required fewer approvals from the SOE before making decisions, and were able to raise money from non-government shareholders, including both public and private VC funds. Unlike the other categories of companies, employees cannot be shareholders in commercial subsidiaries of SOEs; if a company were to conduct an initial public offering, all the proceeds would go to the SOE. SOE-backed companies are also able to operate in some markets that private companies either are prohibited from entering or face large barriers to entering, such as large geostationary telecommunication satellites. These companies may also receive engineering and manufacturing support from their parent SOE or other SOE subsidiaries that are less commercial. Examples of this type of company include CASIC Hongyun, CASIC Xingyun, Expace, and Siwei SpaceView.

### 2. CAS and University Spin-offs

As noted above, many mixed-ownership companies are spin-offs from CAS institutes or universities. Because many CAS institutes act as suppliers to SOEs for specialized space hardware, spin-off companies in this category are generally trying to commercialize technologies developed in their associated institute. From examining business records, STPI found that CAS institutes and universities only take minority stakes in their spin-offs; the majority shareholders in these companies are former employees of CAS or of universities that are now employed by the spin-off. These businesses may receive in-kind subsidies from their former institutes, such as access to facilities and technical support. In other respects, however, they operate like privately held businesses. Examples include Chang Guang Satellite, LaserFleet, and SpaceOK.

### 3. Established Private Companies

Established private companies largely fall into two categories: mature space component suppliers and large conglomerates. In general, these companies began as private establishments 10 to 20 years ago and operate in a number of industrial sectors. Many of these companies were originally manufacturing companies that supplied certain satellite components, like electronics, to SOEs. Since the 2014 policy change, several of these companies have become more engaged in the satellite industry, seeking to operate their

own satellite constellations. Notable examples include HEAD Aerospace, Chengdu Spaceon, CCT Satcom, and Zhuhai Orbita. A few large Chinese conglomerates have recently expanded to the space market by partnering with smaller space companies. Notable examples include Huazun Fangzhou or Tatwah Smartech. Because these companies have established lines of credit, relationships with potential customers, mature technologies, and a decade plus of business experience, they are more likely to expand successfully. As a number of companies in this category are listed on various stock exchanges, some Chinese space experts refer to these companies as "listed companies" and may group non-listed companies with start-up space companies.

### 4. Private Start-ups

Like older and newer space companies in the United States, there are notable differences between Chinese start-up space companies and more established space companies. Start-up companies primarily depend on acquiring venture funding, either from private or public VC funds,[21] as they are generally unable to access bank loans. The largest of these companies have over $100 million in VC funding; the smallest are still shell companies with little funding. These companies are primarily owned by their founders and other important employees. Examples include companies such as Minospace, LandSpace, OneSpace, and iSpace.

Through interviews and other research, we noticed that many of these companies do not appear to have an understanding of potential demand for their products. Many seem to be trying to emulate successful Western space companies, potentially because there has been demand for these companies' products in other markets. They hope to reduce the cost of providing space goods and services below that of traditional Chinese suppliers to generate sales. Chinese private start-up companies are generally willing to sell their products to anyone who wants to buy them. Many of these companies list a wide variety of goods and services on their website, even if they are not actively developing all of these products, suggesting they are still at the prototype stage; they advertise to see what might be attractive to potential customers. We also noticed that many of these companies initially tried to produce entire products by themselves, because potential suppliers were too expensive. They saw vertical integration as a possible move to reduce costs. As these businesses have matured, however, it appears that they have developed supply chains and narrowed what goods and services they will actually sell.

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[21] As noted above, provincial and municipal governments may offer venture funding in order to attract high technology jobs to their jurisdictions. Beyond influencing where a business locates itself, this investment does not appear to affect business decisions, and as such we group these companies with other fully private start-ups.

## 5. Applying Ownership Framework to STPI Database

Using the 4-part framework above, the 78 companies are distributed as shown in Figure 4. Of these companies, more than half fall into the start-up category.

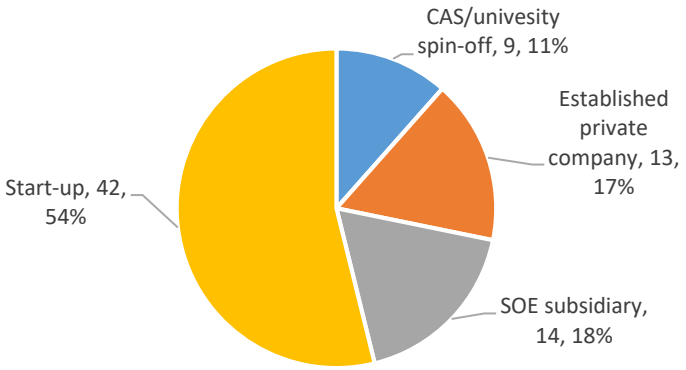


**Figure 4. Ownership of Companies in Database by STPI Category**

The distribution by type of ownership and year of founding shows that most companies created since 2014 have been start-ups (Figure 4). This distribution largely matches the distribution found by China space industry watchers such as the Future Aerospace Research Institute (2019b). Future Aerospace notes that most SOE-owned commercial companies were founded over 10 years ago and that in the last 10 years, only 6 state-owned commercial companies were founded (in comparison, we found 8 state-owned companies that we consider to be commercial that were founded during this time period).


**Figure 5. Founding Dates of Companies in Database by Type of Commercial Category**

## E. Leadership

Founders of companies with whom we spoke or researched tend to be domestically educated, but may have experience working abroad. Through interviews and presentations at conferences, we determined three major reasons why these individuals started their own companies: the promise of a financial payoff, independence to develop their technology free from bureaucracy, and interest in space.

Many founders of Chinese space companies spent their careers developing technologies at SOEs, CAS institutes, and universities. Starting their own companies gave them a chance to commercialize their technologies and technical knowledge. For example:

- Prior to founding MinoSpace and LandSpace, Wu Shufan had been an aerospace professor at several universities in China and Europe and a researcher at the European Space Agency.
- Prior to becoming the chairman of LandSpace, Wang Jian Meng (王建蒙) worked at Xichang launch center, the Beijing Launch and Control Center, then as Executive Vice President of APT Mobile Satcom Limited, a geosynchronous Earth orbit (GEO) communications satellite company.
- Peng Xiaobo, founder of iSpace, was the director of CALT's R&D center (Jilin University Zhuhai College 2016). He was also the head of CASC's First Academy R&D department.

Some company founders, like OneSpace founder Shu Chang, worked in the CASC space investment fund (航天科技集团航天产业基) and as a vice president in strategic investment at Legend Capital (联想控股投资) prior to starting a space company.[22] Following the 2014 policy change, Chang decided to found OneSpace after being unable to identify any space companies he thought would be strong investments (Goh 2018).

Another motivating factor for company founders has been the opportunity to develop their technology free from bureaucratic oversight at SOEs and government institutions. In public talks, several CEOs and company founders cited the ability to develop the technology they had spent their career working on in the manner they saw as best. Starting their own company allowed them to be more innovative with technologies and push boundaries.

The final major motivating factor that we found was that founders (and many of the employees at these companies) felt passionate about space exploration and wanted to devote their careers to advancing space technologies.

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[22] Shu Chang attended Beihang University of Aeronautics and Astronautics for aircraft design and Peking University for a master's degree in economics. Prior to entering the space industry, he worked for Legend Holdings aerospace division (Deville 2018).

## F. Employees

In general, companies that were established after 2014 range in size from 10–200 employees; several older or more established companies have 400 to more than 1,000 employees.[23] In interviews, younger companies that have recently entered the market stated that 70 percent or more of their employees are engaged in R&D, the majority of which had either master's or doctoral degrees, often in engineering or materials sciences. Most of these companies' employees were domestically educated, and worked at SOEs or CAS prior to joining the company. Examining hiring websites listings for space companies shows that many are looking for employees with advanced degrees and work experience in aerospace engineering—and also that these companies are expanding rapidly.

Several companies noted that during the hiring process they primarily look for potential employees that have 5 years of experience at SOEs or government institutions. In interviews with news organizations, company executives said they advertised that their core technical teams have worked on well-known space projects to tout the company's technical prowess. For example, S-motor, a rocket engine manufacture, advertised the core team's heritage working on Long March 11, Kuaizhou 1, and military systems (Shi 2018). Several other companies said they prefer to hire younger employees that have not worked at SOEs, as these people have not been imbued with the work culture of SOEs.

A few key reasons seem to drive employees to choose to work at a commercial company rather than an SOE. Yuan Si, a former general manager at CGWIC, left the SOE to join the multinational Gilat Satellite Networks (Si n.d.). The reason for the departure is unclear. Perhaps most important is that his salary would be higher. In September 2018, a viral post on Chinese social media highlighted the case of an engineer from the Xi'an Aerospace Propulsion Institute that had left the institute to work at LandSpace for 10 times his previous salary (China Money Network 2019).[24] In some instances, employees move to commercial companies because they are able to be more innovative with a technology on which they have worked for years. In a short documentary on OneSpace, an engineer stated that he went to work for OneSpace because he was allowed to implement his ideas on how to improve flight computers, dramatically reducing their weight (CCTV 2018). From interviews, we also heard that when CAS or a SOE spins off a technology for commercialization, employees working on that technology will often follow their team to the new company.

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[23] Source Qichacha and company websites and WeChat handles.

[24] The Xi'an Aerospace Propulsion Institute had attempted to legally prohibit this employee from joining Land Space by stating his work was vital for national programs. This triggered widespread pushback and debate on low pay in SOEs for technical employees.

## G. Customer Base

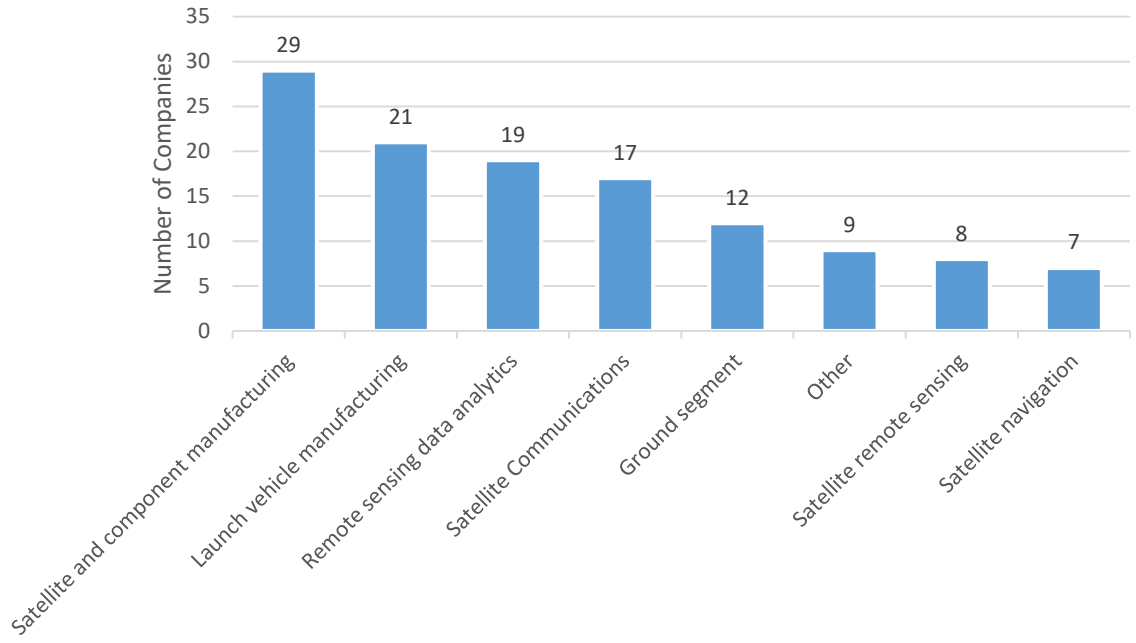
Customers include Chinese government agencies or SOEs, foreign government agencies, and domestic and foreign universities and educational institutions. However, most companies initially have a domestic customer base. For example, launch companies such as LandSpace are targeting about 30 domestic small satellite companies.

Company representatives with whom we spoke did not appear to have thought much about customers. For most, their customer base was aspirational rather than actual. During conferences, in interviews, on websites and promotional materials, companies spoke broadly about their products and services but not about potential customers. Interestingly, many companies do not have websites, and those that do may not have international facing or English language ones. WeChat seems to be the primary mode by which companies communicate with suppliers and potential customers, implying that these are domestic.

Most companies would like to grow to a point where they have a foreign presence, but they do not believe they will be able to do so in the near future, unless perhaps in developing countries. They are hampered in entering markets in developed countries because of restrictions imposed by the U.S. or European governments on the use by Chinese companies or Western components, or by prohibitions on exports by the Chinese government. In Wuhan, one entrepreneur gave an impassioned talk about how companies need to think less about the technical aspects of their products and more about what their customers need. A number of people came up to him after his speech to introduce themselves.

# 4. Overview by Sector

In this chapter, we divide China's space industry into eight sectors: launch; satellite and component manufacturing; satellite communications; satellite remote sensing; satellite navigation; ground segment; remote sensing data analytics; and other. The category "other" includes areas such as downstream data analytics, science, technology, engineering, and mathematics (STEM) education, asteroid mining, and space tourism. We did not find any companies engaging in commercial space situational awareness (SSA) or commercial signals intelligence type activities. Figure 6 shows the distribution of the 78 companies on STPI's database across these eight sectors.




Note: Some companies fall into more than one category so the total adds up to more than 78.

**Figure 6. Distribution of Chinese Commercial Space Companies by Sector**

As with the count, we benchmark our data with that of others, especially China industry watchers. China's Future Aerospace Research Institute published a distribution of China's commercial space primary market segments. Of the 141 commercial companies identified by Future Aerospace, there are:

- 36 satellite manufacturing companies (卫星制造), including 16 satellite component manufacturers (卫星配套制造), 2 payload manufacturers (卫星载荷制造), and 18 satellite integrators (卫星总体制造);
- 22 satellite launch companies (卫星发射), including 14 vehicle manufacturers (火箭总体制造), and 8 rocket component manufacturers (火箭配套制造);
- 39 satellite operators (卫星运营), including 19 communications satellite operators (卫星通信运营), 4 remote sensing satellite operators （卫星遥感运营), and 16 satellite telemetry, tracking, and control (TT&C) providers (卫星测控运维);
- 44 satellite downstream application companies (卫星应用), including 7 satellite navigation application companies (卫星导航应用), 8 satellite communication applications companies (卫星通信应用), 19 satellite remote sensing applications companies (卫星遥感应用), and 10 other satellite applications companies (卫星其他应用) (2019b). [25]

Our distribution in Figure 6 cannot be directly compared to Future Aerospace's distribution, as we categorized some companies into more than one category to reflect the markets in which they operate; Future Aerospace limited companies to just one category.

## A. Launch Vehicle and Component Manufacturers

### 1. Overview

Prior to 2014, launch services in China were the sole domain of SOEs, particularly CASC's CALT and SAST. During this period, CASC conducted some commercial launch activities (e.g., selling launch capacity on Long March rockets to foreign buyers through CGWIC); however, most launches were in support of government or SOE missions. CASC continues to dominate the launch market in China: it conducted 37 of China's 39 orbital launch attempts in 2018 (Krebs 2019). Although most of these launches were for the state, several were commercial launches for domestic commercial satellite companies, such as Zhuhai Orbita and Chuang Guang Satellite, and foreign countries, such as Saudi Arabia.

Despite the dominance of CASC in China's launch market, a number of commercial launch services and launch vehicle system and component manufacturers have been established in recent years. We identified at least 15 companies with plans to sell launch services using their own launch vehicle, including two backed by SOEs. [26] We also

[25] Some of these translations are not direct translations, but represent what we believe to be comparable market segments in the United States for ease of comparison to U.S industries.

[26] Conversations with industry insiders suggest there may be many more (5 to 15) companies interested in developing launch vehicles that are still in stealth mode. For example, since ending our data collection period at the end of May 2019, another launch company, Seres Space Exploration Technology (立极太

identified another six commercial companies that supply engines, components, and testing equipment to launch vehicle manufacturers. Table 2 lists launch companies by ownership structure (whether established, SOE subsidiary, established private or start-up) founding year and the launch category into which they fall.

