SECTION 2: CHINA'S SPACE AND COUNTERSPACE PROGRAMS

Introduction

China has become one of the top space powers in the world after decades of high prioritization and steady investment from its leaders, indigenous research and development, and a significant effort to buy or otherwise appropriate technologies from foreign sources, especially the United States. China's aspirations are driven by its assessment that space power enables the country's military modernization and would allow it to challenge U.S. information superiority during a conflict. As the Commission has documented in previous reports, China has asserted sovereignty over much of the East and South China seas, as well as Taiwan, and is engaged in a course of aggressive conduct to enforce those claims against its neighbors. Among other purposes, China's space and counterspace programs are designed to support its conduct as part of its antiaccess/area denial * strategy to prevent or impede U.S. intervention in a potential conflict. China also believes that space power drives the country's economic and technological advancement and provides the Chinese Communist Party (CCP) with significant domestic political legitimacy and international prestige. Although China's space capabilities still generally lag behind those of the United States and Russia, its space program is expanding and accelerating rapidly as many other countries' programs proceed with dwindling resources and limited goals.

China's rise as a space power has important national security implications for the United States, which relies on its own space capabilities to assess and monitor current and emerging threats to national security and project military power globally. Within this context, this section will examine China's space and counterspace programs, including key organizations involved in the programs; space power's contribution to China's national power; China's development of a robust and comprehensive array of counterspace capabilities; China's rapid space-based C4ISR † modernization; China's progress in space launch, human spaceflight, and lunar exploration; and U.S.-China space cooperation. The statements and assessments presented in this section are based on the Commission's February 2015 hearing on China's space and counterspace programs, unclassified briefings by U.S. and foreign government offi-

* According to the U.S. Department of Defense, "antiaccess" actions are intended to slow deployment of an adversary's forces into a theater or cause them to operate at distances farther from the conflict than they would prefer. "Area denial" actions affect maneuvers within a theater, and are intended to impede an adversary's operations within areas where friendly forces cannot or will not prevent access. U.S. Department of Defense, *Air Sea Battle: Service Collaboration to Address Anti-Access & Area Denial Challenges*, May 2013, 2.

† C4ISR refers to command, control, communications, computers, intelligence, surveillance, and reconnaissance.

cials, consultations with nongovernmental experts on China and space issues, the Commission's July 2015 fact-finding trip to China, and open source research and analysis.

Key Organizations Involved in China's Space and Counterspace Programs

China's space program involves a wide network of entities spanning its political, military, defense industry, and commercial sectors. Unlike the United States, China does not have distinctly separate military and civilian space programs. CCP leaders provide policy guidance and authorize allocations of resources for the program, and various organizations within the People's Liberation Army (PLA) execute space policy and oversee the space research, development, and acquisition process. China's military also exercises control over the majority of China's space assets and space operations.

Although China conducts civilian space activities, such as scientific research and exploration, and Chinese civilian agencies provide input into space policy and space research, development, and acquisition requirements, China does not have an official civilian space program.[1] Tate Nurkin, managing director of research and thought leadership at IHS Jane's Aerospace, Defense and Security, explained to the Commission:

> *China's space program does not have structures in place that make meaningful divisions between military and civil programs, and those technologies acquired and systems developed for ostensibly civil purposes can be applied—and most frequently are—for military purposes. This dynamic indicates that China's space program is also a critical element in the country's ongoing military modernization program.*[2]

Under this nebulous framework, even China's ostensibly civilian projects, such as human spaceflight, directly support the development of PLA space, counterspace, and conventional capabilities.[3] Moreover, although any country's satellites are capable of contributing to its military operations, the PLA during wartime would probably take direct command over all Chinese satellites.

Central Special Committee

One important coordinating body for China's major strategic research and development (R&D) projects is the Central Special Committee, which reports to the CCP Politburo Standing Committee, Central Military Commission,* and State Council.† Established in the early 1960s and led through the decades by some of China's top political leaders,‡ the Central Special Committee brings together

* China's Central Military Commission is the country's top military decision-making body. Congressional-Executive Commission on China, *China's State Organizational Structure*.

† China's State Council, headed by Premier Li Keqiang, presides over China's ministries, commissions, and direct offices. It is responsible for executing laws, supervising the government bureaucracy, and carrying out the administrative functions of the Chinese government. Congressional-Executive Commission on China, *China's State Organizational Structure*.

