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The Emergence of China's Commercial Space Companies and Start-Ups

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Introduction

As a legacy space power, China has a strong foundation for its current efforts and pursuit of space development. In recent years, the nation's space program and capabilities have grown at an impressive pace. Recent achievements include the Chang'e lunar probe missions, deployment of the Tianwen-1 Mars probe, and the reported completion of the BeiDou global navigation satellite system (GNSS).[1] The history of China's space program is inextricably linked with its military; but its overall space strategy in recent years has broadened to align closer to emerging global trends such as space commercialization. Multiple developments in China's national policy and overall space strategy have lent support to the shift of space-related research and development away from the military and towards the private sector. However, China's remaining state-owned defense industrial base, initiatives such as military-civil fusion (MCF), and competitive industrial policy show that China's opening of the space sector still aligns with its strategic national competitive goals and remains tied to the state and People's Liberation Army (PLA).

Historically, global space development was concentrated in the government sphere and activities were carried out by government agencies, the military, and legacy government contractors. However, in more recent years, commercial space companies have been emerging in both established and developing space powers around the world. In 2019, start-up space companies garnered $5.7 billion in funding, which is a $2.2 billion increase from the previous year. Additionally, in 2019, 79 start-up space companies received outside funding, compared to 47 in the previous year. [2] Although the funding amounts are not as substantial as national space budgets, and the company sizes have a small footprint relative to national space programs, the

drastic increase in funding and the number of companies shows that start-up space activity is on an upward trajectory. "New Space"[i] start-ups are cited as being more innovative, agile, and competitive, resulting in changes to both the development of space and broader industry dynamics.[3]

Space technologies provide both hard- and soft-power benefits, making them an attractive area for national investment. Although nation-states have been the face of space-related competition such as during the Space Race of the Cold War, the growing importance of private space start-ups and companies will likely shift the nature of this competition. As the commercial space sector continues to grow, nations will increasingly leverage commercial space capabilities for this competition. Gregory Tassey's framework of technology infrastructure helps to illuminate how the disparate parts of a nation's innovation system work in tandem to improve a nation's overall achievement in a given technology area.[ii] More specifically, technology infrastructure is comprised of a complicated web of human capital, organizations, policy, funding, universities, and industry, which all contribute to the development and functioning of a nation's innovation base. Although each individual piece of a nation's technology infrastructure may not be functioning with the broader system in mind, it is still contributing to the nation's innovation capabilities in one way or another. The recent trend towards space commercialization shows that commercial space companies and start-ups have become an important piece of a modern spacefaring nation's technology infrastructure for space development.

[i] The term "New Space" is often used to describe the recent trend of commercial actors and small start-ups entering the space industry, and can be defined as "the emergence of a different ethos for space where the established aerospace methods and business have been challenged by more entrepreneurial private sector by adopting more agile approaches and exploiting the latest commercial-off-the- shelf technologies."; Sweeting, M. N. (2018). Modern Small Satellites-Changing the Economics of Space. *Proceedings of the IEEE, 106*(3), 343-361. doi:10.1109/jproc.2018.2806218

[ii] For examples see: Tassey, G. (1991). The functions of technology infrastructure in a competitive economy. *Research Policy, 20*(4), 349. doi:10.1016/0048-7333(91)90094-7; Sánchez-González, G., & Herrera, L. (2012). Firm size and innovation policy. *International Small Business Journal: Researching Entrepreneurship, 31*(2), 138. doi:10.1177/0266242611405553; Andries, P., & Faems, D. (2013). Patenting activities and firm performance: Does firm size matter? *Journal of Product Innovation Management, 30*(6), 1091. doi:10.1111/jpim.12047; Mansfield E. (1991). Academic research and industrial innovation. *Research Policy, 20*(1), 1-12. doi:10.1016/0048-7333(91)90080-a

The presence of commercial space actors is not a novel occurrence, however, the scale of commercial space development and mode of interaction between the private and public sectors of the current day is unprecedented.[4] Although many of these commercial space companies and start-ups are working to serve commercial clients, the technology and applications they are developing have military and dual-use applications.[5] The growth of China's commercial space sector is a prime example of this dual-use connection, as many of these companies are connected to and linked with the government's broader civil, state-owned, and military space actors. China's efforts in space development and commercial activity therefore have implications for global spacepowers from both a commercial and security perspective, and particularly for the United States. Before diving deeper into China's current efforts in space, it is important to first take a step back and look at the development of China's space program and industry over the past few decades.