**Table 2. Launch Companies by Ownership Structure and Founding Date**

| | Product category | Established private company | SOE subsidiary | Start-up |
|---|---|---|---|---|
| Tianhang xiangyu | Component supplier | 2007 | | |
| Tianjin Aerospace Reliability Technology Co. | Component supplier | 2009 | | |
| Pushing Value | Component supplier | | | 2013 |
| TSC | Component supplier | | | 2015 |
| AA Engine | Engine manufacturer | | | 2016 |
| Ningbo Space Engine Technology | Engine manufacturer | | | 2018 |
| ChinaRocket | Launch provider | | 1998 | |
| Dragon Drive | Launch provider | | | 2012 |
| Space Transportation | Launch provider | | | 2012 |
| LinkSpace | Launch provider | | | 2014 |
| Landspace | Launch provider | | | 2015 |
| OneSpace | Launch provider | | | 2015 |
| SpaceTrek | Launch provider | | | 2015 |
| Deep Blue Space | Launch provider | | | 2016 |
| Expace/CASIC Rocket Technology Company | Launch provider | | 2016 | |
| iSpace | Launch provider | | | 2016 |
| Jiuzhou Yunjian | Launch provider | | | 2017 |
| S-Motor | Launch provider | | | 2017 |
| Enter Space | Launch provider | | | 2018 |
| Galactic Energy | Launch provider | | | 2018 |
| TWR-Engine | Launch provider | | | 2018 |

空探索技术有限公司), has unveiled a medium-lift launch vehicle (20 tons to LEO, 6 tons to geosynchronous transfer orbit) named 天梦 (Tianmeng). It is targeting reusability and quick-turnaround launch (under a week). Company representatives have said Seres Space Exploration plans to launch from an island, presumably at the Wenchang Satellite Launch Site, as that is China's only launch center on an island (Xinhua 2019b).

Chinese space industry watchers divide launch service companies into two generations. The most prominent companies in China's launch market are all part of the first wave of commercial launch companies. As of July 2019, LandSpace, OneSpace, and iSpace—the three largest private launch companies—have all attempted orbital launches; iSpace is the only one of the three to successfully reach orbit.[27] LandSpace currently has the most ambitious plans, as it hopes to launch medium-lift launch vehicles to sun synchronous orbit (SSO) as well as low Earth orbit (LEO) and GEO. Expace, a commercial launch company backed by CASIC, has conducted two commercial launches since it was spun-off of CASIC in 2016; ChinaRocket, a commercial company backed by CASC, launched its first rocket in August 2019 (Clark 2019b). ChinaRocket[28] was founded in 2016 to make CASC's launch vehicle offerings more competitive commercially (Beijing E-Town 2016). Four of these companies (Expace, iSpace, LandSpace, and OneSpace) have received significant financial support from China's VC community (see Table 3 for details). Another notable early entrant to the launch sector, LinkSpace, has recently demonstrated retro-propulsive hovering capabilities on a large suborbital hopper vehicle.

Since 2017, there has been a second wave of commercial launch services and system suppliers companies that have been founded. Many have conducted engine tests or, in a few cases, suborbital flight tests. Companies in this category have raised significantly less money than launch companies in the first wave, although funding levels vary among second wave companies (Table 3). Several of these companies, such as S-motor, Space Transportation, and TWR-Engine, have developed unique engine technologies or rocket designs. Other launch companies include Galactic Energy, SpaceTrek, Enter Space, Deep Blue Space, and Jiuzhou Yunjian. Galactic Energy appears to be the most advanced of these companies, as it is the only one of these companies that has publicly released a target launch date (March 2020) for its Ceres launch vehicle (Mo 2019).

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[27] iSpace successfully reached orbit on July 25, 2019. Land Space first attempted an orbital launch in October 2018, but failed to reach orbit when its third stage malfunctioned (Jones 2018a); OneSpace attempted its first orbital launch in March 2019, but the vehicle flew off course shortly after liftoff (Clark 2019a).

[28] ChinaRocket—also known as the China Long March Rocket Company—was originally established in 1998 as China Asia-Pacific Mobile Communications Satellite Company under CALT. The company was refocused (and renamed) in 2016 to develop and sell commercial launch services on Long March rockets. ChinaRocket is currently developing two new rockets (Jones 2019b). It conducted its first successful launch in August 2019.

**Table 3. Publicly Known Amount of Capital Raised by Launch Service Providers**

| Company | Total Known Amount Raised (millions RMB) | Latest Round | Date of Latest Round |
|---|---|---|---|
| Expace* | 1,200 | A | Dec. 2017 |
| LandSpace | >800 | B+ | Sept. 2018 |
| OneSpace | <800 | B | Aug. 2018 |
| iSpace | >700 | A+ | Jan. 2019 |
| Galactic Energy | 100 | A | Apr. 2019 |
| Jiuzhou Yunjian | >10 | A | Jan. 2019 |
| LinkSpace | >10 | Pre-A | Mar. 2017 |
| SpaceTrek | >10 | Angel | Mar. 2018 |
| Deep Blue Space | >10 | Seed | Jan. 2019 |
| Space Transportation | >10 | Angel | Mar. 2019 |
| S-Motor | Unknown | Angel | 2017 |
| Enter Space | Unknown | Unknown | N/A |
| TWR-Engine | Unknown | Unknown | N/A |
| ChinaRocket* | Unknown | Unknown | N/A |
| DragonDrive | Unknown | Unknown | N/A |

* Backed by SOEs

## 2. Current Status of Commercial Companies

As of August 2019, with the exception of Expace, ChinaRocket, and iSpace, all of China's commercial launch service providers were still in the phases of conducting R&D or demonstrating their suborbital and orbital launch vehicles, although several have domestic and foreign launch contracts. In general, companies have initially focused on small launch vehicles (up to several hundred kilograms to LEO) (Jones 2019e). Several companies have also announced plans for medium lift vehicles (several tons to LEO). Many of these companies are pursuing reusable launch vehicles through a variety of technologies, including retropropulsive landings and parachute return of an upper-stage glider (Deville 2019). In public presentations, companies have touted their goal to provide rapid response launch times of under 6 months. In a presentation at the Fourth China International Commercial Aerospace Forum in Wuhan, China, Expace president Zha Xiongquan stated that their quickest turnaround was several days from signing a contract with a customer to launch.

Of the 17 companies we identified that are developing rocket engines,[29] 12 are developing liquid-fueled engines and 10 are developing solid-fueled engines (5 have announced plans to build both, generally starting with a solid-fueled engine for their first

[29] Fifteen of these companies are also developing their own launch vehicles; two are solely engine manufacturers.

launch vehicle design and a liquid-fueled engine for their second, larger launch vehicle design). Several companies are trying to apply engine designs from other aerospace sectors (e.g., missiles and aircraft) to launch vehicles, including dual-pulsed solid engines (S-motor) and pulse detonation engines (TWR-Engine). Among companies with plans for liquid-fueled rockets, two fuel-oxidizer combinations appear to be dominating: LOX kerosene (LinkSpace, Galactic Energy) and LOX Methane (LandSpace, [30] iSpace, [31] Jiuzhou Yunjian) (Hebden 2019; Jones 2018c; Jones 2019c). Table 4 lists the technical details we were able to find about proposed Chinese commercial launch vehicles.

**Table 4. Chinese Commercial Launch Vehicle Technical Specifications**

| Company | Propellant | Targeting reusability? | Size of payloads | Notes |
|---|---|---|---|---|
| LandSpace | LOX Methane (Zhuque-2); Solid (Zhuque-1) | Yes, retropropulsion | 200 kg to 500 km SSO (Zhuque-1); 1.5t to 700 km SSO/4.0t to 200 km LEO (Zhuque-2) | |
| iSpace | LOX Methane (Hyperbola-1, 4th stage); Solid (Hyperbola-1) | Yes, retropropulsion; parachutes | 150 kg to 700 km SSO (Hyperbola-1) | Used parachutes for early rocket reuse |
| OneSpace | Solid (OS-M; OS-M2; OS-X) | No | 205 kg to 300 km SSO (OS-M); 300 kg to 500 km SSO (OS-M2) | |
| Expace | Solid (Kuaizhou) | No | 200 kg to 700 km SSO (Kuaizhou-1); 1000 kg to 700 km SSO (Kuaizhou 11) | CASIC subsidiary |
| ChinaRocket | Solid (Jielong-1); liquid, unknown (Tenglong) | Yes, retropropulsion (Tenglong); horizontal take-off and landing | 150 kg to 700 km SSO (Jielong) | CASC subsidiary, rockets designed and built by CALT |
| LinkSpace | LOX Kerosene (NewLine-1) | Yes, retropropulsion | 200 kg to 500 km SSO (NewLine-1) | Currently working on hopper technology |
| Deep Blue Space | LOX Kerosene (Nebula-1; Nebula-2) | Yes, retropropulsion | 500 kg to 500 km SSO (Nebula-1); 5t to LEO (Nebula-2) | |
| Galactic Energy | LOX Kerosene (Pallas-1); Solid (Ceres-1) | | 350 kg to LEO (Ceres-1); 4t to 200 km LEO (Pallas-1) | |

[30] LandSpace tried to purchase a liquid fueled engine from an SOE for its Zhuque-2 launch vehicle in 2015 (Han 2018). However, this purchase appears to have fallen through by April 2017 (Xiao 2017), forcing LandSpace to build its own.

[31] iSpace reported that it chose a LOX methane engine based on what was industrially available from the already existing space industry stock (Zero2IPO Group 2019).

| Company | Propellant | Targeting reusability? | Size of payloads | Notes |
|---|---|---|---|---|
| S-Motor | Solid | Unknown | 160 kg to SSO | Dual-pulsed engine, details unknown |
| Space Transportation | Unknown | Yes, glider/parachute | Unknown | |
| SpaceTrek | LOX Kerosene; Solid (XT-1, sub-orbital) | Yes, retropropulsion | Unknown | |
| Jiuzhou Yunjian | LOX Methane | Yes, retropropulsion | Unknown | |
| Enter Space | Unknown | Unknown | Unknown | |
| Dragon Drive | Liquid | Yes, retropropulsion | 300 kg to LEO | |
| TWR-Engine | Liquid | Unknown | Unknown | Pulse Detonation Engine |
| AA Engine | Liquid | N/A | N/A | Engine manufacturer |
| Ningbo Space Engine Technology | Solid; Liquid | N/A | N/A | Engine manufacturer |

As of August 2019, only five companies had attempted orbital launches: Expace, ChinaRocket, LandSpace, OneSpace, and iSpace. LinkSpace, another early launch company, conducted a vertical take-off and vertical landing hover test of its 8.1-meter tall rocket, reaching an altitude of 20 meters in March 2019. With the exception of LinkSpace, each of these companies' rockets has been solid-fueled. Although companies are targeting orbital launch markets, several, including iSpace, OneSpace, SpaceTrek, and EnterSpace, plan to also sell suborbital vehicles to companies as a platform to verify space technologies.

In December 2018, LandSpace opened its own launch vehicle production facility in Huzhou, Zhejiang province, making it the first private launch company to own a full production facility (China Daily 2018a). In its new facilities, LandSpace hopes to achieve a production rate of 15 launch vehicles a year by 2022 (Jones 2018d). Other launch companies may produce subsystems (e.g., propulsion systems) in their own facilities, but integrate their rockets in facilities owned by the large SOEs. For example, both LandSpace and OneSpace have released images of their rockets in a CASC facility in Xi'an (see Figure 7). As Chinese launch companies receive orders, they are likely to build their own production facilities. OneSpace has reported that it is currently constructing manufacturing and testing facilities in Chongqing, Sichuan, with an annual production capacity of 30 small orbital launch vehicles (OS-Ms) and 20 suborbital launch vehicles (OS-X) (Zhao 2018). EnterSpace, a launch company founded in late 2018, plans to build a factory with a production capacity of 35 launch vehicles a year (Jilin Daily 2019).


Source: OneSpace, LandSpace, CCTV

**Figure 7. OneSpace (left) and LandSpace (right, bottom) rockets in a CASC integration facility (bottom, cordon in photo shows is printed with CASC's name and logo)**

As of July 2019, all private launches have taken place at the Jiuquan Satellite Launch Center or the Wenchang Spacecraft Launch Site. Media reports suggest that the Chinese government plans to make Jiuquan the permanent location for commercial launches (Li and Chen 2018). Chinese media reports suggest that launch companies will continue to use government facilities for launch, but may construct their own launch pads at launch centers to avoid schedule conflicts with CASC rockets. In public presentations and interviews, launch companies report that the government has been supportive of launch companies' needs for launch, even if the government does not allow companies to choose where they will launch. For example, during the Wuhan China International Commercial Aerospace Forum in September 2018, Shu Chang, CEO of OneSpace, stated that OneSpace had hoped to take a video of the launch from space using a satellite. However, the satellite malfunctioned. The PLA was willing to move the launch up by 12 hours so that OneSpace could shoot video from another satellite.

Currently, most launch companies have not disclosed their cost per rocket or cost per kilogram to launch. OneSpace has reported that its suborbital OS-X cost less than 500 million RMB ($78 million) to design and build (Fernholz 2018), as that is approximately how much capital they had raised to that point. In September 2018, the general manager of Expace, Cha Xiongquan, noted that Expace's new launch vehicle, the Kuaizhou 11, would cost approximately $10,000 per kilogram (Yao 2018), but they expect the cost to fall to $5,000 per kilogram over time (Jones 2019b). Private commercial companies hope to beat

Expace on price. Galactic Energy, for example, is targeting a launch price of $2,000 per kilogram (Yang 2019). It is unclear if these companies will be able to meet these ambitious prices.

### 3. Future Market Potential

According to interviews and public presentations, Chinese commercial launch companies are primarily targeting domestic small satellite companies as their customer base. As of April 2019, most payloads launched aboard commercial launch vehicles were those of commercial satellite companies. For example, Expace has launched satellites for Chuang Guang Satellite, Centispace, and several universities. OneSpace's commercial customers include ZeroG Lab and Spacety, whereas iSpace has sold payload capacity on its suborbital vehicles to ADA Space and ZeroG Lab (Yang 2019; Jones 2019c; Spacewatch Global 2018). Most commercial launch companies that have demonstrated a suborbital vehicle have publicly claimed that they have signed contracts with many commercial satellite companies, but have not revealed details, including the identities of their customers. At the 2018 China International Commercial Aerospace Forum, Expace reported it had 15 signed contracts with customers.

Among the limited number of commercial launches that have occurred through April 2019, a few of the payloads have been sponsored by SOEs or government organizations. For example, LandSpace's first orbital launch attempt in October 2018 carried a small satellite for China Central Television manufactured by MinoSpace; OneSpace's first suborbital vehicle carried a technology demonstration for the Aviation Industry Corporation of China; iSpace's July 2019 orbital vehicle carried two satellites for CASIC and Beijing Institute of Technology (a public university) as well as a classified military research payload (Jones 2018a; Zhong and He 2018; Chen 2019). A representative of a launch company whom we interviewed stated that he did not believe the government was interested in purchasing launch vehicles from the private sector, as the government already has adequate launch capacity. This appears to not include CAS institutes or universities, as many commercial launch companies have said that they have sold launches to domestic institutes.

Currently, only LandSpace has pursued customers outside China. In 2017, LandSpace and GOMspace, a Danish CubeSat manufacturer, signed a launch agreement (The Room 2017). In April 2019, LandSpace signed launch agreements with the United Kingdom's Open Cosmos and Italy's D-Orbit (Xinhua 2019a) valued at about $15 million.[32] In several public talks and interviews, LandSpace CEO Zhang Changwu has said that LandSpace is planning on directly competing with foreign launch companies, such as SpaceX and Blue Origin, for global small satellite launches (NetEase Science and Technology 2018).

[32] It is unclear as to what these contracts are for.

LandSpace may be an exception to launch companies solely targeting domestic markets, as discussions with representatives of another launch service provider revealed they were unsure if they would be able to sell to many foreign companies due to other countries' controls on foreign trade with China. In the long run, several launch companies have discussed targeting developing markets, but plan to focus on domestic sales for the immediate future.

Competition within this sector will be fierce due to the number of launch providers and uncertain demand for satellite services in China. In public presentations, many launch companies have stated that they hope to work with other launch companies to grow the market, rather than fight over sales, which would reduce margins. Commercial launch vehicle company executives cite the growing demand for small satellites in China and globally as evidence of a sufficient market for several launch companies (Han 2018), although some launch company executives, such as iSpace's vice president Hu Jia, believe that there may only be room for one or two commercial launch companies that ultimately survive beyond the next 5 to 10 years (Zhang 2019).

Within the small satellite launch market, both CASC and CASIC own companies and sell launch vehicles that service the same market as private launch companies' launch vehicles. Despite this, private launch companies have said that they are not currently competing with SOEs, although they have tacitly acknowledged that one day they will. In a public talk, iSpace President Peng Xiaobo stated that commercial rockets are not competing with launch vehicles that serve national missions, but rather supplementing and filling gaps in China's launch capabilities (Xin 2019). LandSpace CEO Zhang Changwu stated that he did not believe that private launch companies would be competing with SOEs for at least a decade. This is because although SOEs currently launch over 30 vehicles a year, the demand for launches is closer to 50 a year, meaning there is room for private companies (Han 2018). In particular, Zhang Changwu noted that demand for launches from commercial satellite companies is not being filled by SOEs, as SOEs focus on national missions.