‡ The Committee has been chaired by Zhou Enlai, Hua Guofeng, Deng Xiaoping, Li Peng, Zhu Rongji, and Wen Jiabao, indicating today it is likely chaired by Li Keqiang. Tai Ming Cheung, "The Special One: The Central Special Committee and the Structure, Process, and Leadership

Continued

civilian and military leaders and technical experts on an ad hoc basis to evaluate and provide recommendations on strategic dual-use high-technology programs—almost certainly including China's space launch, human spaceflight, and lunar programs. The committee may play a role in important military science and technology projects as well. Although the Central Special Committee today is a government—rather than party—institution, and lacks the broad decision-making authority it had in the 1960s and 1970s, it still signifies China's state-led, top-down policy approach to science and technology development and its focus on large-scale projects.[4]

Leading Small Groups

China has established several leading small groups to help forge institutional consensus regarding its space policies and to provide high-level coordination among the array of political, military, defense industry, and commercial organizations involved. China reportedly has formed leading small groups for human spaceflight, lunar exploration, Earth observation satellites, and heavy-lift launch vehicles.[5] These groups, which are formalized fora rather than institutions, are composed of representatives from relevant organizations selected on a project-specific basis, and are led by top CCP officials.

Ministry of Science and Technology

The Ministry of Science and Technology (MOST), which is directly subordinate to the State Council, formulates and promulgates major long-term strategies for the development of science and technology. MOST's national R&D strategy for the 2006–2020 period, the *Medium-to-Long-Term Plan for the Development of Science and Technology*, coordinates state-funded R&D efforts across government, military, and commercial spheres and places heavy emphasis on funding basic research that affects multiple fields. Concerning China's space program, the strategy updates and accelerates the pursuit of space R&D objectives established in the *State High-Technology Development Plan of 1986* (also known as the 863 Program), which set China's space development on its current trajectory. The strategy for 2006–2020 identifies and funds 13 unclassified technology megaprojects, including a high-definition Earth observation system and human spaceflight and lunar probes. It also reportedly identifies and funds three classified programs, which many analysts believe to be a laser project exploring inertial confinement fusion, the Beidou satellite navigation system, and a hypersonic glide vehicle program.[6]

State Administration of Science, Technology, and Industry for National Defense

The State Administration of Science, Technology, and Industry for National Defense (SASTIND), which is subordinate to the State Council's Ministry of Industry and Information Technology, exer-

of the Chinese Defense and Strategic Dual-Use Science, Technology and Industrial Triangle" (Conference on the Structure, Process, and Leadership of the Chinese Science and Technology System, San Diego, CA, July 16–17, 2012).

cises administrative authority over China's defense industrial enterprises and serves as an intermediary among China's military, defense industry (including its space industry), government ministries, research facilities, and other stakeholders. In this capacity, SASTIND organizes and coordinates space R&D, approves space contracts, and develops standards for the space industry. SASTIND also directly manages China's lunar exploration program.[7]

China National Space Administration

The China National Space Administration (CNSA), which is subordinate to SASTIND and is led by the SASTIND director, is a small organization that is responsible for China's relations with external parties on non-commercial and non-military space-related matters. In this capacity, CNSA coordinates and executes international agreements and other aspects of China's international cooperation efforts in space.[8] Since 2014, CNSA has engaged with the space programs of a range of countries, including Algeria, Germany, India, Italy, the Netherlands, Russia, Sudan, and Turkmenistan, as well as the European Union.[9]

Although CNSA often is incorrectly referred to as China's equivalent of the U.S. National Aeronautics and Space Administration (NASA), it does not have a direct role in overseeing China's space policy; space research, development, and acquisition process; space assets; or space operations.[10]

General Staff Department

The General Staff Department serves as the PLA's headquarters.* As such, it develops short- and long-term requirements for space and counterspace technologies based on guidance from the Central Military Commission and the PLA services. The General Staff Department is also the focal point for China's space warfare operations and planning. The department houses operations, intelligence, and electronic warfare elements—among other capabilities—to assist the PLA in carrying out its functions.[11]

General Armaments Department

The General Armaments Department is responsible for supplying and maintaining the PLA's weapons systems and managing important weapons testing centers and research centers. As such, it oversees the research, development, and acquisition process for China's satellites, launch vehicles, and counterspace weapons and manages large national-level engineering projects, such as China's human spaceflight program. The General Armaments Department, through subordinate entities, is also responsible for the day-to-day operations of the majority of China's military and civilian space activities.[12] Additionally, the department is believed to advise the Central Military Commission on space and counterspace issues via its Science and Technology Committee's expert groups.[13]

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*Directly subordinate to the Central Military Commission, the highest command organ in China's military, are four General Departments: the General Staff Department, the General Political Department, the General Logistics Department, and the General Armaments Department. The General Departments are responsible for executing Central Military Commission policies and conducting the day-to-day administration of China's military.