History of China's Space Development

China has been investing in and developing a significant military and civilian space capability since 1955.[6] Similar to the early Soviet space program, China's space-related R&D was heavily linked with the military and military technology. The space program has remained a top priority in China since it began under Mao Zedong, even retaining its funding for its non-manned space program under the tumultuous period of the Cultural Revolution in the 1960s.[7] At the end of the Cultural Revolution in the mid 1970s, China had already launched seven satellites into orbit—one of which was recoverable, a technology that only the U.S. and Soviet Union had developed at this point in history.[8] In the late 1970s, Deng Xiaoping launched the "Reform and Opening Up" (改革开放) policy, which focused China's national priorities from on fostering economic growth. The defense industry suffered under these reforms, mostly due to the decline in demand for defense-related goods, but amidst these cuts, the space program survived. In 1980 Deng Xiaoping created the China Great Wall Industry Corporation (CGWIC; 中国长城工业集团有限公司) under the China Aerospace Science and Technology Corporation (CASC; 中国航天科技集团公司) as the sole exporter of Chinese launch services and satellites. At the time, it was the only space company able to engage in international cooperation and

trade. Although CGWIC was marketed as a "private" and for-profit space company, as subsidiary of a large state-owned enterprise working in a sensitive technology area, the Politburo Standing Committee of the Chinese Communist Party (CCP) hold ultimate decision-making power over all of its activities and contracts.[9] Although CGWIC was created as a commercial entity, it ultimately remained under state control and in line with government objectives.

During the 1980s and 1990s, China worked on reforming its defense industrial base, mostly through the strategies of defense conversion and enterprise reorganization. Defense conversion was the transfer of military and defense production and development to the state-owned sector, while institutional reorganization was the changing of organizational structures, ownership, and company names as an effort to improve efficiency and innovation.[10] The defense and space sectors experienced a slight lull during this period due to the slowing effect of implementing these reforms. However, in 2000 China issued its first space white paper, which showed renewed interest in and commitment to China's space development. It stated, "The Chinese government has all along regarded the space industry as an integral part of the state's comprehensive development strategy. [...] The aims and principles of China's space activities are determined by their important status and function in protecting China's national interests and implementing the state's development strategy."[11] This recognition of space as key to overall national strategy highlighted the government's growing support for space into the 2000s. Most notably during this period, China launched its first manned mission into space on October 15, 2003. Then-Colonel Yang Liwei was aboard the Shenzhou 5 and orbited around the earth sixteen times before returning back to China—making China the third nation in world history to independently send a person outside of the earth's atmosphere.[12]

Evolution of China's Space Sector Through National Policy

China's development of science, technology, and industry is directly tied to its national-level policymaking. Although China has rapidly commercialized, "China is not letting go of state-driven product-cycle development as entrepreneurship continues to be state funded and technological innovation guided along industrial policy rails."[13] Although China is closed off in

many regards, its national policymaking and organization provides a transparent framework for where the country will focus its energy and resources. Since space is a national priority for China, understanding the goals outlined in key documents is integral to any discussion of space-related activities and developments within space.

National policy decisions related to Chinese industry and S&T development are made by the State Council and relevant agencies, with policy decisions being made by leading groups, or steering committees, at both the state and local levels.[14] National policy decisions are made by national government steering groups, which then dictate the policy agenda of local governments that work to implement national planning. This top-down structure for industrial policymaking directly impacts both the organization and activities of China's national space development. For example, in 2016 the NDRC approved the construction of a Wuhan National Space Industry Base (武汉国家航天产业基地) that is jointly funded by the Wuhan Municipal Government and CASIC, and was constructed by China Fortune Land Development Co., Ltd. under a public-private partnership agreement.[15] The goal of the Wuhan base is to promote the development of the commercial aerospace and high-end equipment industries. To date, it has invested over nine billion RMB in 11 new aerospace companies located in the industrial park.[16] The Wuhan National Space Industry Base provides one of many examples of how China's national industrial policy trickles down to the local level.