The future of China's commercial launch sector will depend on three factors: (1) whether the Chinese government and SOEs are willing to be customers of commercial launch companies; (2) the demand for domestic commercial satellite services; and (3) whether foreign companies are willing to be customers of commercial launches from Chinese companies. As the government and SOEs are the major sources of demand for satellite services in China, if government organizations continue to procure launches from CASC, the market for commercial launch companies will be constrained, limiting the number of launch companies the Chinese space industry can support. From interviews and the literature, it is currently unclear whether private launch service providers will be able to launch military or civil space payloads one day, especially heavier payloads. The government may also choose to continue launching its small payloads on CASC rockets.

Notably, however, one of the payloads on iSpace's July 2019 launch was from CASIC, suggesting the government may purchase launch from commercial providers. Despite this uncertainty in whether the Chinese government and SOEs—the major source of demand for launching large satellites—will purchase from the private sector, companies such as LandSpace are pursuing medium-lift launch vehicles, indicating that at least some companies may try to sell their services to the government once their technologies have been demonstrated.

The demand for many satellite services pursued by commercial satellite operators in China is uncertain. Because the demand for launch is derived from the demand for satellite-based services, if these satellite companies are unable to find a market, many Chinese commercial launch operators will not survive. Foreign satellite companies may supplement the demand for Chinese launch capacity. However, as many foreign companies and governments are wary of China and its space industry—especially Western countries, which have the highest foreign demand for small satellite launches—the willingness of Chinese companies and governments to purchase launch capacity from private Chinese launch services is unclear. Due to barriers to entry, Chinese launch companies' ability to pursue foreign customers is unclear. As of July 2019, only LandSpace had announced contracts with foreign companies. As noted above, executives at the most prominent Chinese commercial launch companies expect the Chinese space market to support anywhere from several launch companies to only one. From interviews with industry watchers, it appears the general consensus is that Expace, LandSpace, and iSpace are the most likely companies to survive long-term.

## B. Satellite Manufacturing

### 1. Overview

Due to China's extensive space activities over the last several decades, China has a robust, technologically advanced satellite manufacturing sector. Since the late 1960s, when China built its first satellite—DFH-1—CAST[33] has manufactured almost all government satellites. CAST has many subsidiaries. Each subsidiary specializes in manufacturing specific satellite sizes to avoid competition within CAST.

According to interviews with experts on China's space sector, starting in the late 1990s, the Chinese government authorized SAST[34] to manufacture satellites in order to introduce competition with CAST. Currently, CAST and SAST remain the dominant satellite manufacturers, providing satellite buses and payloads for all national space

[33] CAST is a subsidiary of CASC and is occasionally referred to as the fifth institute of CASC.

[34] SAST's main subsidiary for satellite production is the Shanghai Institute of Satellite Engineering (SISE). Like CAST, SAST is a subsidiary of CASC. It is the Eighth Academy of CASC.

activities. Some subsidiaries within the two SOEs started to focus on the commercial market in the early 2010s, endeavoring to lower costs, increase efficiency, and attract non-government customers.

These large state-owned satellite manufacturers have trained an experienced workforce in satellite manufacturing. Most founders of commercial space start-ups come from CAST; many commercial companies actively seek to hire engineers from CAST and SAST.

Various CAS institutions specialize in manufacturing specific satellite components. Many of the prominent commercial satellite companies are actually spin-offs from these CAS institutions. They have since expanded their space activities beyond component manufacturing. Examples include Chang Guang Satellite Technology and SpaceOK.

Satellite component manufacturing is one of the oldest commercial market segments in China's space sector. Several private companies established themselves as satellite component suppliers for the government in the early 2000s. A few of these established private component suppliers have expanded their space activities, manufacturing entire satellites. Some have plans to build large LEO constellations; examples include Zhuhai Orbita and Head Aerospace.

## 2. Current Status of Commercial Companies

STPI identified 29 commercial companies that engage in space manufacturing activities, either manufacturing products to sell to other space companies or for their own operations. Although grouped together here, these companies represent a wide-range of businesses, including specialized component manufacturers, companies that manufacture space hardware testing equipment and software, and system integrators.

The R&D barriers to entry for satellite and component manufacturers are lower compared to other space sectors, because many engineering teams possess manufacturing and technical expertise from previous employment at CAST, SAST, or CAS, and the relatively lower cost of systems. For example, many satellite start-ups have built a CubeSat within a few months of their founding. Nonetheless, the technological capabilities of these commercial companies are still limited. All the companies STPI identified are focused on the small satellite (satellites smaller than 500 kilograms) market, because many recognize that they do not have the resources or the technology to build larger satellites. According to interviews, no commercial start-up has built a satellite larger than 30 kg, but in 2019 two companies are attempting to build 100 kg satellites.

Many start-ups also manufacture satellite components as a way to generate revenues and offset costs for more capital-intensive activities. For example, MinoSpace sold ground station equipment in its first few months to generate revenues, even though it currently focuses on manufacturing full satellite systems (Zhang 2017). One interviewee pointed out

that building and deploying LEO constellations requires substantial time and capital. Most companies that plan to build such a constellation generally do not expect profits for their first 3 years. Many of these companies currently plan to manufacture components or small satellites for others until their own constellations become profitable.

These new start-ups tend to build at least one CubeSat as a test satellite in order to verify and validate their technological competencies, even if they do not plan on becoming a manufacturing company. Many of these start-ups have indicated that they may outsource their manufacturing to build their large constellations. Manufacturing is thus a stepping-stone for many start-ups to enter the commercial space industry, as companies must verify their technologies to attract investors. As the industry matures, the number of companies that engage in satellite manufacturing may decrease.

Some commercial start-ups plan to remain in the manufacturing industry. A few are focused on selling entire satellite buses and payloads (e.g. MinoSpace). Many are offering end-to-end turn-key solutions where they manufacture, launch, and operate satellites for customers (e.g., Spacety and Zero Gravity Labs) (Spacety 2018; Shi 2018). These manufacturing companies expect to win contracts from new commercial operators to build satellites for large constellations in LEO, because they can manufacture satellites at lower cost and faster timelines compared to traditional SOE satellite manufacturers. Based on interviews, Chinese commercial manufacturers have significantly lowered their costs by taking larger risks and sourcing cheaper components from non-traditional suppliers rather than using state-of-the-art space components like the traditional SOE satellite manufacturers do.

### 3. Future Market Potential

Most interviewees noted that the commercial space industry in China will likely only support two to three commercial satellite manufacturers, and that companies will have to become specialized component manufacturers to stay viable. The current competition among small satellite manufacturers is already intense; one interviewee described it as a "battle to the death." Another stated that the CubeSat market has become so oversaturated and competitive that companies are manufacturing CubeSats at a loss right now. To remain competitive and differentiate themselves from other commercial companies, companies may have to build larger satellites, which may bring them into competition with CAST and SAST.

A major limiting factor for the commercial satellite manufacturing industry is that all government contracts for satellites are currently given to CAST. This makes the domestic customer base very small for commercial manufacturers. Most major satellite contracts with foreign governments and customers are also given to CAST, as CGWIC negotiates most of these foreign contracts. According to our interviews, many commercial start-ups are unable to leverage CGWIC's network, and must market their products and find

customers on their own. A few commercial manufacturers are negotiating with potential customers from Europe, Africa, South America, and Southeast Asia and may have signed MOUs with them. However, commercial start-ups are currently only able to sign small contracts with clients who have limited means to purchase satellites, like universities and other start-ups. This may change if commercial companies are able to build larger satellites competitive with those manufactured by CAST.

Most start-ups currently engaged in manufacturing satellites do not plan on pursuing manufacturing as their primary activity. Only one company noted in an interview that it wants to remain a traditional satellite manufacturer and hopes to compete with CAST. It plans to do so by offering better prices, timelines, and services to its customers. In terms of services, it claims that it is willing to share its technical expertise with its customers, which CAST may be unable to do.

## C. Satellite Communications

### 1. Overview

Satellite communications is one of the most established commercial space sectors in the world, a result of the profitability of long distance telecommunications earlier on and the current profitability of direct-to-home satellite television broadcasting services. Prior to the late 2010s, China did not have any fully private satellite communications companies as the country heavily regulates its telecommunications industry.

The GEO satellite communications market in China is dominated by SOE-backed commercial companies—primarily China Satcom (part of CASC) and its subsidiary APT Satellite, and Asiasat, which is partially owned by CITIC Limited (Euroconsult 2018). According to Euroconsult, the two largest sources of demand for capacity are television signal distribution and network backhaul, with enterprise networks following third due to regulations restricting their size (Euroconsult 2018). Unlike in foreign markets, direct-to-home television broadcasting in China is a free-to-air service meant for rural markets. As such, it does not generate large revenue streams in China.

The LEO satellite communications sector in China is nascent, as it is globally. Many of our interviewees believe that LEO mega-constellations will become a large market, as several foreign companies have ambitious plans to develop their own constellations. Chinese companies are also eyeing this market, as start-ups and SOEs have announced plans for their own mega-constellations. Because the industry is at such an early stage, SOEs have not yet been given a monopoly over the LEO communications industry. Consequently, many industry watchers believe that LEO satellite communications may be one of the better opportunities for start-ups to establish themselves.

## 2. Current Status of Commercial Companies

STPI identified 17 companies engaged in satellite communications activities, but only five of them are start-ups without any backing from CAS (Table 5). Most of these companies plan to construct their own satellite constellations, but some, such as Xihua Tech, plan to use hosted payloads. One start-up, Galaxy Space, has announced plans to sell broadband satellite communications, emulating OneWeb's business model. Another, LaserFleet, plans to build a LEO constellation that will employ laser communications to provide broadband services. Both of these companies are in the early stages of development. As of May 2019, neither had launched a satellite of its own. Most start-ups are focused on narrowband satellite communications, pursuing internet of things (IoT) communications markets.

SOEs have several commercial consumer/business-oriented LEO communications satellite constellations under development: CASC's Hongyan, CASIC's Hongyun, CASIC's Xingyun, and LinkSure's Swarm constellations.[35] The Hongyan, Xingyun, and Swarm constellations are planning to sell broadband global internet access and 5G mobile data, targeting rural, aviation, and maritime markets. CASC has also announced plans for Hongyan to engage in narrowband activities. Xingyun, which is managed by CASIC subsidiary LEOBIT, will focus on narrowband activities, and will target IoT devices. Satellite communications companies have also mentioned other potential markets such as supplementing Beidou satellite navigation for increased accuracy and providing inflight connectivity (Jones 2018b; Zhao 2018), discussed briefly in Section G below.

All of these companies are still in the early stages of development. None of them have launched any satellites for their proposed constellations as of May 2019, with the exception of SpaceOK, which launched Jiading-01 in late 2018 (SHINE 2018), and the first satellite for CASC Hongyan constellation (Jones 2019f). Xingyun launched a test satellite in 2017, and Commsat has also launched a few test satellites, but none of these satellites will be used for their communications constellation (Li 2018). Most companies expect to have their constellations in space within the next 5 years and start selling services at that point. In other words, these companies do not expect to have any revenues from their constellations for several years. Many of them are engaged in other activities, such as component manufacturing, space education, and advertising in order to generate revenues in the meantime.

[35] A demonstrator satellite for Hongyan was launched at the end of 2018 (Barbosa 2018). LinkSure, a private internet company, plans to work with CASC to build, operate, and launch the satellites.

**Table 5. Commercial Satellite Communications Companies by Founding Date, Ownership Structure, and Application**

| | Application | CAS/ University Spin-off | Established Private Company | SOE Subsidiary | Start-up |
|---|---|---|---|---|---|
| APSTAR | GEO comms. | | | 1994 | |
| China Satellite Communications | GEO comms. | | | 2001 | |
| China Communication Technology (CCT Satcom) | GEO comms. | | 2007 | | |
| LinkSure Network | LEO broadband | | 2013 | | |
| SpaceOK | IoT | 2014 | | | |
| Commsat | IoT | | | | 2015 |
| Guodian Gaoke | IoT | | | | 2015 |
| Spacety | IoT | 2016 | | | |
| Aerospace Science and Technology Space Engineering Development Company (CASIC Hongyun) | LEO broadband and IoT | | | 2017 | |
| LEOBIT (CASIC Xingyun) | IoT | | | 2017 | |
| LaserFleet | Laser comms | 2017 | | | |
| Xihua | IoT | | | | 2017 |
| Tatwah Smartech | GEO comms. | | 1993 | | |
| CASC Hongyan Constellation | LEO broadband and IoT | | | 2016 | |
| Qiansheng Exploration | LEO comms. | | | | 2017 |
| Galaxy Space | LEO broadband | | | | 2016 |
| HEAD Aerospace | LEO comms. | 2007 | | | |

The narrowband communications companies are currently targeting the IoT market. Some manufacture and sell IoT receivers to generate revenues as they wait for their constellations to be completed. They are currently marketing space-based IoT to industries in remote areas, such as the agricultural, oil, and shipping industries. However, as revealed in interviews, most companies have not yet developed full business models for their IoT constellations; they are still developing applications for space-based IoT.

Some established private Chinese companies, such as Tatwah Smartech and Huaxun Fangzhou (CCT Satcom), are entering the GEO satellite communications market in other

countries. Both of these companies have been around for much longer than the majority of Chinese commercial space companies, but have only recently entered the space industry. They have expanded into the satellite communications industry by buying satellite capacity and investing in local satellite communications companies of other countries.

These companies believe the GEO high throughput satellite market will be profitable, especially for countries with underdeveloped telecommunications capabilities. Currently they are targeting developing countries that participate in the BRI as well as those with large youth populations that have high demand for internet connectivity.

In 2018, CCT Satcom purchased G Telecoms, the third largest telecommunications operator in the Philippines, and Tatwah Smartech invested approximately $30 million in Sri Lankan satellite operator SupremeSat (Cheng, Hu, Zhou 2018; CN Info 2018). The two companies chose not to enter the domestic Chinese market because of heavy government regulations and because they did not believe they could compete with China Satcom.

### 3. Future Market Potential

Several companies mentioned the difficulties in acquiring spectrum in China due to the lack of a defined regulatory process. A communications company noted that obtaining domestic spectrum is a first-come, first-served proposition. According to interviews, currently, there is only enough L-band spectrum to support one to two IoT constellations, but as Table 5 shows, more than two companies are proposing IoT constellations. Two such companies have already secured priority access to L-band frequencies in China, giving them a large domestic advantage.

From an international perspective, one subject matter expert noted that first movers in global constellations will be able to reserve the best bands for satellite communications. Because Western companies have engaged in launching large LEO constellations operations first, Chinese companies believe that they are at a major disadvantage as second comers. Chinese companies who are latecomers will have to use the more expensive high frequency bands, otherwise they may not obtain access to spectrum at all.

Chinese companies believe most of the opportunities in the burgeoning commercial space industry are in the communications sector. The market potential of any space-based service depends on whether it can be sold directly to consumers in China, expanding the customer base beyond the government and other businesses. Chinese space experts with whom we spoke believe that communications is the only space application that new Chinese space companies will be able to sell directly to consumers, because the average citizen uses telecommunications daily. Companies do not believe that the average citizen will purchase remote sensing data or other space applications in the near future.

China’s large population provides a huge potential market for commercial satellite communications. Start-ups, however, will have to innovate and pursue non-traditional

communications applications, because SOEs have a monopoly on the mainstream telecommunications and broadcasting industries due to strict government regulations. Currently, most companies that we identified in our research are pursuing space-based IoT because SOEs do not yet dominate that market. These commercial space companies also hope to provide communications services from space needed to operate "smart cities."

Chinese commercial start-ups look towards the United States and other Western markets for direction concerning the satellite communications industry. When asked why the communications sector is seen as the most promising sector in the commercial space industry, one industry insider responded that most space companies that have completed an IPO in the world are communications companies. No launch companies have completed an IPO; very few companies in remote sensing have either. Iridium, Globalstar, and Orbcomm were mentioned frequently as benchmark companies in interviews. The success of these Western companies and their upcoming mega-constellations have generated lots of excitement in the satellite communications sector in China, making it easier for start-ups to obtain funding for similar mega-constellation projects.

## D. Satellite Remote Sensing

### 1. Overview

China has a robust government remote sensing program with 7 satellites series, including Huanjing ("Environment"), Haiyang ("Ocean"), Gaofen ("High Resolution"), and Yaogan ("Remote Sensing") (Euroconsult 2018; Global Security 2018). In the Yaogan series, 69 satellites have been launched since 2006 (Xinhua 2018d; Euroconsult 2018). However, most of the data from these satellites are unavailable to the public or for purchase; all of the data from these government programs are controlled by departments and institutes inside the government, according to expert interviews.

China did not have commercial remote sensing satellites series or commercial remote sensing companies prior to 2014, when Jilin-01 was launched by Chang Guang Satellite Technology. Although the commercial remote sensing industry is in its infancy, it is growing rapidly. Compared to other commercial space sectors, the remote sensing sector is one of the most established with concrete products, services, and customers.

### 2. Current Status of Commercial Companies (Business Plans and Technological Capabilities)

STPI identified eight companies engaged in commercial remote sensing activities, less than half the number of companies in telecommunications. The smaller number of commercial remote sensing companies is consistent with information obtained from interviews: commercial opportunities in the remote sensing sector are fewer than in telecommunications, and therefore there are fewer companies.