The China Satellite Launch, Tracking, and Control General (CLTC), which is subordinate to the General Armaments Department, is the entity responsible for managing China's space launches and the telemetry, tracking, and control functions for its spacecraft systems.* In this capacity, the CLTC runs a significant portion of the General Armament Department's land-based space infrastructure, including its launch centers, control centers, telemetry and tracking stations, and naval space tracking vessels. In addition, the CLTC designs and manufactures space launch and telemetry, tracking, and control equipment, constructs China's land-based space infrastructure, and handles space launch and telemetry, tracking, and control functions for foreign customers of China's space industry.[14]

Space Launch Centers

The CLTC has four launch centers—Jiuquan, Xichang, Taiyuan, and Wenchang—each of which launches military, civilian, and commercial spacecraft. Jiuquan Space Launch Center, which became operational in 1960, is China's oldest and largest launch facility. From Jiuquan, China launches many of its intelligence, surveillance, and reconnaissance (ISR) satellites and all spacecraft involved in its human spaceflight program.[15] Xichang Launch Center is China's most active facility and the only one capable of conducting launches to geosynchronous Earth orbit.† From Xichang, China primarily launches most of the country's commercial satellites as well as government-owned communications satellites.[16] Taiyuan Satellite Launch Center is China's least active launch site. From Taiyuan, China primarily launches meteorological, Earth resource, and scientific satellites. The PLA also conducts test launches of its ballistic missiles from the complex.[17]

In late 2014, China opened the Wenchang Satellite Launch Center on Hainan Island, the southernmost province of China. Once full operations begin, Wenchang will launch all of China's future ISR satellites and manned spacecraft. According to Kevin Pollpeter, deputy director of the Study of Innovation and Technology in China Project at the University of California Institute on Global Conflict and Cooperation, "the launch center's closer proximity to the equator than China's three other launch centers can increase launch payloads by 10–15 percent and satellite life by two to three years, a factor important for developing the country's commercial launch market. Launches will also be directed over the ocean, which will permit debris from launches to land safely out to sea."[18]

* Telemetry, tracking, and control is the process of monitoring spacecraft systems, transmitting the status of those systems to the control segment on the ground, and receiving and processing instructions from the control segment.

† Geosynchronous Earth orbit can be achieved at about 22,000–23,000 miles above the Equator. The highest orbital band within geosynchronous Earth orbit in frequent use is known as "geostationary Earth orbit." At this altitude, satellites move at the same speed as the Earth's rotation, enabling them to cover large geographic areas. Satellites in geostationary Earth orbit are used primarily for early-warning missile and nuclear test monitoring, electronic intelligence, commercial communications, and satellite television and radio.

Figure 1: China's Space Launch Centers

Source: Economist, "Space: Ready for Launch: China's Secretive Space Program Takes a Step into the Open," January 8, 2015.

Space Tracking and Control

Space operations require a substantial amount of support from land-based infrastructure. Most of this support is provided by two CLTC-managed control centers: (1) the Xi'an Satellite Telemetry and Control Center, China's main facility for controlling satellites and managing satellite data; and (2) the Beijing Aerospace Flight Control Center, China's main facility for controlling China's human and lunar missions.[19]

The Xi'an and Beijing control centers rely on a network of 10–20 telemetry and tracking stations positioned throughout China. The stations, which act as middlemen to relay information between China's spacecraft and the control centers, can only communicate with spacecraft when they are directly overhead. The centers thus are unable to maintain constant communication with spacecraft that travel beyond the area visible from China's territory. To help alleviate these coverage limits, the CLTC has built telemetry and tracking stations in Namibia, Pakistan, and Chile, and leases access to stations in Kenya and Australia.* China is constructing a sixth overseas telemetry and tracking station in Argentina, a reported investment of over $300 million, in exchange for providing Argentina a share of the antenna's usage time and access to imagery from its surveillance satellites.[20] Additionally, the CLTC operates as many as six Yuanwang naval space tracking vessels, which serve as mobile telemetry and tracking stations. The Yuanwang ships have provided critical C4ISR support to China's intercontinental ballistic missile tests and some of its human spaceflight missions.[21]