There are a number of national policy documents that have guided China's continued investment in the space sector and have included space as a component of China's overall national strategy. These documents include both broader industrial and S&T policy documents, as well as space-specific plans. The first of the broader policy documents is the Medium- and Long-Term Science and Technology Development Plan (MLP), which was jointly developed by the NDRC and MOST, and published by the State Council in 2006. This document outlines China's plan to reach "world advanced levels" in strategic areas such as information technology, energy, and space. The MLP lists space and aerospace technology as a "frontier technology" area, as well as identifies related basic research as a major national strategic need.[17] Then, there are the National Five-Year Plans (FYP), which provide the basis for all of China's forward-looking strategic development. Starting with the 11th FYP (2006-2010), China began to increase

emphasis on space technology, as well as the need for non-governmental investment in related sectors.[18] Emphasis on space as a national priority increased with the 13th FYP (2016-2020), as it identified space as a breakthrough field and as a core piece of the national innovation infrastructure.[19] The 13th FYP also mentions the importance of the eight regional aerospace innovation clusters, particularly for their provision of spin-off technologies that can help fuel the commercial space and aerospace sectors.[20]

The third core S&T policy document is the "Made in China 2025" (MIC 2025) plan, which was drafted by MIIT and published under the State Council as a comprehensive plan to promote innovation and Chinese "indigenously developed" products in both traditional and high-technology industries. Although it includes a multitude of key areas for development, it highlights 10 priority areas, one of which is the space and aerospace sector.[21] The MIC 2025 plan has energized China's efforts in high-technology development, and public and private companies in China cite this plan as part of their overall corporate strategy. MIC 2025 pushes forward the goal of China becoming globally dominant in all outlined technology areas by 2025, including in the space and aerospace industry. A final relevant policy document is the 2014 State Council Guidance 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), also referred to as "Document 60".[22] This policy was aimed at opening strategic sectors to private investment and improving market access across seven key sectors, one of which is civil space infrastructure. Within Document 60's sub-section on space infrastructure, the policy encouraged private capital and investment into civil space and other areas within the space industry such as remote-sensing satellites and ground stations.[23] Document 60 is often cited as the foundational document for allowing private investment into the space sector in China.[iii] The

[iii] Although Document 60 is credited with the opening of China's space sector, a recent report by IDA finds that it may not be as high-impact as expressed in Chinese media and reporting. The report explains, "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." (IDA 2019. 14.) Therefore, it is likely that the opening of China's commercial space sector occurred through the combination of multiple relevant policies that were published post-2000.

persistent inclusion of the space sector in broader national policy documents shows that it is a key focus of China's overall national development and S&T strategy.

In addition to broad S&T policy documents, the State Council has also issued four space white papers in 2000, 2006, 2011, and 2016 to provide explicit support and guidelines for the space industry. The main purpose of these white papers is to build on the policy goals outlined by other related national policy documents and message space priorities to other global actors. The documents highlight key space achievements, outline areas for global collaboration, as well as provide goals and targets for segments such as launch and satellite communications. Interestingly, the development of the commercial space industry has been mentioned in all of China's space white papers, starting with the encouragement of commercial launch in the 2000 white paper.[24] In addition to the space white papers, the State Council published the 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]) in 2015, which outlines space as a strategic sector and priority for development and innovation. It particularly outlines government guidance and support as key to promoting commercialization and international cooperation within the sector.[25] More recently, the 2016 space white paper highlights, "Non-governmental capital and other social sectors are encouraged to participate in space-related activities, including scientific research and production, space infrastructure, space information products and services, and use of satellites to increase the level of commercialization of the space industry. The government has increased its cooperation with private investors, and the mechanism for government procurement of astronautic products and services has been improved."[26] The clear support for the space industry and commercial space industry within China's policy documents facilitated the growth of its commercial space sector, and allowed for start-ups to enter the market. Additionally, the provisions and industry goals laid out in the space white papers are pursued by both government and private actors, making the activities of space start-ups linked with the promotion of China's overall success in the space industry.