**Table 6. Earth Observation Companies by Ownership Structure and Year of Founding**

| | Applications | CAS/ University Spin-off | Established Private Company | SOE Subsidiary | Start-up |
|---|---|---|---|---|---|
| 21AT | Multispectral | | 1992 | | |
| Zhuhai Orbita | Hyperspectral and Video | | 2000 | | |
| HEAD Aerospace Group | Aiming for Automatic Identification System (AIS) | | 2007 | | |
| Space View | Multispectral | | | 2012 | |
| Chang Guang Satellite Technology | Video | 2014 | | | |
| Hangsheng Satellite | Aiming for Video and AIS | 2015 | | | |
| Qiansheng Exploration | Aiming for Multispectral, Hyperspectral, and SAR | | | | 2017 |
| ADASpace | Aiming for an "AI" constellation | | | | 2018 |

Source: STPI Database

The four most prominent commercial remote sensing companies are Twenty-First Aerospace Technology (21AT), Chang Guang Satellite Technology, Space View, and Zhuhai Orbita. All four companies were established before 2014,[36] although they were not heavily engaged in commercial remote sensing activities prior to that year. These companies all have several remote sensing satellites operating in orbit; they all provide remote sensing imagery and services for their customers. With the exception of 21AT, they all plan to launch a constellation of LEO remote sensing small satellites. The constellations are likely to consist of approximately 30 satellites, although the full constellation for Chang Guang is to consist of 138 satellites (Euroconsult 2018; "长光卫星技术有限公司" n.d.; Xinhua 2018a; Jones 2018e; CityofZhuhai.com 2018). All the satellites are LEO small satellites: the highest altitude for any of the satellites is 650 kilometers and the heaviest satellite is 450 kg. The satellites either capture multispectral images, hyperspectral images, or video. As of April 2019, Chang Guang had 12 satellites in orbit in its Jilin-1 constellation, the most satellites of any company (Clark 2019a). None of the current satellites in orbit have synthetic aperture radar (SAR) capabilities, but a few companies are planning on launching satellites with SAR capabilities.

[36] Chang Guang was incorporated in 2014, but it has existed as part of Changchun Institute of Optics, Fine Mechanics, and Physics of CAS since 2005, producing satellite components for the government and CAS (Expert interview, East Money News 2018).

Only Chang Guang has manufactured its own remote sensing satellites; the company was originally in satellite component manufacturing ("长光卫星技术有限公司" n.d., CCTV 中文国际, n. d. ). Surrey Satellite Technology Ltd (SSTL) manufactures satellites for 21AT, which 21AT leases, rather than owns, due to export restrictions (SSTL 2018). Zhuhai Orbita contracted the Beijing Institute of Space Mechanics and Electricity to build its satellites (Cao 2018). As a CASC subsidiary, Space View operates the CASC SuperView (GaoJing) constellation, which was manufactured by CAST (Zhao 2016b). Space View also distributes images from several Chinese government satellites located outside of Chinese territories. Two commercial satellite manufacturers, MinoSpace and Spacety, also produce remote sensing satellites, but they do not plan to launch their own remote sensing satellites or engage in the remote sensing industry (Euroconsult 2018; Spacety n.d.; 微纳星空 n.d.)

Other commercial remote sensing companies have either launched a test satellite or do not yet have any satellites in orbit. According to their company websites, they plan to construct constellations of approximately 20–30 satellites for various remote sensing applications in LEO over the next 3 to 5 years. As the commercial satellite manufacturers and commercial TT&C service providers become more mature, these new remote sensing companies may outsource their manufacturing and operations to other commercial companies. One of them, ADAspace, has already contracted with Spacety to manufacture its satellites (ADAspace n.d.; Spacety n.d.)

## 3. Future Market Potential

Fewer commercial companies engage in remote sensing activities than in the other major commercial space activities. More independent start-ups appear to be involved in satellite communications than other major satellite sectors. Our interviewees suggested that the market potential of the remote sensing satellite sector is smaller than the satellite communications sector in China, as it is for the global space market. Interviews revealed a few of the reasons that may limit new entrants to the remote sensing market in China.

The four most advanced commercial remote sensing companies mentioned above are more mature than the independent start-ups that were established in late 2015 and early 2016. Zhuhai Orbita and 21AT were established in the early 2000s. Chang Guang and Space View both have access to more resources given their close connections to CAS and CASC, respectively. As a result, the domestic remote sensing market may already be saturated, even though it is only 5 years old, discouraging other start-ups from engaging in remote sensing satellite activities.

Many interviewees believe there is less room for creative innovation and more technological barriers to entry for recently established satellite companies in remote sensing than in the telecommunications industry. Most of the innovation in the remote

sensing industry comes from generating new applications from remote sensing data, which fall under downstream remote sensing data analytics. Most satellite companies do not seem to focus on developing their analytics capabilities, although many may offer limited analytics services. The satellite remote sensing industry companies compete on a small number of capabilities (e.g., resolution and the swath of satellites). Most commercial start-ups do not have the technology or the resources to compete with the more advanced companies, deterring them from entering this industry.

Commercial space companies are likely to have access to only a limited customer base for sales of remote sensing data. Similar to other countries, government agencies are the main purchasers of remote sensing data in China. However, the Chinese central government already has many remote sensing satellites, built and operated by Siwei, a large SOE owned by CASC. The Chinese government produces its own remote sensing products (Euroconsult 2018). Despite the central government's remote sensing activities, according to interviews, provincial and municipal governments may be unable to access remote sensing data from central government departments, so some government entities may be forced to use commercial companies for remote sensing needs.

This limited market is unlikely to be able to support more than a few companies. If the market is to expand, the Chinese central government would have to pursue policies similar to those of the United States regarding commercial remote sensing. It would have to choose to purchase remote sensing products from commercial sources in order to grow and support its commercial remote sensing industry. However, this is unlikely to happen because the government historically purchases all its goods and services from SOEs and established government suppliers.

The other major customer base for remote sensing data are downstream analytics companies. Our interviewees emphasized that the downstream market will determine the viability of the commercial remote sensing industry. Most Chinese remote sensing data analytics companies currently rely on free data from foreign government satellites, such as Landsat, as they are unable to access Chinese government remote sensing data. Chinese remote sensing companies may be able to sell imagery to these companies, especially if they are able to offer higher frequency imaging, even if the images are lower resolution. Some satellite remote sensing companies are trying to sell remote sensing imagery directly to the public, but consumer demand for such images is currently small (Chang Guang Data Email n.d.). As many of the remote sensing companies are currently focused on imaging, not analytics, this sector will rely on companies to purchase their data and transform the data into relevant products for other businesses and consumers.

Despite these limitations, some market factors may favor satellite remote sensing over other means of collecting remote sensing information. According to interviews, drones are prohibited from flying at altitudes over 1,000 meters in China. Consequently, satellites are one of the only ways of capturing wide-field remote sensing data. For industries that require

remote sensing information for broad areas, satellite remote sensing companies are the only supplier. Ultimately, even if remote sensing companies are able to offer exclusive data products, the demand for their images will depend on uncertain downstream demand from several sectors.

## E. Satellite Navigation

Although primarily the domain of the government-run Beidou system, STPI found seven commercial companies that plan to provide satellite navigation services from their own platforms. Two companies, CASC Hongyan and Future Navigation, plan to launch commercial constellations that will supplement Beidou's signal to increase GNSS accuracy. Both CASC Hongyan and Future Navigation have launched technology demonstration satellites.

As noted above, several satellite communications operators offer some satellite navigation services as a supplement to their primary communications markets. STPI identified three companies that have discussed offering satellite-based Automatic Identification System services on their IoT communications constellations to improve maritime navigation and hazard avoidance. Future Navigation is the only company STPI identified that plans to operate solely in the satellite navigation sector.

## F. Ground Segment

### 1. Overview

According to interviews, until recently, all ground stations in China were built for government purposes; third parties have been prohibited from using these government ground stations. Although the government has procured ground station equipment from foreign companies, it has built and operated its own ground stations (Nyirady 2018). The government provides TT&C services for most satellite operators within China, as the government has owned most satellites. With the exception of 21AT, Chinese space companies have only pursued commercial TT&C in the past 2 to 3 years. 21AT is the only older commercial space company that operated its own ground stations.

### 2. Current Status of Commercial Companies

According to our interviews with Chinese space companies, many commercial satellite companies first proposed to engage in all satellite sectors, including satellite manufacturing, operations, ground stations, and downstream applications. Because there was no space infrastructure for commercial use, the first commercial satellite start-ups were unable to outsource any of their activities. As the commercial space industry in China has developed, satellite start-ups realized they do not have the capital to build their own ground stations because the cost of building ground stations in relation to likely revenues from

their small satellite operations would be too large. This has created a demand for outsourcing ground station and TT&C servicing. As such, some start-ups have begun to focus on providing TT&C services to fill this missing segment of the market.

STPI identified 12 companies engaged in the ground station and TT&C service market. According to China space experts, as of March 2019 about 10 companies were developing TT&C services, marketing themselves primarily as TT&C solutions providers. Other companies STPI identified in this segment provide their own ground stations as services, but ground station services are not their primary business. 21AT, for example, owns and operates a ground station in Beijing, and services a few foreign satellites, but ground station services are not its primary business (21AT n.d.).

These TT&C service providers have business models similar to that of Kongsberg Satellite Services (KSAT) and Swedish Space Corporation (SSC). These two companies collaborate with other companies to gain access to ground stations elsewhere in the world. Some of the new Chinese space companies view KSAT and SSC as potential partners.[37] Others plan to construct their own ground stations, viewing KSAT and SSC as competitors rather than as collaborators. Most of the new Chinese companies have either built or plan to build their own ground stations (GuiderStar n.d.). Some Chinese satellite manufacturers also make ground station equipment, which they may sell to these commercial TT&C service providers.

One TT&C service provider has captured 100 percent of the domestic commercial market, servicing 16 commercial satellites in 2018. The company positioned itself as a TT&C service provider early in 2016, giving it the advantage of an early start. It already has four ground stations operating in China, located in the three main corners of the country. The company plans to finish constructing its last ground stations in China this year, and has initiated plans for the construction of ground stations in Europe, Africa, South America, and the South Pacific. Similar to other TT&C service providers, the company has put its ground stations in locations to maximize geographic coverage. Its goal is to own and operate all of its ground stations so as to have full control of its infrastructure, which it believes will give it a competitive advantage.

### 3. Future Market Potential

As of early 2019, these commercial TT&C companies had very few customers, as most of them do not yet have the infrastructure to service satellite companies. Their current customers are mainly the new commercial satellite companies and universities. The customer base for the TT&C industry should grow as commercial satellite companies

[37] Some foreign ground segment providers also view Chinese companies as potential partners and customers. Both SSC and RBC Signals, another ground station provider, attended the 4th China (International) Commercial Aerospace Forum in Wuhan, China in September 2018.

develop and more satellites are launched into orbit. For commercial satellite companies with plans for mega-constellations and global coverage, these TT&C companies could provide access to foreign users. However, the health of the commercial TT&C industry will depend on growth in the commercial satellite industry in China. As a result, these new TT&C start-ups are also targeting foreign customers to grow their customer base.

With plans to construct ground stations all over the world, these commercial TT&C companies would not only provide Chinese customers access to foreign communications markets, but would also provide foreign customers access to the Chinese satellite communications market. Because most foreign TT&C service providers do not have ground stations in China (e.g., KSAT and SSC), these Chinese companies should have an advantage in capturing business from satellite companies that want access to ground stations in China. According to interviewees, the Chinese government will not easily permit foreign companies to build their own ground stations in China. Companies with constellations in LEO will most likely need access to a ground stations in China to service Chinese users, unless their satellites have inter-satellite communication capabilities. Demand for ground stations for Chinese clients would increase business for Chinese space companies in a number of sectors.

## G. Downstream Data Analytics

### 1. Overview

In China, remote sensing data have generally not been made available for private and commercial users in part due to reasons of national security. Prior to the establishment of commercial satellite operators, private companies could only access remote sensing data from non-Chinese sources. Consequently, the Chinese remote sensing data analytics industry is not very developed. Because the government and research centers possess full rights to government satellite data, most data processing and data analyses activities are conducted by dedicated in-house departments. As founders of a remote sensing analytics company stated in an interview, they wanted to work on remote sensing data processing upon graduation, but in the early 2010s there was not a single company in China that specialized in such activity. As a result, they founded one of the first companies dedicated to processing remote sensing data.

### 2. Current Status of Commercial Companies

STPI identified 19 companies that engage in remote sensing data analytics, including a few subsidiaries of SOEs. These companies are primarily downstream service providers.[38] Although many of these companies do not own or operate their own satellites,

[38] STPI defines the downstream sector to include activities in remote sensing, satellite communications, and satellite navigation that transform data and knowledge from space into products and services for

some satellite operators conduct in-house processing of data from their own satellites and sometimes from other satellites as well. For example, Space Eye, a 21AT subsidiary, processes and packages data from the 21AT satellites as well as from the government TH-01 satellite series. According to interviews, commercial start-ups that do not have their own satellites acquire remote sensing data from various sources, seeking the cheapest distributors of imagery on China. This includes many established foreign distributors as well as commercial start-ups in China.

Most of these data analytics start-ups have found some success in agriculture, most notably Jiahe Info and Jiage Tiandi (Moss 2018). They currently provide data to agricultural insurance companies on an expedited timeline, allowing insurers to quickly evaluate damages after natural disasters. Chang Guang has also provided such services to insurance companies (CCTV 2018a). These remote sensing analytics companies also provide crop-monitoring services for farmers, informing them when and where to irrigate, fertilize, or harvest.

**Table 7. Data Analytics Companies by Ownership Structure and Founding Dates**

| | CAS/University Spin-off | Established Private Company | SOE Subsidiary | Start-up |
|---|---|---|---|---|
| Qiansheng Exploration | | | | 2017 |
| Chang Guang Satellite Technology | 2014 | | | |
| Zhuhai Orbita | | 2000 | | |
| ADASpace | | | | 2018 |
| 21AT | | 1992 | | |
| Space View | | | 2012 | |
| Space-One Aerospace Technology | | 2007 | | |
| Beidou Aerospace Group | 2011 | | | |
| SSTC | | | 1986 | |
| Jiahe Info | | | | 2013 |
| GAGO Inc. | | | | 2018 |
| Piesat | | | | 2008 |
| Rapisense | | | | 2016 |
| Siwei Star | | | 2016 | |

end users. The global downstream space market accounts for most of the revenue in the satellite value chain (Euroconsult 2018; Strada and Sasanelli 2018).

| | CAS/University Spin-off | Established Private Company | SOE Subsidiary | Start-up |
|---|---|---|---|---|
| Space Eye | | 2005 | | |
| Beijing Spot Image | | 1998 | | |
| TITAN Group | | | 2001 | |
| Guangdong Beidou Aerospace Science and Technology Co., LTD | 2013 | | | |

### 3. Future Market Potential

The remote sensing data analytics industry is in its infancy in China. Many companies do not appear to have a good grasp on demand for remote sensing applications from Chinese businesses and industries outside of agriculture. These start-ups look towards U.S. companies, such as Planet, for business and innovation strategies. Many currently lose money because the costs of acquiring remote sensing imagery in China are still high. As the commercial remote sensing operating industry develops, remote sensing imagery costs should fall and imagery quality improve, according to experts, allowing analytics companies to experiment and develop more applications. These companies will then be able to attract more customers, opening up new markets for such data. Many interviewees argued that the future of commercial remote sensing satellite manufacturing and operations hinges on the ability of the downstream industry to develop and expand its customer base.

These Chinese downstream start-ups do not have the technical expertise to compete with foreign companies on international markets. However, they do not face competition from foreign companies on the Chinese market. Competition among the Chinese start-ups on the domestic market is strong. One interviewee noted that his company is constantly developing new software to increase efficiency in data processing in order to remain competitive with other similar companies in China.

## H. Other Areas

STPI identified several companies engaged in activities tangential to space, most notably education. Several STEM education companies, such as Aerospace Maker and SpaceD, specialize in space curriculum and extracurricular space activities, including building educational satellites. Commsat and Satellite Herd also engage in education for the promotional value and to generate short-term revenues. Most of these companies provide various courses about space for middle school and high school science classrooms. One of the most popular courses is a satellite course where students build a CanSat or a CubeSat as a final project. Some of these satellites built by students have even been

launched (Aerospace Maker). Commsat provides students an opportunity to send and receive signals through its Young Pioneer-1 satellite, an educational CubeSat launched in early 2018. Young Pioneer-1 was the first satellite Commsat launched, which used it as a test satellite for the communications company (Xinhua 2018b). Experts have noted that these space educational activities help promote space and engage a new generation with the space industry. Citizens, in turn, are likely to become more supportive of China's commercial space industry after they are exposed to these activities.

Among other space activities, one company, Origin Space, proposes to engage in asteroid mining, and another, Space Vision, has plans for space tourism. There is very little information available on either of these companies.