Defense Industrial Organizations

The China Aerospace Science and Technology Corporation (CASC) and China Aerospace Science and Industry Corporation (CASIC) are the primary state-owned defense industrial enterprises that support the General Armament Department in the research, development, and manufacturing of space and counterspace technologies and systems. Formed in 1999 out of a single entity, the Chinese Aerospace Corporation, these two conglomerates were established to inject competition into China's aerospace industry—a move the country's leaders hoped would spur the industry to become more efficient, more innovative, and less of a financial burden on the central and local governments.[22] Since the division, CASC and CASIC have demonstrated advancements in these areas, though their progress has resulted from improvements to internal processes rather than from expanded competition, as the two conglomerates have largely focused on different product areas with little overlap.[23]

China Aerospace Science and Technology Corporation

CASC plans and oversees the development, production, and testing of space launch vehicles, manned spacecraft, space stations, deep space exploration spacecraft, and ballistic missiles. It also heavily invests in satellite applications, information technology, and other industries to which space technology is applicable. CASC employed over 170,000 individuals in 2012, the latest year for which statistics are available. The corporation comprises 8 large research and production academies,† 14 specialized firms, and 12 companies publicly listed in either China or Hong Kong, and is home to 11 defense science and technology (S&T) laboratories, a national engineering laboratory, and 5 engineering research centers.[24] Two subordinate organizations are particularly important to China's space activities:

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* China previously operated a telemetry and tracking station in Tawara Atoll, Kirabati, but closed the station in 2003 when Kirabati recognized Taiwan. Jane's Space Systems and Industry, "XSCC-Xian Satellite Control Center"; Brian Harvey, *China in Space: The Great Leap Forward*, Springer, 2013, 65.

† The term "Academy" for these subordinate organizations should not be taken literally, as Gao Ruofei, Executive Vice President of the China Great Wall Industry Corporation, informed the Commission during its July 2015 trip to China. Instead, these should be characterized as "research, development, and manufacturing entities." Gao Ruofei, China Great Wall Industry Corporation, briefing to Commission, Beijing, China, July 22, 2015.

- The China Academy of Space Technology, one of CASC's eight academies,* is responsible for the development and production of satellites and spacecraft. The Academy developed many of China's high-profile space projects, including the Shenzhou series of manned spacecraft, the Chang'e lunar orbiter, and the Tiangong-1 space laboratory. It also designs many of China's C4ISR satellites and plays a role in the formation of China's national space technology development plans. The Academy employs over 10,000 people.[25]
- The China Great Wall Industry Corporation is one of CASC's 14 specialized firms and serves as its commercial representative for launch services and satellite systems. In this capacity, the corporation is responsible for international marketing, contracting, and export management. It is China's sole commercial entity engaged in these functions. Once contracted, the corporation conducts these commercial launches in conjunction with other CASC and PLA entities. The corporation also engages in international space cooperation efforts and provides products and services for a wide range of civilian applications that nominally utilize space technology, including satellite technology, information technology products, electronic products, and real estate.[26] China Great Wall Industry Corporation was placed under U.S. sanctions in 1991, 1993, 2004 (twice), and 2006 for exporting missile technology to Pakistan and Iran, with the last of the sanctions lifted in 2008 following the company's establishment of an internal compliance program based on U.S. training.[27] In a briefing to the Commission during its trip to Beijing in July 2015, the corporation's executives emphasized the implementation of this program and the company's promise to never engage in the import and export of missiles and their associated products.[28]

China Aerospace Science and Industry Corporation

CASIC is China's largest missile designer and manufacturer. As such, the organization plans and oversees the development, production, and testing of China's direct-ascent antisatellite assets and operationally responsive launch capability, including the associated road-mobile launchers and small satellites. CASIC employed more than 135,000 workers in 2013, the latest year for which statistics are available. It comprises five academies, two scientific research and production bases, six companies publicly listed in either China or Hong Kong, and over 570 enterprises and institutes.[29]