Space development provides soft-power benefits in the form of diplomacy and commercial trade, as well as hard-power benefits through defense and dual-use applications. Joan Johnson-Freese aptly describes space as a "strategic asset," saying, "At the strategic level,

space assets are used for arms control verification and as early-warning systems. Space offers capabilities for linking vast distances and gathering information, improving education, expanding medical resources, creating jobs, and monitoring and managing environmental issues, among others. These capabilities clearly are of strategic value to all countries."[27] The BeiDou GNSS system is a prime example of space as a strategic asset, as it has been leveraged for military, commercial, and diplomatic purposes. BeiDou satellites are used by the PLA for position, navigation, and timing (PNT), they enable GPS-dependent businesses both in China and globally, and the satellites comprise a key piece of the Digital Silk Road under the Belt and Road Initiative (BRI) and are used to improve the connectivity of countries across Asia, Africa, and South America.[28] BeiDou satellites are one of many examples of why space technology has emerged as a national priority for China, and a review of China's S&T policy at the national level further shows that space development is a national priority for both the soft and hard power benefits it provides. The policy documents discussed are not an exhaustive list of all of the national policymaking relevant to China's space development, but these are the policies that have carried the most weight in the expansion of China's commercial space sector.

China's space industry has developed in line with the global trend of space commercialization, but its commercial companies have not received as much global media attention as companies such as SpaceX or Planet Labs. There are dozens of new commercial space companies and start-ups working in different industry segments, including satellite manufacturing, satellite services, and satellite launch. The development of a commercial space sector is supported and facilitated by national policies, as well as through initiatives such as Military-Civil Fusion (MCF) that aim to move the production of defense or dual-use technologies to the private sector. While most of China's space start-ups are linked directly to the government or state-owned defense industrial base through funding or direct ownership, even those which are not directly linked to the government constitute an important piece of China's overall technology infrastructure. Furthermore, many of the space start-ups in China are partnered with traditional SOEs through the use of shared facilities, technology transfer arrangements, or supplier relationships. The following section highlights examples of Chinese space start-ups in the launch and satellite segments to illustrate their connection to China's

government space sector and contribution to China's overall development of space technologies.

Chinese Space Start-Ups

China's commercial space activity has continued to grow exponentially since the central government's publication of Document 60 in 2014, the MLP for National Civil Space Infrastructure in 2015, and the space white paper of 2016. A 2019 report by IDA identified 78 commercial Chinese space companies, 45 of which were founded in 2014 or later, and a 2020 publication by Bryce Space and Technology has identified 31 Chinese space start-ups. [29] Commercial space start-ups and companies are emerging across the core segments of launch, satellites, ground stations, and satellite services. Examples of recent achievements by Chinese space start-ups includes the first completed commercial launch by iSpace, the test of a 5G broadband satellite by Galaxy Space, and successful testing for reusable launch vehicles by Space Transportation and Linkspace.[30] To better illustrate the activities and types of companies operating as commercial or start-up space companies in China, the rest of this section will provide details on two key players within China's emerging space industry: Landspace Technology Co., Ltd. and HEAD Aerospace.