# 5. Assessment of China's Emerging Commercial Space Sector

In this chapter, STPI builds on the preceding chapters and evaluates the strengths of and challenges facing China's emerging commercial space sector. We highlight the unique characteristics of the Chinese commercial space sector that are likely to shape it in the coming years, and discuss potential developments in the industry over the next 5 years.

## A. Strengths

### 1. Government's Drive to Reduce China's Reliance on Foreign Technologies

Because of long-standing U.S. restrictions on access to space technologies, China's space industry has been forced to develop its own technologies and capabilities. Consequently, China's commercial space sector may not suffer the same vulnerabilities to foreign restrictions going forward as other high-technology sectors.

Interviewees from many of the companies with whom we spoke indicated that China's space industry (and hence its support for the commercial space sector) would not be as strong or as independent if it relied more on foreign space technologies. One of the interviewees noted that "U.S. International Traffic in Arms Regulations (ITAR) restrictions helped China in the end because it forced us to develop our own capabilities and technologies. If there weren't ITAR restrictions, China [probably] would not be so far advanced in its own capabilities and technologies."

To make the same point differently, another interviewee pointed to the history of the aviation sector, and noted that "[if] Boeing didn't sell to China, China would have created a much better airplane a long time ago. But because Chinese airlines have been able to purchase aircrafts from the U.S., China only developed a similarly-sized airplane last year."

While China's overall space capabilities still lag behind those of the United States, China has built its own capabilities, and does not rely on foreign technologies. Consequently, China's space sector may be less vulnerable to other countries in the event of changes in foreign relations. This has not been the case in other sectors such as telecommunications. When the U.S. Government banned ZTE from purchasing U.S.-made chips in April 2018, it highlighted just how vulnerable China's telecommunications sector is (Knight 2018; White 2018; Fang 2019). Both the telecommunications sector and China's central government will want to prevent a similar situation from happening in the future.

As a result, many believe that the ZTE incident will cause China's chip making industry to progress at a faster rate than it otherwise would have (Knight 2018; White 2018).

China's central government has long been cognizant and wary of the country's dependence on foreign technologies (Liu and Cheng 2011). The push for indigenous innovation was solidified under China's 2006–2020 Medium- and Long-Term National Science and Technology Development Plan in which domestic innovation became an official priority (Liu and Cheng 2011). The Chinese government has already taken steps to reduce exposure to other countries' control of key space infrastructure, such as access to GNSS with the construction of Beidou. This may be repeated in other fields. For example, Chinese concerns about data security abroad may lead the Chinese government to fund or build a Chinese satellite communications constellation, whether owned and operated by an SOE or a private company.

### 2. Political Support from the Government

Since the Chinese government's decision to encourage private investment in certain space activities in 2014, China's commercial space sector has enjoyed both targeted and indirect support from the Chinese government in the form of policy support (e.g., Document 60), financial support from provincial governments, and in-kind technical and facilities support (e.g., land, launch facilities) from national, provincial, and municipal governments, CAS, and the SOEs.

As described in Chapter 2, many major government initiatives have encouraged the government and SOEs to support the development of the overall space industry, which may benefit the commercial space sector. The central government is currently developing a set of space laws to provide regulatory certainty to commercial space companies. However, it has shown no sign of shifting to competitive procurement policies for space missions that would open up sales opportunities for commercial space companies.

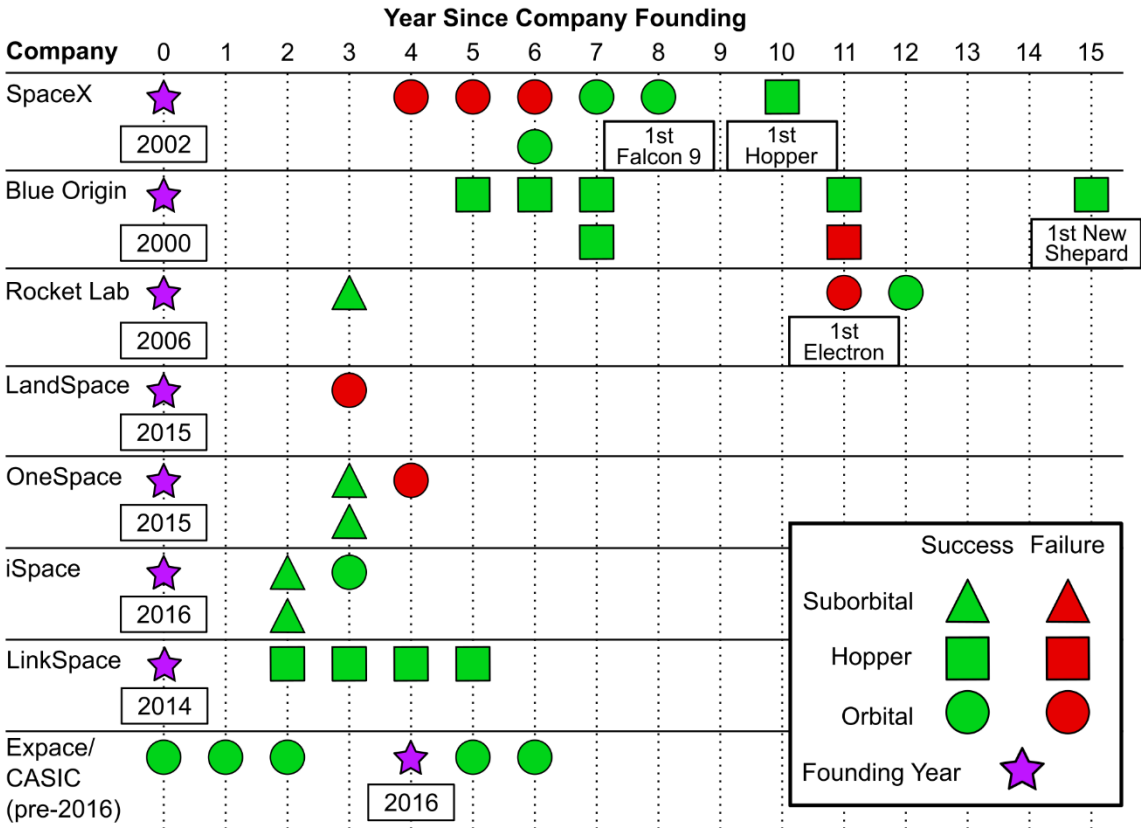
While there is no evidence that this has yet occurred, going forward, the commercial space sector may also benefit from China's civil-military integration policy. SOEs have been encouraged to integrate private companies into military supply chains in an effort to boost innovation and reduce prices, and ensure better civil-military integration. According to Jia Lide, a Director at the Jiuquan Satellite Launch Center, "the launch of private commercial rockets from the center is a concrete embodiment of the commercialization of China's aerospace industry, demonstrating the future strategy of our country's space development."

### 3. Being a Second Mover

Many of the Chinese companies that have been established in the last several years base their business models on those of companies in the United States or Europe that have

been successful, as shown by the few space companies in China who are trying to engage in activities that do not have a successful counterpart in the West (e.g., asteroid mining). By emulating first movers in the West, Chinese companies may be able to reduce the overall level of risk they take. By deliberately choosing to follow rather than lead, these companies may be able to focus on making secondary innovations (e.g., process, production, marketing) that ultimately may make them more successful than their Western counterparts, a strategy that has worked to China's advantage in many sectors such as IT, manufacturing, and high-speed railroad equipment (Wu et al. 2006; Breznitz and Murphree 2012; Chan 2017; Xinhua 2017). As an employee of one company noted, once China sees the tide, "China is able to help push the tide in a certain direction and we're able to make great headway in a short amount of time." Another company noted that once China sees that an industry is expanding, then "we can make improvements on this to meet our market needs or to improve its overall performance or services. We can see what works and then can improve upon it and mass market."

Interviewees from several companies noted that they are waiting for U.S. commercial space companies to figure out and understand the needs of the market: who the potential customers are, what downstream applications are feasible, and which business models can be successful. Chinese commercial space companies are reducing risk by carefully watching the advances and missteps of American companies. In an interview, the employee of a satellite company noted that "[China] has copycat innovation, and not bold innovation. We follow the U.S. rather than lead in innovation…most companies in China are risk-averse." Figure 8 shows how quickly Chinese launch companies have been able to move as compared with the U.S. based first movers SpaceX and Blue Origin.




Note: CASIC launched three Kuaizhou rockets prior to founding Expace in 2016

**Figure 8. Milestones Achieved by Launch Companies by Number of Years after Founding**

Several companies noted that the decision by China's central government to encourage private investment in the space sector likely originated from seeing the successes that U.S. space companies have had over the last decade. Similarly, Chinese VC firms are funding commercial space companies because they see Western VC firms investing in this sector. An employee of one company whom STPI interviewed stated that "VC funders in China are all relatively young. They don't have the experience or wisdom to figure out what to fund so a lot are looking to the U.S. to see what [Western] VCs are funding in the U.S. and then they fund similar projects in China. For commercial space, Chinese VCs see that companies like SpaceX has received a lot of VC funding and they feel comfortable with investing in similar things in China."

However, being a second mover in the commercial space industry also creates a weakness in terms of spectrum allocation. Representatives of several Chinese companies expressed concerned that they will be unable to obtain the spectrum they need because the large international companies, such as OneWeb, Telesat, Iridium and SpaceX (and CASC and CASIC), have already claimed the most desirable spectrum bands for satellite communications, forcing Chinese commercial companies to use the less desirable V and Q bands, which are more expensive to operate in. Competing with already established

companies for potentially limited markets will be difficult. Representatives of companies similarly worry about lost opportunities in other areas, principally loss of markets because the first mover took the "low hanging fruit" and the best customers.

### 4. Ability to Draw on State Space Capabilities

Over the past five decades, China has developed many independent space technologies and capabilities for its military, civil, and commercial space programs. Almost half of the companies interviewed explicitly noted this institutional expertise as a strength. Launch companies focused on commercial markets have used technical support from CASC and facilities in Xi'an to integrate payloads with their rockets. Some of the R&D that has led to the products of the commercial space sector, especially at early stages, appears to have been at least indirectly funded by the government through CAS and SOEs prior to being transferred to the commercial space companies.

Although China's traditional space supplier industry has been slow to reduce the cost of components, market forces are changing these attitudes. In a public presentation, the CEO of Commsat said that when Commsat started, traditional suppliers, such as CAS and some SOE subsidiaries, were not paying attention to the needs of start-ups because purchases from start-ups were small. A traditional manufacturer of satellite components noted in an interview that it only sold to SOEs because new commercial space companies were unable to afford its products. This state of affairs has changed as some start-ups have demonstrated to CAS that they pay more quickly than SOEs, and that the value of their purchases is likely to increase. Some CAS academies have set up teams dedicated to serving commercial companies at price points that commercial companies can afford, even if they are not as high in quality as the components used by SOEs.

### 5. Ability to Draw on Broader Manufacturing Capabilities

China is one of the largest manufacturing countries in the world of consumer electronics, telecommunications equipment, solar panels, and high-speed railcars and locomotives, among other items. It has a thriving, internationally competitive, and innovative (especially on cost) high technology manufacturing sector. It is home to a large number of skilled manufacturers that can meet a variety of price points. In addition to leveraging SOE supply chains and capabilities, the emerging Chinese space sector can leverage the broader Chinese manufacturing sector, which is able to move quickly to scale production while remaining cost competitive. In a short CCTV documentary on OneSpace, company representatives noted that they were able to source components from the civil *aviation* manufacturing industry, as opposed to traditional space technology suppliers, due to that industry's ability to meet their needs at lower cost (CCTV 2018b).

### 6. Access to a Large, Young, Well-Trained Workforce

During the course of developing its domestic space capabilities, China has built up its space infrastructure and human capital, both of which can be leveraged by Chinese commercial space companies. China has a robust technical space work force that has been educated and trained domestically at SOEs, CAS, and Chinese universities. Many commercial start-ups rely on the experience of this existing workforce for their own R&D. Several interviewees noted that their companies do not hire recent graduates, but prefer to hire people with 4 to 5 years of experience in the space sector especially SOEs (but also internationally).

Several companies noted that one strength of China's space sector is that its workforce is relatively young compared to its Western counterparts. One subject matter expert observed that at international space conferences or business meetings, the average age of the Americans appears to be 50 or older, while those from China are in their 30s. The consensus among our interviewees was that because commercial space is such a nascent sector, it needs young, innovative thinkers who are willing to work long hours and embrace the start-up culture. One employee of a state-backed company with whom we spoke stated that his company hires young talent as part of its strategy because (he felt) older generations may not be as suited to thinking creatively as those who are younger.

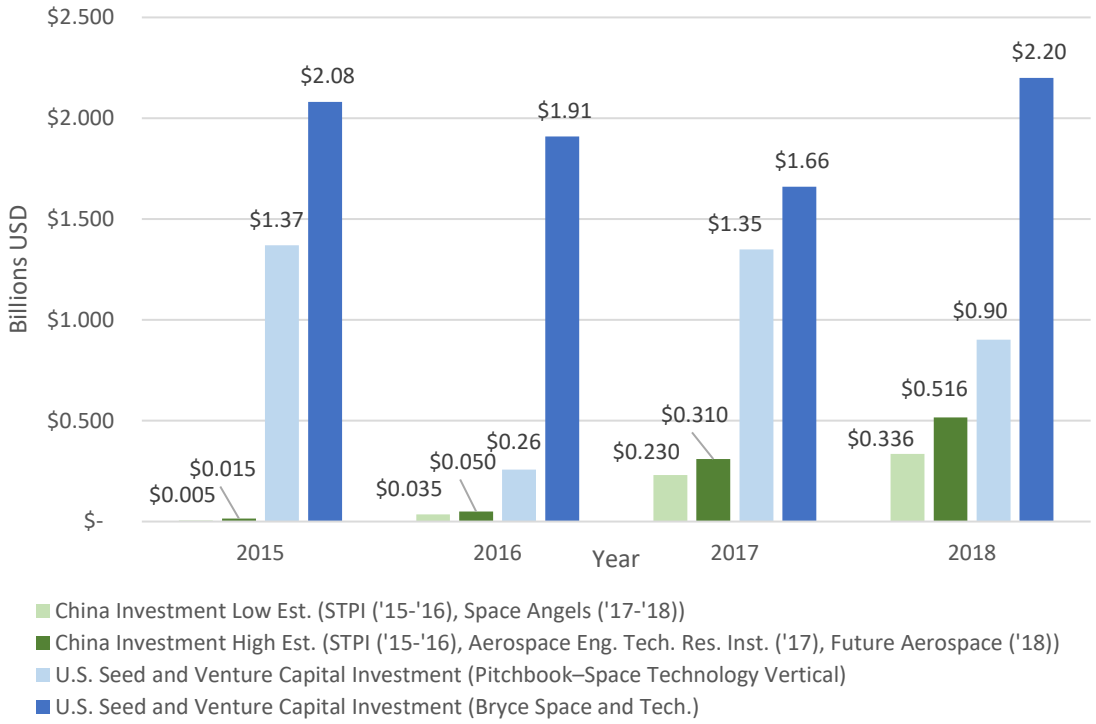
Interviewees also noted that many Chinese space companies (and China at large) had a 9-9-6 work culture where employees work long work days (9-9-6 refers to a work that goes from 9 am to 9 pm, 6 days a week). Some in China believe that working these long hours makes China's commercial space sector more productive, although one could argue employees in the United States work just as hard or even harder. Such a work culture may also lead to employees burning out or quitting.

### 7. Availability of Capital

Over the last several decades, Chinese venture capitalists have invested in China's high-technology sectors. As described in Chapter 3, VC companies have begun to invest in the space sector, contributing to the large influx of capital, especially starting in 2015.[39] Chinese space companies were the recipients of one of the largest shares of global investments in space in 2018 (Space Angels 2019), although Chinese investment in space remains well below the amount of money invested in U.S. space companies (Figure 9). According to Wu Shufan, the founder of satellite-manufacturing start-up MinoSpace "Chinese economic growth has been so fast and in the past two years space has gotten into what we call the 'wind window'. … And if you are in the wind window, even a pig can fly" (de Selding 2019).

[39] Overall, Chinese VC investment in start-ups by the last quarter of 2018 was $94 billion, about the same as the United States' $92 billion (Rowley 2018).

Investments in the Chinese space sector have continued to rise each year over the last 4 years. Despite this, Chinese space entrepreneurs have indicated a winter of capital, as described in Chapter 3.C.3, which may indicate that funding is available, but is only going to certain companies. VC investments in some space sectors, such as launch, are coalescing around a smaller number of companies, suggesting that these companies are the most likely to survive. These venture capitalists can help commercial space start-ups successfully navigate Chinese (and potentially foreign) markets. A knowledgeable group of venture capitalists can also help weed out underperforming companies.




Note: STPI estimated the high and low ranges for 2014–2016 by using known investment figures for the eight companies with public deals during this time period and extrapolating those figures to other commercial space companies that existed concurrently. Chinese investment estimates are discussed in Section 3.C.