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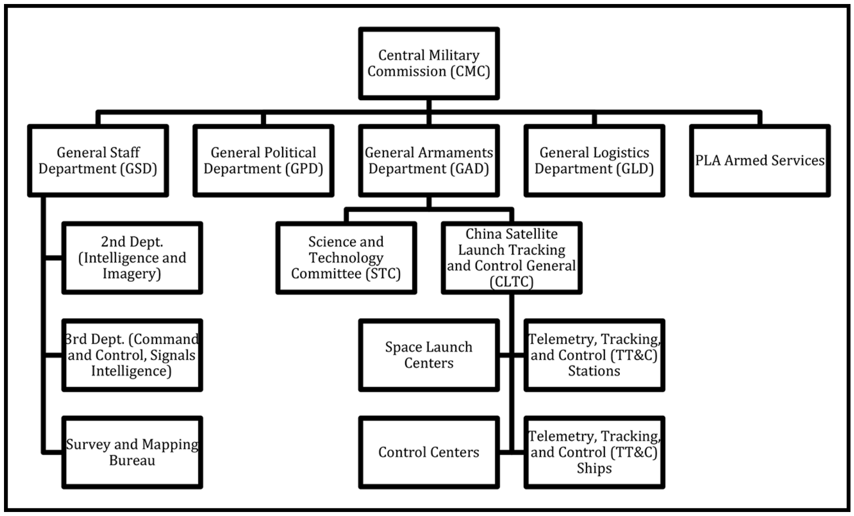
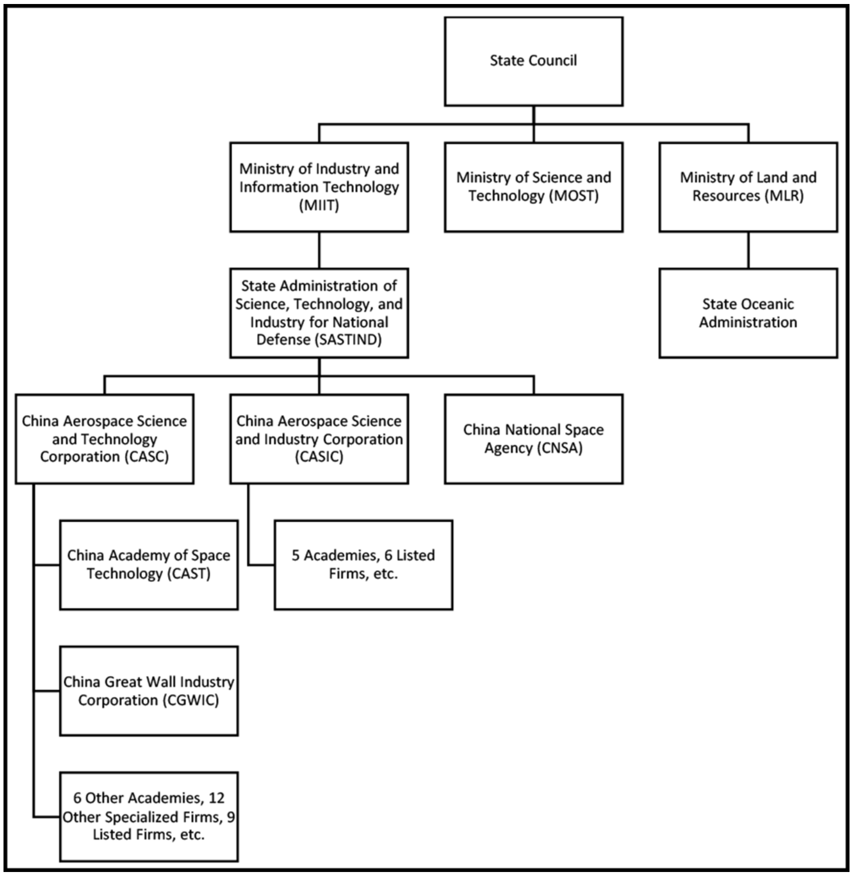
*The other seven academies are the Academy of Launch Vehicle Technology, the Academy of Aerospace Solid Propulsion Technology, the Academy of Aerospace Propulsion Technology, the Sichuan Academy of Aerospace Technology, the Academy of Spaceflight Technology, the Academy of Aerospace Electronics Technology, and the Academy of Aerospace Dynamics.

Figure 2: Select Military Organizations Involved in China's Space Program



Source: Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 96–106; Eric Hagt, "Integrating China's New Aerospace Power in the Maritime Realm," in Andrew S. Erickson and Lyle J. Goldstein, eds., *Chinese Aerospace Power: Evolving Maritime Roles*, Naval Institute Press, 2011, 386.

Figure 3: Select Civil and Defense Industry Organizations Involved in China's Space Program



Source: Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 96–106; Eric Hagt, "Integrating China's New Aerospace Power in the Maritime Realm," in Andrew S. Erickson and Lyle J. Goldstein, eds., *Chinese Aerospace Power: Evolving Maritime Roles*, Naval Institute Press, 2011, 386.