Landspace Technology Co. Ltd. (北京蓝箭空间科技有限公司)

LandSpace is a private small satellite launch company that was founded in Beijing in 2015 by Tsinghua University and veterans of China's space SOEs.[31] The company describes itself as "an innovative space enterprise in the strategic context of national civil-military integration, mainly targeting domestic and international commercial launch demands of micro- and small-satellite manufacturers, operators, scientific research institutions and higher education institutions."[32] On an archived version of the LandSpace webpage, it also mentioned that its innovative business intends to support China's strategic national development outlined in the MIC 2025 plan.[33] LandSpace's investment partners include FounDream, YungPark Capital, CTC, and the state-managed Chinese High-Tech Equipment Fund, and it also previously partnered with large space SOE CASC for the provision of its solid rocket motors.[34] Although LandSpace's

first attempted launch was unsuccessful in October 2018, the company is still forging ahead in its development of small and medium launch vehicles for both domestic and international payloads.[35]

In addition to growing its domestic business, LandSpace has actively engaged with international partners. In 2017, Landspace signed its first foreign space launch contract with Danish nanosatellite company GomSpace.[36] The launches were planned to begin in March 2018 on Landspace's then LS-1 four-stage solid-propellant launcher, with its partner GomSpace advertising a rideshare opportunity on the launch.[37] Unfortunately for LandSpace, the contract with GomSpace was terminated due to CASC's cancellation of its contract for the provision of solid rocket motors for LandSpace's LS-1 rocket due to sensitive technology control.[38] CASC's reneging on the provision of critical technology to LandSpace provides an interesting example that works against the core narrative of MCF and collaboration between SOEs and private space enterprises. The movement of CASC away from LandSpace makes the company a more independent commercial enterprise. Since losing CASC's rocket motor, LandSpace has developed a new line of launch vehicles, the Zhuque 朱雀 (ZQ-1 and ZQ-2), and has worked to independently develop the Tianque 天鹊 (TQ-12) liquid oxygen methane engine for use in its launch vehicles.[39] Since releasing its new line of launch vehicles, LandSpace has signed launch agreements with UK's Open Cosmos and Italy's D-Orbit for the provision of CubeSat launch services and on-orbit delivery for the companies. Both agreements were signed at the Second Belt and Road Forum in April 2019, indicating the significance of both agreements to national strategic initiatives and LandSpace's support for government policies like the Belt and Road Initiative (BRI).[40]

LandSpace's original small payload space launch vehicle, the LS-1, was based on the CASC Long March 11 launch vehicle, which is used for Chinese government payloads.[41] When being interviewed about the LS-1, the CEO of LandSpace, Zhang Changwu (张昌武) explained, "the company did not raise money from the state, he says, though some of its vendors are state-owned".[42] This statement is contradicted by the state-run Chinese High-Tech Equipment Fund being an investor in LandSpace, and evades the reality of its initial family of launch vehicles being a direct spin-off of CASC technology. Another interesting aside on the LS-1 is that

LandSpace also had plans to make the vehicle road-mobile, which is not commonly used for commercial satellite launch.[43] No evidence has been identified that indicates the new Zhuque family of launch vehicles is planned to be road-mobile, but the initial road-mobile plan for the LS-1 provides and explicit example of the dual-use nature and potential military application of commercial space technologies.

Since LandSpace was founded in 2015, the company's relative level of success or innovation is still unclear. With CASC's technology support from its early years, the company was able to sign both domestic and global launch contracts within two years of its founding date. Its original launch vehicle of the LS-1 was a direct spin-off of the CASC LM-11 launch vehicle, which facilitated its quick rise as an operating launch company. Technology transfer from CASC and government funding through the High-Tech Equipment Fund provided LandSpace with an advantage that many of its global peers will not receive from their respective governments. Although LandSpace's partnership with CASC has deteriorated, the company actively supports national policies such as the Belt and Road Initiative, showing that is still working in support of government goals. The movement away from Chinese government support will improve LandSpace's image as a private space start-up, but its operation as a private company that has received explicit Chinese government support connects its activities and relative success with China's overall space strategy.