**Figure 9. Chinese Venture Capital in Space as Compared to the United States – Investment by Year (2014–2018)**

Despite growing domestic VC, there is high interest among commercial companies to receive funding from foreign entities (especially now that they are allowed to accept foreign funding, as discussed in Chapter 2). As a representative of one company noted, "foreign VCs bring more than just money, they also bring access to additional resources like connections to other space companies that are also funded by the same VC, knowledge about the regulations and laws, etc. of the country in which the VC is based in [which

would be helpful for a Chinese company wishing to enter that foreign market]. This is as or more valuable than the money itself."

## 8. A Culture of "Scrappy" Entrepreneurship

Several representatives of commercial space companies noted during interviews that, because they need to generate revenue over the short-term to keep their businesses afloat, they are engaged in activities that differ from those they plan to produce according to their long-term ambitions. Although engaging in these activities may delay companies from achieving their ultimate goals, it does provide a steady stream of revenues, and can give investors confidence that companies will start making profits in the short-term, something that many start-up space companies in the West have historically struggled to do. Companies are taking a variety of approaches to generating revenues in the short-term: some are selling space-related products such as shipping container tracking systems; others are selling education materials; still others are selling satellite components to established companies.

For example, one Chinese company is planning to provide narrowband IoT services using its own LEO constellation. The company currently only has test satellites in space and no customers. While the company is in the R&D phase of testing and manufacturing its own satellites, it is generating revenue by selling CubeSat payloads on its test satellites. Company representatives noted that the payloads on its test satellites were sold to different companies or individuals who were using CubeSats to increase their brand image or for purposes of public relations. Another source of short-term revenue for this company comes from developing space-related education curriculum. The curriculum is currently taught in dozens of schools around China, and accounts for approximately 60 to 70 percent of the company's total revenues. Interviewees noted that education is a stable business in China, and that the company may continue its education business, either in an integrated way or spun-off as a separate company, even after its satellite businesses generate revenue.

Other companies have developed different models to generate near-term revenues. Chinese media report that in light of the number of schools in China (e.g., 70,000 high schools), Spacety has made education its principal near-term market. For example, upon its founding, it planned to launch an optical telescope (calling it the "Mini Hubble") and then charge amateur scientists 2,000–3,000 RMB (~$275-$400) to use it on an hourly basis.[40] It plans to expand into commercial services only later. Similarly, one company that we spoke with will be selling satellite components to other satellite companies until it is able to launch and operate its own constellation.

[40] It is unclear if the mission was ever launched. All articles about this service, such as Jing 2017 and Long and Yu 2017, are from 2017.

Commercial space companies are trying to innovate on cost to reduce the price of their products by turning to non-traditional suppliers. In an interview on the Chinese news outlet CCTV, OneSpace noted that it was able to source many of its components from bulk production by non-traditional space suppliers, such as aircraft component manufacturers, resulting in a reduction in cost (CCTV 2018b). Employees of a major satellite company with whom we spoke noted that the first two satellites the company made were both costly and time-intensive; they took approximately 2 years each to build. Company representatives stated that they were ordering from traditional satellite component suppliers, and buying custom-made parts. By switching to mass-produced, commercially available components, the company reported that it has been able to decrease its production time by up to half and reduce its costs by two-thirds.

Chinese commercial space companies have also been able to reduce costs by relaxing standards on quality assurance and quality control as compared to traditional space companies. Several companies noted that one of the reasons that costs are so high for traditional satellites is that they need to have close to 100 percent reliability. The amount of testing and iterative processing needed to maintain that level of quality assurance and quality control drives up costs and production time. By trading off reliability with risk, companies note that they are able to cut down costs significantly. As employees of one SOE-backed company with whom we spoke noted, "for new space companies, if we're able, for example, to reach 90 percent reliability but it cuts our costs down by 50 percent, then that's acceptable to us. By having our costs cut by half, we can send up two satellites. That makes sense for commercial space but not for traditional government space activities."

### 9. Potentially Large Domestic Market Unencumbered by Foreign Competitors

Approximately half the companies interviewed noted that a major strength of China's commercial space sector is that China has a large domestic market. In particular, they felt that demand from Chinese households and businesses for telecommunications and remote sensing data, the two major areas in which Chinese commercial space companies hope to operate, could be large. As of 2018, China had over 800 million internet users, with 98 percent using mobile devices to access the internet (McCarthy 2018); in 2017, 42 percent of China's population (roughly 575 million people) lived in rural areas (World Bank 2018). China is rapidly introducing IoT devices in both urban and rural areas.[41] China has large aviation and maritime industries with growing data and communication needs. China's

[41] China has access to some unusually large markets. For example, China's mobile payment market (at $15.4 trillion) is more than 40 times the U.S. market ($377 billion). Market studies claim that the Chinese IOT market may become larger than the rest of the world's. If the emerging space sector can access this market, it will benefit from this substantial, domestic source of demand for their products.

large agricultural and construction industries could provide significant sources of demand for remote sensing images and data analytics.

Due to Chinese government regulations, foreign companies may have difficulties operating in these sectors, potentially allowing Chinese start-ups to capture these markets. Although space markets are not explicitly restricted to domestic companies, they can be effectively restricted by government policies that prioritize buying images from domestic companies. Furthermore, the domestic space market is predicted to be large. Chinese experts believe that domestic space markets will be about $800 RMB ($114 million) by 2020 (Li 2019). Without divulging its methodology, the Chinese think tank FutureAerospace has forecasted that by 2025, China is expected to have about 3,100 commercial satellites; this market could be worth $2 billion (2019b). This is about half the number of small satellites projected globally over this timeframe. Whether Chinese companies will actually launch this number of satellites over the next 5 years is uncertain, especially as many of these companies do not have access to large amounts of capital.

Chinese commercial satellite and launch vehicle component manufacturers and integrators may be able to sell to SOEs. The literature claims that the Chinese government has encouraged SOEs to include commercial space companies in their supply chains. Although some satellite manufacturing services have been provided by foreign companies such as SSTL, trends in recent years suggest that China is moving to solely procuring satellites domestically. Selling services that have historically been provided by companies with close ties to the government, such as mobile services, are likely to be restricted to domestic companies. Chinese satellite companies face export control laws that do not allow satellites to be launched on foreign providers without approval, reserving this market for domestic launch providers.

Approximately half the companies interviewed noted that two strengths of China's commercial space sector are that China has a large domestic market, and that the sector can leverage China's established manufacturing infrastructure. According to one interviewee, "[there is] a huge market in China and we have lots of manufacturing experience built up over the past few decades and we have all aspects of the supply chain within China so we can cut down production costs. This is a strength for China."

By having exclusive access to the potentially large domestic market, Chinese space companies may be able to establish themselves and their products prior to competing with large, established foreign space companies. Many of the interviewees pointed to high-speed railroad equipment and app-based services (e.g., bikesharing) where the market was first proven domestically and then expanded abroad as models for the commercial space sector. IoT could be another market that follows this trend.

### 10. Potential Sources of Growth in Foreign Markets

Interviews with Chinese commercial space companies revealed that, of those that have actual products on the market or tangible services for sale, few had customers outside of China. Companies indicated that they aspire to expand beyond China, but because China's commercial space sector is nascent, they are prioritizing finding their footing in the domestic market first. Companies also indicated that when they eventually expand to foreign markets, they will prioritize developing countries that participate in BRI rather than Western markets because they are likely to be at a competitive disadvantage compared to more mature Western companies in Western markets. Furthermore, they are more likely to encounter protectionist policies to shield domestic space companies from foreign competition in Western countries. Western countries are also likely to be more susceptible to the United States' geopolitical influence over its allies in their stances towards products from China's commercial space industry (Chatzky 2019).

Chinese commercial space companies view developing countries that participate in BRI as being more open and willing to buy from Chinese commercial space companies. These countries tend to have less antagonistic views and policies towards China, may have already opened their doors to China's state-owned space industry, and may have already benefited economically from being a part of the BRI. China's state-owned space industry has already increased its presence and sales in Africa and Latin America over the past two decades. For example, Chinese SOEs have collaborated with Brazil on several remote sensing satellites. China has targeted and attracted developing countries to become consumers of its space program by offering low cost or free products and services, providing financing for governments in need, financing and building massive infrastructure development projects in exchange for market access for the use and mining of natural resources, and land lease agreements. Although none of the sales of space products thus far are from China's commercial space sector, the growing presence of China's state-owned space industry in these countries may have indirectly opened the doors for China's commercial space industry to enter these developing markets in the future. As one interviewee noted, "BRI has been very helpful for opening up potential markets for Chinese commercial space companies. These countries really did not have much of a choice if they wanted space assets or access before. Everything was predominantly from the U.S. and it was costly for these countries. But now Chinese companies present an option for these countries."

## B. Weaknesses

### 1. Lack of Business Acumen

The biggest challenge facing China's commercial space sector that emerged from our research and interviews is that the Chinese commercial space industry does not have a clear

understanding of the market. In a public presentation, Commsat's CEO warned of the dangers of companies primarily focusing on R&D, and not enough on profitability and meeting customer needs. He stated that the Chinese commercial space sector "must understand the demand of clients first, then we can talk about what services should be provided." He also noted that his own personal philosophy is to "find out what [Commsat's] clients need in terms of service and products, and then [Commsat] can go look for the appropriate services and products to provide."

Similarly, the CEO of OneSpace noted that his largest concern for China's commercial space sector was that it would repeat the mistakes of other failed sectors, such as focusing only on technology development and not profitability, nor identifying market demand for products and services developed.

The same sentiments were echoed in company interviews. One employee of a satellite company with whom we spoke stated that "the biggest challenge [to China's commercial space sector] is that there is no real understanding of market needs for satellites. It is easy to send satellites into orbit; the real question is 'what are they doing once they're up there?' Finding possible clients, figuring out what [the satellites] are going to be used for—these are the difficult questions. Market forces and needs are not clear on these issues so this is the biggest challenge."

A representative of a satellite manufacturing company noted that a lack of understanding of market needs is actually hindering China's commercial space sector. As an upstream provider of satellites, the company depends on downstream demand. The representative "hopes the downstream companies can figure out what they need so companies like [ours] can offer the right products."

The lack of clear understanding of market needs also concerned launch companies. A representative of one launch company with whom we spoke stated that "there are a lot of companies in China focusing on small satellites and they can launch a lot of satellites and constellations quickly, but the bigger question is "who's going to be their customers?" "What will be the applications of these satellites?" [Chinese] satellite companies need to know their market. [Our company] is here to serve the increasing number of satellite companies and our [company's] future depends on [the satellite companies] figuring out their market because once they do, then they will need more launches. But if they don't figure out their market, then [the launch companies] will probably be badly affected."

Chinese commercial space companies appear to have taken heed from the missteps of the housing sector, which fully embraced the "if you build it, they will come" concept. This approach has resulted in a large number of ghost cities throughout China (Shepard 2016; Fong 2018; McMahon 2018; Panckhurst and Dong 2018; Shelton et al. 2018). Companies are beginning to recognize that if China's commercial space sector is to succeed, it is crucial they have a clear understanding of what the market needs, rather than developing

products and services in the hope that customers will eventually want them. Even though the companies interviewed pinpointed this challenge, none offered a solution on how to better understand market and customer needs.

## 2. Challenges with Chinese Venture Capital

While VC investment in Chinese commercial space companies is growing, VC levels in China could be up to two orders of magnitude lower as compared with VC investment in the United States (Figure 9).

A number of companies complained of a winter of capital during the first part of 2018, referring to the inability of many companies to attract VC, an apparent sharp departure from preceding years. In interviews conducted in March 2019, when asked about this phrase, company representatives stated that during the first half of 2018, VC firms were hesitant to invest, but since that time companies with strong business plans have been able to attract capital. This suggests that VC firms may have initially saturated the market when private investment in space was first allowed; only more recently have they begun conducting more due diligence on companies' market prospects.

It is not just the lack of VC that companies find to be a challenge. There are signs that VC invested in commercial space companies has also been poorly allocated. State-backed venture capitalists seem to be making more investments in launch groups. A Jilin province-backed VC firm, the Jisheng Asset Management Company, recently invested in a new launch company with no proven technology. The motivation for the investment may have been an effort to bring more high technology jobs to the province. If many state-owned VC firms begin to invest in commercial space, especially when there is unlikely to be enough demand to sustain many companies, a large percentage of these companies will likely go bankrupt, akin to the solar panel market.

A final challenge highlighted by companies that were interviewed is that Chinese VC firms have a shorter investment horizon than do their Western counterparts. An industry insider noted that Chinese VC funding in commercial space typically uses a 3+2 system in which a VC firm guarantees to leave its investment in a company for 3 years with a promise of an additional 2 years, for a total of 5 years. Foreign VCs in China, on the other hand, tend to have longer investment horizons. The industry insider noted that it is common for foreign VCs to use an 8+3, 8+5, or even an 8+7 system when investing in Chinese companies. This means that the minimum time that foreign VCs invest in a company is 11 years, which is more than double what companies can expect from a Chinese VC. Several companies noted that because Chinese VCs operate on a shorter time horizon, the pace that China's commercial space sector is able to develop is hindered.

### 3. Competition with State-Owned Enterprises

Although the potential of China's large domestic market is a strength, it is unclear how many profitable space markets will be accessible to Chinese commercial space companies. Globally, the most profitable markets for satellite services are direct television broadcasts and geostationary telecommunications (SIA 2018). Euroconsult valued China's satellite communication operations and services market at $1.5 billion in 2017, but noted that only a small percentage was generated by commercial companies.[42] Currently, in China, satellite communications are provided by SOEs or their subsidiaries; within the Asia Pacific region, there are established market players and competition is fierce. As APT Satellite (a CASC subsidiary) noted in its 2018 annual report, there was "severe fierce market competition" in the Asia Pacific region for satellite broadcasting and telecommunication satellites due to the oversupply of satellite transponders, which will continue in 2019 (APT Satellite 2019). Other market segments, such as satellite broadband are currently relatively small (SIA 2018). Within the Chinese market, both CASIC and CASC are developing LEO broadband constellations (the Hongyun constellation and the Hongyan constellations, respectively). Linksure, an established private internet service provider, is building another LEO constellation for satellite internet. These incumbents are powerful, and have much more political influence and financial resources than emerging companies.

As a result, few commercial space companies are targeting the GEO satellite communications market in China. Chinese companies noted that they are considering targeting developing countries that participate in BRI in Africa, and Southeast Asia. As the representative of a satellite company noted, "the cost is high to build telecommunications infrastructure in these developing countries but the potential profits are also much higher as well." Representatives of several Chinese commercial space companies noted that few, if any, are thinking about entering developed markets such as the United States or the European Union because Chinese companies are not technologically competitive with their Western counterparts and they face more market restrictions in developed countries. Moreover, in developed countries the market potential, based on the percentage of the population that currently has communications access, is low compared to that of developing countries. An employee of the satellite company provided the following example: "Indonesia has a lot of people, most of whom do not have cell phones yet but it is moving in that direction. On the other hand, the entire country of New Zealand is only a small fraction of Indonesia's population, maybe on par with the number of people in the [Beijing] Haidian district. The potential is so much higher for Indonesia than New Zealand."[43]

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[42] This number excludes maritime services.

[43] This interview is an illustration of the lack of understanding and unrealistic expectations of unsatisfied demand in developing country markets. Cell phone penetration in Indonesia is close to 100 percent, and

Representatives of many companies noted that because the traditional communications market in China is closed to commercial companies, they are considering finding or creating a niche for themselves in remaining markets. During the China (International) Commercial Aerospace Forum in Wuhan in September 2018, communications satellite operators stated they were targeting maritime, aviation, and IoT markets in China. However, the first two markets are already dominated by large foreign companies such as Inmarsat. Although the Chinese government may limit the domestic market to be serviced by Chinese companies, these start-ups are unlikely to have much success penetrating foreign markets.

The market for IoT devices may serve as a source of sales for Chinese commercial space companies. However, most IoT devices are located in cities, so other communication technologies, such as mobile broadband or fiber optics, may capture most of this market. Start-ups that hope to build telecommunications satellites are unlikely to capture a large share of this market. This is likely to remain the case unless the Chinese government relaxes the monopoly of SOEs in the domestic telecommunications market.

Representatives of Chinese commercial space companies commented that the central government is not a customer in the same way that the U.S. Government is for U.S. space companies. Several noted that they sell components to SOEs but to their knowledge, no commercial space company has received big government (central or provincial) contracts on a scale similar to those of SpaceX, Planet, or Spire. As all major government space activities are currently conducted by SOEs, these SOEs are unlikely to willingly cede market share to start-ups. Consequently, government demand for commercial space services is likely to remain low.

Companies did not view the absence of the central government as a primary customer as a weakness. Rather, they noted that this is simply the environment in which they operate, and they are searching for different avenues and markets than start-ups in the United States. Furthermore, when asked about current competition in the commercial space sector, most companies noted that there is not a lot of cutthroat competition. Most companies recognize that not all of the current companies will survive with their current business models, but they are all striving for the success of the sector together.