Space Power's Contribution to China's National Power

Military Contributions

In the early 1980s, China set out to transform its military from a large infantry-based army designed to fight protracted wars into a smaller, well-trained, and "informationized" force.* China accelerated this effort in 2004, when the PLA formally institutionalized the concept of "informationization."[30] Since then, the PLA has based its "preparations for military struggle" on the strategy of "winning local wars under the conditions of informationization," ac-

* In Chinese military doctrine, "informationization" refers to the application of advanced information technology to military operations.

cording to authoritative PLA documents.* [31] This requires China to narrow the technology gap between the PLA and the world's most advanced militaries through a focus on information technology and on developing and procuring new, high-tech communications and data fusion systems for battle space management and for long-range, accurate weapons. At the operational level, PLA writings identify information superiority as the key factor in all antiaccess/area denial tasks, which includes the fielding of an integrated air defense and the coordination and synchronization of strikes against an adversary's forces. According to China's most recent *Science of Campaigns*, an authoritative document on PLA campaigns published by China's National Defense University, "the struggle for . . . information superiority has infiltrated into each campaign phase . . . and become a decisive condition for seizing the battlefield initiative." [32]

PLA strategists and analysts recognize that space forces are crucial to the PLA's transformation into an informationized force as well as its ability to achieve information superiority during a conflict. According to Dean Cheng, senior research fellow for Chinese political and security affairs at the Heritage Foundation, these PLA analysts have specifically noted that "more and more essential data . . . is gathered from or transits through satellites." They assess that space systems now provide a majority of battlefield communication, battlefield surveillance and reconnaissance, weather condition assessment, and precision guidance functions, rendering "space dominance" an essential component of realizing "information dominance." [33] The PLA has accordingly developed space capabilities in pursuit of achieving these and other functions, including ISR, ballistic missile warning, space launch detection and characterization, environmental monitoring, satellite communication, and position, navigation, and timing.

- *Intelligence, Surveillance, and Reconnaissance*. Space-based systems can monitor areas of interest to help provide China's political and military leaders with information on an adversary's location, disposition, and intent; assist in tracking, targeting, and engaging an adversary's forces; and provide a means to conduct battle damage assessment. They also can provide situational awareness and warning of attack.
- *Ballistic Missile Warning*. Space-based systems, in conjunction with ground-based systems and operators, can provide China's political and military leaders with timely warning and characterization of foreign ballistic missile events and nuclear detonations to support threat/non-threat determination and follow-on decision making.
- *Space Launch Detection and Characterization*. Space-based systems, in conjunction with ground-based systems, can provide information necessary to assess both foreign and domestic space launches. Launch detection data can be used to evaluate events that could directly or indirectly threaten China's space

*China's most recent defense white paper, published in 2015, updated this term slightly to "winning informationized local wars." China Information Office of the State Council, *China's Military Strategy*, May 26, 2015, 3.

assets so the PLA can achieve timely warning and take appropriate countermeasures. This capability also can support analysis of China's domestic space launches.

- *Environmental Monitoring*. Space-based systems can provide data on meteorological, oceanographic, and space environmental factors that affect PLA operations. Additionally, space capabilities can provide data to assist the development of forecasts, alerts, and warnings regarding factors in the space environment that may negatively impact China's space assets, space operations, and their terrestrial users. Imagery capabilities can provide Chinese planners with current information on sub-surface, surface, and air conditions, allowing PLA commanders to avoid adverse environmental conditions or take advantage of other conditions to enhance operations. Such monitoring also can support intelligence preparation of the operational environment by providing PLA analysts with information necessary to assess potential adversary courses of action.
- *Satellite Communications*. Satellite communications can provide the PLA with the ability to establish or augment telecommunications in operating areas that lack suitable land infrastructure. Potential PLA applications of satellite communication technology include providing instant global connection between deployed forces and the Central Military Commission, transmitting critical intelligence between echelons of command, and tying sensors to weapons systems.
- *Positioning, Navigation, and Timing (PNT)*. Space-based PNT assets can provide information PLA forces can use to more effectively plan, coordinate, and execute operations. Precise and reliable PNT information is essential to the performance of virtually every modern Chinese weapon system.[34] The PLA can apply precision timing to synchronize operations and conduct attacks from stand-off distances, thereby allowing Chinese forces to avoid threat areas and defend against opposing naval forces from a position as far as possible from the Chinese coast.