HEAD Aerospace (北京和德宇航技术有限公司)

HEAD Aerospace is a private small satellite company that was founded in 2007 and has its headquarters in Beijing. It is a more established private space company that started as a sub-component manufacturer for SOEs, and in recent years it has evolved into a high-technology and innovative commercial Internet of Things (IoT) satellite manufacturer. In addition to its domestic growth, it also has subsidiary offices in Hong Kong, the Netherlands, and France; representative offices in South Africa, Spain, Morocco, and Shanghai; as well as joint laboratories in Italy and Switzerland.[44] An archived version of the Chinese website from 2018 listed that the company has partnerships with the Chinese Academy of Sciences, Airbus Defence & Space, Tests & Radiations Co., Harmonic Drive AG, CASIC, ISIS Space, KUKA, MBDA

Missile Systems, ORBCOMM, Hyperion Technologies, SITAEL, MEDES, NewSpace Systems, Kongsberg, CASC, and SupremeSAT.[45] Its current website lists SOLERMEMS, NewSpace Systems, Astronika, GomSpace, Cobham, Synopta, Hyperion Technologies, and EIE Group as additional partners.[46] Head Aerospace is a member of multiple international space organizations such as the International Astronautical Federation (IAF), is a certified National High-Tech Enterprise, and a certified supplier to aerospace and defense SOEs, CASC and CASIC. HEAD Aerospace is also designated as a National High-Tech Enterprise under China's High and New-Technology Enterprise (HNE) program, which provides the company with preferential taxes and support from the Chinese government.[47]

HEAD Aerospace is actively engaged in both domestic and foreign partnerships through its network of subsidiaries, representative offices, and research laboratories. Its foreign subsidiary, HEAD Aerospace Netherlands is a limited liability company that operates as an independent entity in the Netherlands under HEAD Aerospace Beijing. It is located in the Space Business Innovation Centre (SBIC) of the Noordwijk Space Business Park, which is close to ESA-ESTEC.[48] According to the HEAD Aerospace company website, its Netherlands office is working with both national and international partners to identify opportunities for small satellite applications ranging from maritime surveillance and monitoring, hyperspectral and all-weather earth observation, and data collection and monitoring for the development of space Internet of Things (IoT).[49] In 2015 HEAD Aerospace established an electric propulsion joint laboratory with the Lanzhou Institute of Physics (兰州空间技术物理研究所) and Italian microsatellite company SITAEL.[50] The Lanzhou Institute of Physics is a research lab of the China Academy of Space Technology (CAST), which is the main spacecraft development and production facility in China, as well as a subsidiary of the SOE CASC.[51] In addition to its CAST partnerships, HEAD Aerospace also lists domestic partnerships with the Chinese Academy of Sciences (CAS), China Electronics and Technology Group Corporation (CETC), China Aerospace Science and Industry Corporation (CASIC), and the Shanghai Academy of Spaceflight Technology (SAST), which are all government or state-owned entities.[52] The wide range of HEAD Aerospace's partnerships provides it with a strong network of domestic support from traditional Chinese space actors as well as outreach to foreign partners and markets.

HEAD Aerospace's main product is the Skywalker constellation (天行者星座), which is comprised of remote-sensing microsatellites equipped with automatic identification systems (AIS) for maritime and environmental monitoring. The first satellite in the Skywalker constellation (HEAD-1) was launched on November 14, 2017 as a hosted payload on the launch of the Fengyun-3D weather satellite on a Long March 4C rocket. The 45-kilogram microsatellite was constructed by the Shanghai Academy of Spaceflight Technology (SAST) and remains a part of the current 48 satellite constellation.[53] In addition to its core business of earth observation satellites, HEAD Aerospace is also developing an Internet of Things (IoT) satellite terminal, sub-systems for other satellite applications (e.g., a solar wing drive mechanism for BeiDou satellites), sub-components for civil space missions, and ground stations to manage its satellite network.[54]