### 4. Restrictions on Foreign Collaboration and Technologies

Currently, the United States restricts exports of space technologies to China and forbids U.S. companies from using Chinese launch vehicles. In recent years, other spacefaring countries and companies have also become wary of China because of the likelihood that their technologies may be stolen. As a preventive measure, some foreign

smart phone and internet use are rising rapidly. The interviewee's assessment of Indonesia's market was incorrect.

companies have made the decision not to sell their current generation of technologies to Chinese companies.[44] As a consequence, Chinese companies have been unable to access cutting edge space technologies or potential customers for those technologies.

Current U.S. restrictions may be a downside for both Chinese and American companies, however. For instance, one of the companies we interviewed noted that it has been contacted by American companies interested in using the company's services but because of current restrictions, it was unable to provide these services, causing both sides to lose out in the end.

## 5. China's "Brand Problem"

Credibility has been and remains one of the greatest problems facing Chinese companies on foreign markets. In some circles, China has had a reputation for producing and selling cheap, low quality products, and Chinese companies are combating this image as they try to expand their presence abroad. Because Chinese private companies often have close ties with China's central government, there is increased concern, particularly from U.S. buyers (though not as much European ones), that seemingly private Chinese companies may be working for, are a front for, or can be manipulated by China's central government and are, therefore, potential national security concerns (Garsd 2018; Schulze 2019). In other sectors, examples include Chinese telecom company ZTE that pled guilty to violating U.S. sanctions by exporting U.S.-origin items to Iran without obtaining proper export licenses from the U.S. Government (Department of Justice 2017). Huawei, China's biggest telecommunications company, finds itself in a similar situation with evidence that there was governmental interference in the company such as ordering employees to use devices and equipment for spying or to disrupt communications (Price 2019; Toh 2019).

Until China's central government can show that there can be separation between Chinese companies and the central government, and changes in the culture from one that is based on connections and backdoor dealings to one that promotes transparency and openness, Chinese companies, including those in commercial space, are likely to continue to find it difficult to enter some high technology markets in developed countries, particularly if those companies are in sectors that have direct connections to national security. That such a change will occur is likely unrealistic.

A representative of a satellite company with whom we spoke expressed frustration, stating that "Chinese companies suffer from a brand image problem. This is a problem when Chinese companies start expanding to international markets. We may not be looked upon favorably by others because our company is a Chinese company and even though we

[44] This constraint may not be very strict, or may be lip service paid to national policies and U.S. pressures. In the course of this project, we noted that at least three companies in the Denmark, United Kingdom and Italy have signed contracts with Chinese commercial launch providers for launch services.

are completely private and have nothing to do with China's central government, other countries may not believe us. This is something we have to combat and overcome…This is not limited to commercial space companies of course. This is true for all high-tech sectors that could be considered important or are of national security concerns. For us, we're located in Beijing. Outside companies and countries may not trust exactly what our company says it does or believe what our story is."

### 6. Increasing Costs of Labor and Other Workforce Challenges

While Chinese salaries in the space sector remain well below salaries in Western space companies, the cost of labor in China is increasing. Our interviews and searches on Chinese job websites showed that salaries in the space sector in China are lower, but not significantly so, than those in the United States. Salaries for talented Chinese researchers are rising. As noted in Chapter 3, a commercial space company was able to poach a researcher from the Xi'an Aerospace Propulsion Institute by offering a salary that was 10 times his previous salary. Although skilled labor in the commercial space industry in China will likely remain cheaper than in the West for the foreseeable future, somewhat cheaper labor may be insufficient to make the Chinese commercial space sector competitive with that of the West.

Some industry observers with whom we spoke also pointed to looming workforce shortages driven by changing demographics and attractiveness of other industries, such as IT and software development, which is drawing talented students away from aerospace engineering.

### 7. Lack of Regulations

A lack of specific commercial space regulations and policies from the central government was seen as a problem by many companies and subject matter experts. Document 60 is often cited in the West as the impetus for opening up China's commercial space sector (Shiong 2019), but interviews with company representatives indicated that few considered the document as the driving force for the emergence of a commercial space industry in China. Representatives from several companies noted that commercial space companies were already forming prior to the publication of Document 60. The success of companies like SpaceX was more of a motivating factor for the fast development of China's commercial space sector over the past 5 years than Document 60. As a representative from a satellite manufacturing company noted, the company did not form as a result of Document 60. Rather, Document 60 provided the company with support and political cover to develop and expand in directions that they probably could not have before the policy was announced.

Representatives of commercial space companies mentioned that they would like to see the central government issue regulations, policies, and guidelines specific to

commercial space. As discussed in Chapter 2, commercial space companies generally follow regulations and procedures designed for traditional space SOEs, which do not take into consideration the nuances or differences that exist between the traditional and commercial space sectors. As a representative of one satellite company we interviewed noted, because there are no specific policies or regulations for commercial space, "companies may not be able to do something because they don't know what is allowed and what isn't. They might not want to go past this invisible line so they don't push too far. If there are no specific regulations, we don't know where this line is. We want more regulations and policies—it would be easier if we knew what we can or are allowed to do and what we can't or aren't allowed to do. Otherwise, there's too much room for interpretation." However, this may be changing given the recent release of launch regulations for commercial space.

Policy experts noted that one challenge for Chinese commercial space companies is that they have to rely on a myriad of guidelines that were formed for other industries or sectors because there are none that are specific to commercial space. Many of the guidelines followed by commercial space companies are those issued under various policies surrounding China's civil-military integration efforts (Yang 2011; Laskai 2018). As a space law expert noted, there are big differences between military and commercial space activities and the current regulations, policies, and guidelines provide more focus and direction for military applications. The expert also mentioned that this could hinder advances in China's commercial space sector because the overall objectives and aims of policies encouraging civil-military integration are fundamentally different from those needed by the commercial space sector. The space law expert further noted that the central government has held at least one discussion on drafting a "guiding opinions" document for the commercial space industry but to this person's knowledge, there has been no further progress on if or when this policy might be officially published.

As of April 2019, members of the central government had publicly stated that a space law was being worked on and would be published in the next 3 years. However, similar statements have been made during the last several years. China will likely develop a space law in the future, but what it contains, and whether it addresses industry concerns, is unknown.

### 8. Lack of Clarity on Government Support for Commercial subsidiaries of SOEs

Although a number of Chinese commercial space companies are not privately controlled, they operate in commercial markets. Interviews revealed that, historically, SOEs have been supported by the government even when they are not profitable. However, just because a company is backed by the state does not mean it is immune from all market forces. An interview with a SOE-owned company representative revealed that employees of his company believed that if they do not become commercially successful, their parent

SOE would dissolve the company. For new commercial space companies that are backed by SOEs, it is unclear whether the government will allow them to fail or continue to provide funding if the SOE is not profitable.

## C. Chinese Commercial Space Sector in the Future

The future of China's emerging commercial space sector depends on a variety of factors, including the sector's current strengths and weaknesses discussed above. Whether China's commercial space sector succeeds depends on factors such as global trends in space (e.g., the financial success of U.S. and other Western nations' constellations in LEO, and growth in the small satellite market); trends in adjacent sectors (e.g., the proliferation of IoT devices); and other domestic trends (e.g., increasing procurement of launch and space services from private companies by the Chinese government and SOEs). Assuming Chinese companies can continue to raise funds at current or higher levels and continue to make technological progress, four factors are likely to determine the course of the emerging commercial space sector in China: government policies and financial support; size of global markets that China can access; international willingness to trade with China; and developments in adjacent sectors (that would affect space-based activities). Each is discussed briefly in turn.

### 1. Government Policies and Financial Support

The Chinese government has sent mixed signals to the emerging commercial space sector. Some parts of the government have signaled support for a growing commercial space sector in the belief that it will bring more efficiency and innovation to the national space enterprise in addition to contributing to economic growth. Government leaders have encouraged venture capitalists and other high net-worth individuals to invest in the space sector. Many provincial and local governments have embraced commercial space in hopes of attracting high paying jobs to their localities.

Other parts of the government, especially those associated with the space sector and SOEs, have been more cautious and sometimes dismissive of the emerging sector; they regard commercial space as a risk to their own existence. While commercial space companies have benefited from support for R&D and access to government space infrastructure, government contracts with emerging firms have been few and far between (especially with SOEs and the PLA—the major source of demand for space products), although SOEs and military-affiliated institutes have purchased some launch services from commercial providers. Regulations and guidance for the commercial space sector have also been slow in coming.

If China's commercial space companies develop world-class capabilities, SOEs and other traditional space institutions will find it increasingly difficult to dismiss the sector. In that case, the Chinese government is likely to open up government contracts to

commercial providers. If Chinese commercial companies can develop a large domestic market, or obtain preferential access to markets in BRI countries, it may be relatively easy for them to scale up to serve other foreign markets, as Chinese companies have done in other sectors such as telecommunications and consumer electronics.

## 2. Size of Global Markets

Although Chinese space companies may have trouble accessing foreign markets, trends in demand for commercial space products in China are likely to follow trends in the broader space sector. The global space sector is undergoing structural changes based on factors such as reductions in manufacturing costs through the use of standard components, miniaturization, and standardization of manufacturing, especially of satellites but also launch—and a switch to purchases of space services rather than launch vehicles. Several analysts of the global space industry have been predicting rapid growth in space markets, especially for small satellite communication constellations, the technology and application on which Chinese companies have focused. The marketing research firm NSR has forecasted that more than 7,000 small satellites would be launched by 2027, with constellations expected to dominate the market (NSR 2 2019).

In the launch sector, globally over 120 companies are vying to provide launch services for small satellites; it is unlikely that more than five will survive (Werner 2019). In the United States, these companies are focusing on disruptive products (e.g., use of reusable engines), processes (e.g., entirely 3D printed engines) and business models (e.g., rideshares). Chinese companies are watching these trends closely, and will likely emulate whichever approach works best, especially with respect to launch or satellite service provision at low cost.

Even if they were not competing internationally, it is likely that only a handful of launch companies such as Expace, iSpace or LandSpace will survive. Once some entrepreneurial companies have succeeded, it is possible that the Chinese government may provide greater levels of support. However, these companies will likely be required to serve government interests.

In the communications sector, given the high cost of and government restrictions placed on GEO satellites, as well as the high cost of launching a large number of satellites for broadband internet in LEO, Chinese commercial companies to date have focused on LEO constellations for mobile-to-mobile device connections and IoT applications. As with the launch sector, given the lack of business savvy we have observed, most of the companies we identified will likely not survive. Since satellite communications companies are late to the game (compared to their Western counterparts such as OneWeb), they will likely also receive the less desirable bands of the spectrum, which is likely to raise the costs of their operations. The small number of companies that succeed may become competitive with Western firms.

For the remote sensing sector, representatives of most companies with whom we spoke do not believe remote sensing will become a strong domestic market. SOEs are likely to continue to supply aerial and space-based imagery that the Chinese government uses. However, as noted by industry experts during interviews, provincial and municipal governments may not be able to access this imagery, and so may prove to be an important customer of commercial remote sensing companies. Chinese commercial space companies in this market are also looking to foreign markets, but may face tough competition with established providers. Contrary to this view, we argue that as the quality of imagery and analytics improves and costs fall, the Chinese government, especially at the provincial levels, may become increasingly interested in buying remote sensing data and products from the commercial sector. Downstream analytics of imagery data are likely to greatly benefit from advances in other sectors such as AI and machine learning. Assuming Chinese commercial space companies can develop these capabilities, especially if fierce domestic competition makes them more innovative, Chinese companies may outperform Western companies in this market segment.

As the Chinese government will likely not allow foreign companies like KSAT to set up ground stations in China without explicit partnerships such as the one they have with the Israeli firm Gilat, domestic TT&C companies will likely benefit from the protected Chinese market for selling ground station services. This is an area where growth depends on the general growth of the space sector—the more satellites in orbit, the greater the customer base for TT&C companies.

### 3. International Willingness to Trade with China

In the near-term, foreign government controls on exports and imports of Chinese commercial space products, especially those of the United States, are likely to limit opportunities for further development of China's commercial space sector. Current trends suggest U.S. allies may be more open to selling to or buying goods and services from Chinese commercial space companies, although the European Union has taken a much tougher stance with regard to Chinese practices pertaining to export subsidies and theft of intellectual property. Collaboration with Western firms other than those in the United States could strengthen indigenous capabilities. Regardless of actions taken by Western nations, Chinese government efforts to enhance domestic manufacturing capabilities in high-tech sectors may reduce the influence foreign nations' export restrictions could have on Chinese space companies. However, whether Chinese commercial space companies would be able to access the same level of technology from Chinese suppliers as they would from foreign suppliers is unclear. Additionally, this support may further hamper efforts of Chinese companies to sell in Western markets.

Although countries outside North America and the European Union are less likely to restrict the purchase of Chinese space goods and services (provided no export laws are

violated, such as when launching a satellite), rising tensions may make Western businesses and consumers less likely to buy Chinese goods, especially from companies in defense-adjacent markets, such as space.

### 4. Developments in Adjacent Sectors

On the upstream/supply side, innovation and advances that reduce costs in adjacent sectors such as advanced manufacturing, robotics, automation and 3D printing could provide the Chinese space manufacturing sector a competitive advantage in cost. Chinese companies have already demonstrated some unique space capabilities, such as filming the launch of rocket from a satellite. Chinese companies will likely continue to apply advances in technologies from adjacent sectors in innovative ways to the space sector.

On the downstream/demand side, the survival of many Chinese commercial space companies, especially private companies, will depend on finding new space market activities that rely on demand from adjacent sectors. For example, if IoT devices and applications proliferate, the need for data connectivity is likely to increase. However, these markets may be better served by mobile and fiber ground networks, leaving little room for space-based communication networks. Ultimately, the future of China's commercial space sector will likely hinge on the development of demand for space applications from adjacent sectors.

## D. Key Indicators of Interest

Below is a list of some sample indicators for viability of the private commercial space sector examined in this report:

- Chinese government purchases
  - What percentage of payloads launched on private commercial launch vehicles are government payloads versus those of private companies? If the government is a regular customer, this would suggest launch companies may be able to survive if private smallsat companies fail due to insufficient demand. Examining which government departments and organizations launch on private launch vehicles may also provide insight into what parts of the government support commercial space companies.
  - Does the government start purchasing communications services from private companies? If government organizations that had historically relied on SOEs for satellite communications (such as PLA) use a private company, this would indicate confidence in data security.
  - Does the government increase internal sharing of Earth observations data, especially to provincial or municipal governments? If so, this would reduce demand for private images, although it may be mitigated if companies offer

capabilities government does not provide (e.g., high revisit rate) or do so at a significantly lower price point.

  - Do private companies act as suppliers to SOEs? Or are SOEs sourcing from traditional suppliers (e.g., CAS)? If they are sourcing from CAS-backed commercial companies, do these companies have other customers? If not, a lack of other customers may indicate that the sector has not changed much with the introduction of private companies and private capital, aside from ownership structures.
  - Do SOEs purchase or otherwise take over successful private companies? If so, the long-term independence of the space sector from the government may be low.

- Government policy and support
  - Does the government release regulations for commercial space companies? How frequently are they updated? Do regulations ease bureaucratic hurdles or make them more onerous?
  - How do regulations change for private companies and individuals' use of satellite telecommunication services?
  - Does the government open up market sectors that are profitable internationally (e.g., direct-to-home broadcasting) but are currently not open to commercial companies?
  - Are private companies able to access choice spectrum as compared with SOEs?
  - Does the government build a dedicated launch pad for commercial launches or ease barriers to launching from government sites?
  - Do SOEs exit markets that have promising private companies?
- Private market activities
  - Do companies start entering market segments that directly compete with SOEs (e.g., GEO telecommunications, medium and heavy launch)? This may indicate that SOEs are not meeting demand and the state is supportive of commercial efforts, which in turn would be a good sign for private companies that are targeting adjacent sectors.
  - Do private companies start to engage in more traditional satellite telecommunications activities (versus newer activities such as IoT communications)? This would indicate private Chinese companies may be cost competitive with SOE-backed companies, which may indicate they could be internationally competitive.