Analysis of authoritative Chinese documents indicates Beijing believes space superiority would be critical to almost every component of its military operations (particularly long-range precision strikes) during a potential Taiwan Strait conflict and against the United States and other potential adversaries in the region.[35] In 2009, then PLA Air Force Commander and current Vice Chairman of the Central Military Commission Xu Qiliang said space had become a "new commanding height for international strategic competition" and having control of air and space "means having control of the ground, oceans, and the electromagnetic space, which also means having the strategic initiative in one's hands."[36] China's 2015 defense white paper* affirms the importance of space in China's strategic calculus:

* Defense white papers—China's most authoritative statements on national security—are published by the State Council's Information Office and approved by the Central Military Commission, Ministry of National Defense, and State Council. Beijing primarily uses these documents as a public relations tool to help ease deepening international concern over China's military modernization and answer calls for greater transparency.

Outer space has become a commanding height in international strategic competition. Countries concerned are developing their space forces and instruments, and the first signs of weaponization of outer space have appeared. . . . China will keep abreast of the dynamics of outer space, deal with security threats and challenges in that domain, and secure its space assets to serve its national economic and social development, and maintain outer space security.[37]

The PLA also is pursuing a robust and comprehensive array of counterspace capabilities. China has not published an officially endorsed document describing its counterspace strategy and doctrine and likely is still developing its tactics, techniques, and procedures. Since the early 2000s, however, PLA doctrinal publications and military writings on space warfare * and China's demonstrated and developmental counterspace capabilities indicate China's program is primarily designed to deter U.S. strikes against China's space assets, deny space superiority to the United States, and attack U.S. satellites.[38] These purposes are likely driven by three security-related assessments:

- The PLA assesses that obtaining and demonstrating the ability to damage or destroy the satellites an adversary considers essential to its national security and military operations could deter that adversary from attacking China's space assets, potentially in the event of a conflict arising from China's coercive actions in its near seas. According to a PLA writing on space deterrence, "it is necessary to display one's own power to the enemy so that they perceive the deterrent force, and also to get them to realize that this force is capable of creating loss or consequences that would be difficult for them to accept."[39] Moreover, China's military strategists perceive counterspace capabilities to be a more credible and flexible deterrent than nuclear and conventional capabilities, as the threshold for the use of counterspace capabilities is lower because it would not involve a significant loss of life.[40]
- Beijing recognizes that its satellites are vital for its commercial and civil sectors and that disruptions to these systems—even for short durations—could contribute to internal instability by harming China's economy and government operations.[41]
- The PLA assesses U.S. satellites are critical to the United States' ability to sustain combat operations globally. PLA analysis of U.S. military operations states that "destroying or capturing satellites and other sensors . . . will deprive an opponent of initiative on the battlefield and [make it difficult] for them to bring their precision-guided weapons into full play."[42] In another study, the PLA estimated that the United States developed a comprehensive surveillance system comprising approximately 50 satellites as well as unmanned aerial vehicles and

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* PLA doctrinal publications and military writings on space warfare include the following: the *Science of Service Strategy* (2013 and 2005 editions), the *Lecture on Space Operations* (2012), the *Science of Campaigns* (2006), and "Developing the Theory of Strategic Deterrence with Chinese Characteristics" in *China Military Science* (2004).

aircraft during its participation in the North Atlantic Treaty Organization campaign in Kosovo. The same study estimates space systems provided 70 percent of U.S. battlefield communications during the campaign, 80 percent of its battlefield surveillance and reconnaissance, and 100 percent of its meteorological data, and did so 24/7 through all weather conditions.[43]

Economic and Commercial Contributions

Senior Chinese government and aerospace officials publicly tout the economic and commercial benefits of China's space program, highlighting four areas in particular: market creation and spin-off technologies, satellite application technologies, commercial launch services, and satellite exports.[44]

Market Creation and Spin-off Technologies

Chinese analysts assess that China's space program has had a transformative impact on the country's national economy. In their view, the demand created by large, complex space projects involving numerous government and commercial entities and utilizing a wide range of technologies can spur advancement in areas such as computers, microelectronics, precision manufacturing, automatic control, new energy, and new materials. Moreover, they assess that China's space program provides demand for skilled labor and expanded science and engineering educational programs. These analysts point to the U.S. Apollo program as the best example of the transformative impact a national space program can have on a country's economy.[45]

Beijing has taken a concentrated and hands-on approach to ensuring its space program realizes similar effects, and Chinese analysts point to numerous benefits it has provided. In their view, Chinese investments in space technologies have their most profound impact on high-technology development, with each dollar invested estimated to yield $10 in gross domestic product growth. Furthermore, 80 percent of 1,000 new materials developed domestically are identified in one analysis as having resulted from research in space technology. More than 2,000 space-based technological achievements have reportedly been transferred to various sectors of China's national economy, and nearly 1,000 space industry products have been converted for civilian use. Chinese analysts highlight that China's human spaceflight program—which involves over 3,000 commercial enterprises—has been particularly important to China's technological progress in electronics, new materials, and automatic control.[46]