HEAD Aerospace has created multiple international partnerships with foreign defense-focused firms such as Kongsberg, MBDA Missile Systems, and Airbus Space & Defence. Its subsidiary HEAD Aerospace Netherlands and office in France are primarily used to seek out international partnerships and clients, providing the company with opportunities to compete in the global space and satellite services markets.[55] HEAD Aerospace's joint laboratory with SITAEL and the Lanzhou Institute of Physics facilitated a direct link between the top Chinese state-owned research institute related to space vehicles and development (CAST) and an Italian small satellite, propulsion system, and avionics producer.[56] Although the scope of the technology sharing and exchange in the joint electric propulsion laboratory is unclear, it does provide an example of how a Chinese commercial space companies could be linking government entities with foreign partners for sensitive R&D and potential technology transfer. In addition, HEAD Aerospace is connected with China's space and defense SOEs and has received support and technology directly from companies such as SAST. Although HEAD Aerospace is a commercial Chinese space company, it is inextricably linked with the Chinese government which puts the true nature of this company and others like it into question. The level of SOE and government support for Chinese commercial space companies like HEAD Aerospace provides them with a strong network of support and potential advantage against global peers.

Impact of China's Commercial Space Development

China's commercial space development comprises a core part of China's space technology infrastructure, and the dual-use nature of the technology being developed ultimately supports the nation's broader goals for space across military, commercial, and civil applications. Furthermore, many of the space start-ups emerging in China retain some degree of connection to state-owned enterprises or government and military entities. The tight control China's military has over the space sector through its operation of all launch facilities in China further exacerbates the problem of blurred lines between the new private space actors and legacy public actors within China's space industry.[57] For example, many of China's commercial space companies conduct their launches at the Jiuquan Satellite Launch Center[iv], which is also used as a, "key facility for short-range ballistic missile, land attack cruise missile, and space intercept testing."[58] The opening up of the commercial space sector in China benefits China's military and goals for technological achievement in this area. In their paper on the convergence of the US and China's space development strategies, Erickson and Walsh explain the multitude of motivations for China's government, including "exploiting commercial spin-on technologies for defense applications but also expectations of a large degree of defense spillovers to the overall economy, the prestige factor of having a manned space program, and the deterrent effect of demonstrating, deploying, and indigenously developing sophisticated space-based capabilities."[59] China's commercial space activities will carry over to its strategic space activities, making it imperative to study the activities of Chinese commercial space start-ups within the context of how they fit into the broader picture of China's space development.

One risk that arises from the increase in the number of Chinese commercial space companies is the potential for technology transfer from foreign partners. Since technology restrictions vary from country to country, Chinese firms can seek partnerships with different global actors depending on the sensitivity level of the technology area it is trying to develop.[60] For example, the German company Daimler-Benz assisted China with the development of the DFH-3 COMSAT platform, which is also used in China's military communications satellites.[61] And

[iv] The Jiuquan Satellite Launch Center is also called the People's Liberation Army Strategic Support Forces (PLASSF) Base 20.

although partnerships that are created may be limited to civilian or commercial areas, the dual-use nature of space technology can make it difficult to distinguish what areas may ultimately contribute to China's military or government space capabilities.[62] Many of China's commercial space companies have funding, ownership, or direct collaboration with CASC or CASIC. However, the commercial face put forward by Chinese commercial space companies and start-ups may make it easier for them to engage with foreign partners and then share the technology or access gained with China's government space entities.

HEAD Aerospace and LandSpace are examples of a much broader group of Chinese commercial space companies and start-ups, meaning that there are many more companies within China's space industry that are likely to have similar government ties and activities. Although it is unfair to say all commercial companies in this sector have illicit goals or are operating in direct support of the Chinese government, their relationship to the CCP and state-owned enterprises has important implications for technology transfer and fair global competitiveness. China's industrial strategy and national innovation system impacts the commercial actors within in it, and companies looking to engage with Chinese entities on high-technology and space-related activity need to keep potential risks such as technology transfer, dual-use crossover, or CCP and PLA connections in mind. Foreign firms working in the space industry and other high-technology sectors therefore need to do their due diligence to understand the complex web of relationships underlying potential Chinese partners. This particularly holds when working on dual-use technology and space-related research, as it could unintentionally benefit the Chinese government or military.

Implications for the US and Global Space Competitiveness

The emergence of Chinese commercial space companies has multiple implications for the United States. First, Chinese government support of its commercial space companies provides them with a potential competitive advantage against emerging U.S. or global space start-ups looking to compete in the international market. Second, the creation of joint ventures and laboratories with international entities could facilitate technology transfer of sensitive or dual-use technology. And third, the success of Chinese commercial space companies provides

China with both soft- and hard-power benefits, which could threaten U.S. security and leadership in space.