  - Are private companies launching full constellations? Are they able to replenish constellations?
  - Does the launch cadence for private launch increase over time? Companies have stated they hope to produce 10–30 rockets a year, which is likely technically feasible. Are any of them finding that level of demand?
  - Do private companies buy launch services from CASC, SOE-backed commercial launch companies, or private launch companies equally? Are companies repeat customers of specific launch companies, especially as the company matures? Rides on early launch vehicles may be discounted due to risk as vehicles are verified (we did not see any specific evidence for this, but it does not seem unlikely); rides on SOE-backed vehicles may be subsidized by the state. Repeat customer are more likely to be able to afford the full cost of launch, as satellite companies would need to bring in large amounts of capital to afford multiple launches. This could indicate amount of demand downstream for whatever satellite service they offer.
  - Are Chinese companies establishing ground stations in foreign countries or buying ground station services?
- Financing
  - What private investors of record are investing in commercial companies? This would indicate confidence in these companies and the space sector from groups that are very risk sensitive.
  - What percentage of investment is conducted by public versus private investors? The total amount invested in a sector is likely less important, as government investors seem to be interested in gaining high tech jobs and supporting SOE-backed and CAS-backed companies, meaning they may just invest in companies not likely to succeed. If a large percentage of funding is from public VC, this may indicate long-term instability in the market and may crowd out companies without government subsidies that could have been more successful.
  - Are companies announcing funding rounds on a 6 month to 1-year timeline or updating their investors in their government records frequently? Companies discussed that their funding rounds were shorter than that of American companies, meaning that more frequent rounds of funding would indicate they are meeting milestones set by investors.
  - What do exits from the market look like? Is there consolidation of the market through mergers and acquisitions? Are any companies going out of business? What percentage of companies ultimately exit through an IPO?

  - Do foreign investors (especially U.S. VC) invest in Chinese space companies?

- International
  - Do private companies announce sales to BRI nations?
  - Do they have customers from around the globe? Or are they just partnering with international companies that are looking to make money in Chinese markets? For example, if international companies that sell satellite components or services to satellite operators are signing contracts with Chinese companies, rather than international satellite operators or downstream service providers, this may indicate lack of international demand for Chinese space products.
- Other
  - How is the terrestrial mobile coverage growing? Expanding mobile network coverage in China would reduce demand for satellite-based broadband and IoT communications.
  - Do talented SOE and CAS employees keep moving to the commercial sector? Competition for talented employees is tough; which companies do they go to? Companies that keep technical job postings open for many months may not be attracting good employees, indicating these companies may not viable in the long term. Do talented engineers ever move back to SOEs?
  - Do Chinese companies start producing their own standards or adopting international standards (for example, for activities such as on-orbit servicing, assembly and manufacturing (OSAM)? Any sort of standardization may reduce the costs of production. If Chinese companies are producing standards, this could indicate strong technical capabilities and mature markets.

## E. Conclusion

Most Chinese commercial space companies are only 2 to 3 years old. While they are currently in an embryonic stage and many appear to be struggling, some are slowly gaining their footing. Noting that it took even companies such as SpaceX and Blue Origin a decade or more to become successful, in the next decade, a small number of Chinese commercial space companies could grow to a point where they have critical mass, especially if markets that benefit from the launch and use of small satellites grow rapidly. If this is the case, the Chinese government is likely to take a greater role in ensuring the success—and contribution to the Chinese economy and national security—of the commercial space

sector, as it has done in adjacent sectors such as telecommunications and IT. Policies from the United States and other Western governments probably will not have a large effect on the growth of China's commercial space sector, especially if Chinese commercial space companies are able to survive in domestic markets. Foreign government controls on exports and imports of Chinese space products are already tough, making it unlikely that any other restrictions would heavily hinder the commercial space sector.

If the Chinese government and large SOEs continue to dominate the space sector and constitute the majority of demand for future space applications, the development of the Chinese commercial space sector could follow the model of high-speed railroad equipment. In such a scenario, Chinese companies would likely slowly develop capabilities by first serving the large domestic market, and then expanding internationally using the advantages they would have accumulated on the domestic market with respect to cost and capabilities. This scenario would favor the SOEs, especially the SOE subsidiaries focused on commercial business.

If, on the other hand, space applications of interest to businesses and households (rather than governments) emerge, China can leverage its capabilities in rapid mass production, its skilled space industry workforce, and its ability to quickly develop products—similar to what China has done in telecommunications and IT sectors. Commercial companies would likely fare better under this scenario, as there would be more opportunities for them to capture the market, domestically and internationally.

# Appendix A. List of Chinese Commercial Space Companies

| | English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|---|
| 1. | 21AT | 二十一世纪空间技术应用股份有限公司 | 1992 | Yes | Established private company | Earth observations, ground segment, EO data analytics |
| 2. | AA Engine | 西安空天引擎科技有限公司 | 2016 | Yes | Start-up | Launch, satellite and component manufacturing |
| 3. | ADASpace | 成都国星宇航科技有限公司 | 2018 | Yes | Start-up | Satellite and component manufacturing, Earth observations, EO data analytics |
| 4. | Aerospace Maker | 航天创客(北京)科技有限公司 | 2017 | Yes | Start-up | Other |
| 5. | Aerospace Science and Technology Space Engineering Development Company | 航天科工空间工程发展有限公司 | 2017 | No | SOE subsidiary | Communications |
| 6. | APSTAR | 亚太通信衛星有限公司 | 1994 | Yes | SOE subsidiary | Communications |
| 7. | Astrocruise | 深圳巡天空间技术有限公司 | 2017 | Yes | SOE subsidiary | Satellite and component manufacturing |

| English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|
| 8. Atspace | 精航伟泰测控仪器（北京）有限公司 | 2010 | Yes | SOE subsidiary | Satellite and component manufacturing |
| 9. Beidou Aerospace Group | 北斗航天卫星应用科技集团有限公司 | 2011 | Yes | CAS/university spin-off | EO data analytics |
| 10. Beijing Future Navigation Technology Co. Ltd. / Centispace | 北京未来导航科技有限公司 | 2017 | Yes | Start-up | Satellite navigation |
| 11. Beijing Spot Image | 北京视宝卫星图像有限公司 | 1998 | Yes | Established private company | EO data analytics |
| 12. CASC Hongyan Constellation | 航天科技集团鸿雁系统业务 | 2016 | No | SOE subsidiary | Communications, satellite navigation |
| 13. Chang Guang Satellite Technology (also known as Charming Globe) | 长光卫星技术有限公司 | 2014 | Yes | CAS/university spin-off | Satellite and component manufacturing, Earth observations, EO data analytics |
| 14. China Communication Technology | 华讯方舟科技有限公司 | 2007 | Yes | Established private company | Satellite and component manufacturing, communications |
| 15. China Satellite Communications | 中国卫通集团股份有限公司 | 2001 | No | SOE subsidiary | Communications |
| 16. China Spacesat Technology | 中国东方红卫星股份有限公司 | 1997 | Yes | SOE subsidiary | Satellite and component manufacturing |
| 17. ChinaRocket | 中国长征火箭有限公司 | 1998 | No | SOE subsidiary | Launch |
| 18. CissData | 国科赛思（北京）科技有限公司 | 2015 | Yes | Start-up | Satellite and component manufacturing |

| English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|
| 19. Commsat | 北京九天微星科技发展有限公司 | 2015 | Yes | Start-up | Earth observations, communications, other |
| 20. Deep Blue Space | 北京深蓝航天科技有限公司 | 2016 | Yes | Start-up | Launch |
| 21. Deep Blue Space[45] | 北京深蓝空间遥感技术有限公司 | 2017 | Yes | Start-up | EO data analytics |
| 22. Dragon Drive | 深圳驭龙航天科技有限公司 | 2012 | Yes | Start-up | Launch |
| 23. Enter Space | 吉林进取空间科技有限公司 | 2018 | Yes | Start-up | Launch |
| 24. Expace/CASIC Rocket Technology Company | 航天科工火箭技术有限公司 | 2016 | No | SOE subsidiary | Launch |
| 25. Full Suns Energy | 上海伏日能源科技有限公司 | 2015 | Yes | Start-up | Satellite and component manufacturing |
| 26. GAGO Inc. | 北京佳格天地科技有限公司 | 2018 | Yes | Start-up | EO data analytics |
| 27. Galactic Energy | 北京星河动力航空科技有限公司 | 2018 | Yes | Start-up | Launch |
| 28. Galaxy Space | 银河航天(北京)科技有限公司 | 2016 | Yes | Start-up | Satellite and component manufacturing, Earth observations, communications, satellite navigation |
| 29. GoSpace | 北京金海洋航天科技有限公司 | 2012 | Yes | Start-up | Other |
| 30. Guangdong Beidou Aerospace Science and Technology Co., LTD | 广东北斗航天卫星科技有限公司 | 2013 | Yes | CAS/university spin-off | EO data analytics |
| 31. GuiderStar/SilkroadSAT | 丝路卫星通信有限公司 | 2015 | Yes | Start-up | Ground segment |

[45] There are two companies with the same English name, Deep Blue Space, but they have different Chinese names.

| English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|
| 32. Guodian Gaoke | 北京国电高科科技有限公司 | 2015 | Yes | Start-up | Satellite and component manufacturing, communications, satellite navigation, ground segment |
| 33. Hangsheng Satellite | 湖南航升卫星科技有限公此 | 2015 | Yes | CAS/university spin-off | Satellite and component manufacturing, Earth observations |
| 34. HEAD Aerospace Group | 北京和德宁杭技术有限公司 | 2007 | Yes | Established private company | Satellite and component manufacturing, Earth observations, communications, satellite navigation |
| 35. iSpace | 北京星际荣耀空间科技有限公司 | 2016 | Yes | Start-up | Launch |
| 36. Jiahe Info | 武汉珈和科技有限公司 | 2013 | Yes | Start-up | EO data analytics |
| 37. Jiuzhou Yunjian | 北京九州云箭空间科技有限公司 | 2017 | Yes | Start-up | Launch |
| 38. Kechuang Space Association | 广东科创航天科技有限公司 | 2014 | Yes | Start-up | Satellite and component manufacturing |
| 39. Keyidea | 南京凯瑞得信息科技有限公司 | 2011 | Yes | Established private company | Ground segment |
| 40. LandSpace | 北京蓝箭空间科技有限公司 | 2015 | Yes | Start-up | Launch |

| English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|
| 41. LaserFleet | 深圳航星光网空间技术有限公司 | 2017 | Yes | CAS/university spin-off | Satellite and component manufacturing, communications |
| 42. LEOBIT | 航天行云科技有限公司 | 2017 | Yes | SOE subsidiary | Communications |
| 43. LinkSpace | 深圳市翎客航天技术有限公司 | 2014 | Yes | Start-up | Launch |
| 44. LinkSure Network | 上海连尚网络科技有限公司 | 2013 | Yes | Established private company | Communications |
| 45. MinoSpace | 北京微纳星空科技有限公司 | 2017 | Yes | Start-up | Satellite and component manufacturing, ground segment, other |
| 46. Ningbo Space Engine Technology | 宁波天擎航天科技有限公司 | 2018 | Yes | Start-up | Launch |
| 47. OneSpace | 北京零壹空间科技有限公司 | 2015 | Yes | Start-up | Launch |
| 48. Origin Space | 北京起源太空科技有限公司 | 2017 | Yes | Start-up | Other |
| 49. Piesat | 北京航天宏图信息技术股份有限公司 | 2008 | Yes | Established private company | EO data analytics |
| 50. Pushing Value | 北京普世万优科技有限公司 | 2013 | Yes | Start-up | Launch, satellite and component manufacturing |
| 51. Qiansheng Exploration | 北京千乘探索科技有限公司 | 2017 | Yes | Start-up | Satellite and component manufacturing, Earth observations, communications, ground segment, EO data analytics |

| English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|
| 52. Rapisense | 北京迅感科技有限公司 | 2016 | Yes | Start-up | EO data analytics |
| 53. Satellite Herd | 北京航天驭星科技有限公司 | 2016 | Yes | Start-up | Satellite and component manufacturing, ground segment, other |
| 54. Siwei Star | 四维高景卫星遥感有限公司 | 2016 | Yes | SOE subsidiary | EO data analytics |
| 55. S-Motor | 北京灵动飞天动力科技有限公司 | 2017 | Yes | Start-up | Launch |
| 56. Space Eye | 北京天目创新科技有限公司 | 2005 | Yes | Established private company | EO data analytics |
| 57. Space Transportation | 北京凌空天行科技有限责任公司 | 2012 | Yes | Start-up | Launch |
| 58. Space Tube | 湖南斯北图科技有限公司 | 2016 | Yes | Start-up | Satellite and component manufacturing, communications, ground segment |
| 59. Space View | 北京航天世景信息技术有限公司 | 2012 | Yes | SOE subsidiary | Earth observations, EO data analytics |
| 60. Space Wisdom | 北京宇航智科科技有限公此 | 2015 | Yes | Start-up | Ground segment |
| 61. SpaceD | 北京爱太空科技发展有限公司 | 2016 | Yes | Start-up | Other |
| 62. SpaceOk | 上海欧科微航天科技有限公司 | 2014 | Yes | CAS/university spin-off | Satellite and component manufacturing, communications |
| 63. Spaceon | 成都天奥信息科技有限公司 | 2017 | Yes | Start-up | Ground segment |
| 64. Space-One Aerospace Technology | 天一华宇航天科技集团 | 2007 | Yes | Established private company | Ground segment, EO data analytics |

| English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|
| 65. SpaceTrek | 北京星途探索科技有限公司 | 2015 | Yes | Start-up | Launch |
| 66. Spacety | 长沙天仪空间科技研究院有限公司 | 2016 | Yes | CAS/university spin-off | Satellite and component manufacturing, communications, other |
| 67. SSTC | 航天恒星科技有限公司 | 1986 | No | SOE subsidiary | EO data analytics |
| 68. Tatwah Smartech | 中山达华智能科技股份有限公司 | 1993 | Yes | Established private company | Satellite communications |
| 69. Tianhang xiangyu | 天航祥宇空间技术有限公司 | 2007 | Yes | Established private company | Launch |
| 70. Tianjin Aerospace Reliability Technology Co | 天津航天瑞莱科技有限公司 | 2009 | Yes | Established private company | Launch, satellite and component manufacturing |
| 71. TITAN Group | 北京航天泰坦科技股份有限公司 | 2001 | Yes | SOE subsidiary | EO data analytics |
| 72. TSC | 鑫精合激光科技发展（北京）有限公司 | 2015 | Yes | Start-up | Launch, satellite and component manufacturing |
| 73. TWR-Engine | 深圳推重比引擎科技有限公司 | 2018 | Yes | Start-up | Launch |
| 74. TY-Space | 北京天银星际科技有限责任公司 | 2015 | Yes | CAS/university spin-off | Satellite and component manufacturing |
| 75. UCAS Co, LTD | 北京国科环宇空间技术有限公司 | 2004 | Yes | CAS/university spin-off | Satellite and component manufacturing |
| 76. Xihua | 北京 曦华科技发展有限公司 | 2017 | Yes | Start-up | Satellite and component manufacturing, |

| English Name | Chinese Name | Founding Year | Private Ownership Identified | Company Category | Sector |
|---|---|---|---|---|---|
| | | | | | communications, ground segment, other |
| 77. ZeroG Lab | 北京零重空间技术有限公司 | 2017 | Yes | Start-up | Satellite and component manufacturing, Earth observations |
| 78. Zhuhai Orbita | 珠海欧比特宇航科技股份有限公司 | 2000 | Yes | Established private company | Satellite and component manufacturing, Earth observations, EO data analytics |

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# Abbreviations

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|---|---|
| BRI | Belt and Road Initiative |
| CALT | China Academy of Launch Vehicle Technologies |
| CAS | Chinese Academy of Sciences |
| CASC | China Aerospace Science and Technology Corporation |
| CASIC | China Aerospace Science and Industry Corporation |
| CAST | China Academy of Space Technologies |
| CGWIC | China Great Wall Industry Corporation |
| CMI | Civil-military integration |
| CNSA | China National Space Administration |
| CSS | China Space Station |
| GAD | General Armaments Department |
| GEO | geosynchronous Earth orbit |
| GNSS | Global Navigation Satellite System |
| GSD | General Staff Department |
| IDA | Institute for Defense Analyses |
| IoT | internet of things |
| IPO | initial public offering |
| ISS | International Space Station |
| IT | information technology |
| ITAR | International Traffic in Arms Regulations |
| ITU | International Telecommunication Union |
| KSAT | Kongsberg Satellite Services |
| LEO | low Earth orbit |
| LM | Long March |
| MIIT | Ministry of Industry and Information Technology |
| MOST | Ministry of Science and Technology |
| MOU | memoranda of understanding |
| NASA | National Aeronautics and Space Administration |
| NDRC | National Development and Reform Commission |
| OSTP | Office of Science and Technology Policy |
| PLA | People's Liberation Army |
| PPP | Purchasing Power Parity |
| R&D | research and development |
| RMB | Renminbi |
| SAR | synthetic aperture radar |
| SASAC | State-owned Assets Supervision and Administration |
| SAST | Shanghai Academy of Spaceflight Technology |
| SASTIND | State Administration for Science, Technology and Industry for National Defense |
| SOE | State-owned Enterprise |

| | |
|---|---|
| SSC | Swedish Space Corporation |
| SSO | sun synchronous orbit |
| STEM | science, technology, engineering, and mathematics |
| STPI | Science and Technology Policy Institute |
| TT&C | telemetry, tracking, and control |
| UAV | unmanned aerial vehicles |
| VC | venture capital |
| VTVL | vertical takeoff, vertical landing |