Through its national strategy and policy planning, China has facilitated the growth of commercial space companies in areas such as launch, satellite manufacturing, remote-sensing, and imagery. Although these companies advertise themselves as being wholly commercial or privatized entities, many of them have close ties to the Chinese government through funding, technology, leadership, and joint projects. Space is a strategic area of development for China, which has motivated the Chinese government to support these companies and eventually compete with U.S. or other global space companies. Although Chinese commercial space companies and start-ups are currently focusing their efforts on opportunities within the domestic Chinese market, they are starting to engage with international partners and establish overseas offices. To remain competitive with Chinese space companies, the U.S. government should continue to support U.S. space start-ups through the provision of contracts in events such as the Air Force Space Pitch Days, favorable tax rates, and programs for joint government-commercial R&D.[63] China's strategy of sharing public resources to support private enterprises for space development helps to shield Chinese space start-ups from the inherent risk in starting a new business in an emerging market. Continued coordination and cooperation between the U.S. government and private space enterprises will help to facilitate the success of New Space companies and maximize U.S. competitiveness in the global space industry.

Another risk inherent to cooperation with Chinese firms is the potential for sensitive technology transfer or IP theft. Although the Committee on Foreign Investment in the United States (CFIUS), Foreign Investment Risk Review Modernization Act (FIRRMA), Export Administration Regulations (EAR), and International Traffic in Arms Regulations (ITAR) work to protect sensitive U.S. technologies key to both commercial and military space, their review processes are not foolproof. EAR and ITAR regulations are often vague, which can make it difficult for academics and research scientists to closely adhere to restrictions.[64] Although Chinese commercial space companies and start-ups appear to be private entities, many of them are still strongly connected to the Chinese government or state-owned defense sector. It is

therefore important for private firms to recognize this risk and conduct thorough due diligence before engaging with Chinese commercial space companies.

Finally, the growth of Chinese commercial space capabilities provides it with a multitude of benefits that increase its standing as a global space power on par with the United States. Current U.S. export controls somewhat limit the nation's ability to work with other spacepowers, which may in turn, cause U.S. partners to turn to China for collaborative opportunities or trade.[65] China has engaged many different countries for space cooperation, and "Beijing is using space cooperation to engage in what might be termed 'geotechnological balancing,' or the use of space activities to restrict American power and to try to reshape the international system in its favor."[66] The combination of soft- and hard-power benefits provided by a robust space industry as well as the increase in the development of dual-use space assets by Chinese commercial space companies and start-ups such as communication or remote-sensing satellites make China's pursuit of commercial space a strategic decision. Although the U.S. cannot block Chinese global space activity or development, it can take a variety of actions to ensure that China does not overtake its leadership in space. The U.S. should consider making its export control lists more targeted to specific technologies, as well as review them more frequently to match the pace of technology development.[67] This will prevent unnecessary blocks of commercial partnerships with other nations or harm to the competitiveness of its space industry. Furthermore, the United States should consider increasing its interaction with China in space through multilateral partnerships with other allies such as the EU nations to ensure that it is not being left out of multilateral cooperative activity. A potential avenue for this cooperation is bilateral or multilateral space exploration and collaboration between NASA and China National Space Administration (CNSA) on scientific projects.[68]

The United States should stay abreast of the development and activities of China's commercial space start-ups as they have become an important and growing part of China's strategy for space development. Furthermore, space-related companies, research facilities, and entities should be aware of the existing ties between Chinese commercial space companies and start-ups and the Chinese government before entering into partnerships or research agreements. Although many of China's space start-ups are commercial entities and not under

the full control of the Chinese government, their remaining connections to SOEs and China's military space sector still present a level of inherent risk. It is clear that China will continue to invest in and promote space for its overall national development, with the emergence of Chinese commercial space companies and start-ups being an important new development in the nation's overall efforts and strategy.

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