China's efforts to introduce spin-off technologies (that is, technologies originally developed for the space industry that also can be applied to commercial and civilian applications) are led by eight industrial parks known as "aerospace bases." These bases—located in Beijing, Chengdu, Hainan, Inner Mongolia, Shanghai, Shenzhen, Tianjin, and Xi'an—are the products of partnerships between the space industry and their respective provincial governments. The bases manufacture space industry products and then attempt to leverage the industry's capabilities in space technologies to build civilian products. These civilian products involve technologies in areas identified by the central government as strategic emerging industries, including high-end manufacturing equipment, alternative energy, new materials, alternative energy automobiles, and new-generation information technologies.[47]

Satellite Application Technologies

Chinese analysts emphasize the importance of China's space program in the development of satellite application technologies—that is, supplementary products that build upon the information provided by space technologies to add value for consumers. In their view, China's space program has facilitated the development of these technologies in three primary areas. First, it has led to the development of satellite communications applications such as satellite television and telecommunication services. Second, China has launched several lines of Earth observation satellites that provide remote sensing data, which have been used for functions such as agricultural use monitoring, environmental protection, and municipal planning. Many of China's civil-government agencies are dependent on this data. Third, the program has facilitated the development of satellite navigation products such as receivers for China's Beidou constellation. The Beidou system could further stimulate innovation in mobile Internet applications for consumers and in other areas of consumer, civil, or commercial application that require PNT data. In August 2015, Alibaba, a private Chinese firm, and China North Industries Corporation, a Chinese state-owned defense conglomerate, formed a joint venture worth roughly $310 million to "build applications and technology to support and work with the [Beidou] system." [48]

Commercial Launch Services

Commercial launches provide China's space industry with revenues, opportunities to measure the quality of its products and services against international competitors, and synergies through integration with its military space sector. Despite these ostensible benefits, China has struggled to develop its commercial space launch capabilities and realize desired growth in market share. According to Beijing, these shortfalls are the result of U.S. export controls, which since 1999 have prohibited U.S.-manufactured satellites and satellites containing U.S.-manufactured components from being launched by China as well as the purchase by China of these items.[49] These laws have progressed through several iterations, as explained in July 2014 by a firm specializing in international trade law:

> *Originally all satellites, whether military, commercial, or remote-sensing, were subject to controls under Cat. XV of the U.S. Munitions List in the International Traffic in Arms Regulations (ITAR). In the early 1990s most commercial satellites were moved to the Export Administration Regulations (EAR) of the Department of Commerce. Then, after some violations associated with launches in China, Congress passed legislation transferring all satellites back to ITAR. Those controls have been in place since March 15, 1999.*[50]

The Obama Administration changed satellite export control rules further in November 2014, moving many commercial satellite and satellite technology exports back to EAR jurisdiction, meaning they can now be approved for export or for launch on foreign rockets, unlike under the ITAR regime. Exports to China, however, along with North Korea and any state sponsor of terrorism, are still banned under EAR based on the FY13 National Defense Authorization Act, which permitted this rule change but included a specific clause to ensure controls remained in place for these countries.[51] In addition to exports, China is still blocked from offering launch services for U.S.-made satellites or any satellites with U.S.-made components, as launches of satellites on foreign rockets are seen as "permanent exports."[52]

Despite the obstacles posed by U.S. export control regulations, China is marketing its launch services to Europe and the developing world, aiming to capture 15 percent of the global launch services market by 2015. While China achieved this objective with roughly 19 and 26 percent market share in 2011 and 2012, respectively, it only held 11 percent in 2013, the last year for which data is available.*[53] Executives at the China Great Wall Industry Corporation, China's sole commercial satellite and launch services provider, stressed the continued impact of these obstacles in a briefing to the Commission during its trip to Beijing in July 2015, stating that although the company's products and practices are "just as good" as those of U.S., European, and Russian providers, it is unable to compete in the "whole market" due to U.S. export controls.[54]

China launched a Chinese-made satellite for Nigeria in 2007, the first such launch for a foreign client since 1999. In 2011, China launched a satellite for European satellite communications provider Eutelsat, its first launch of an entirely foreign-made satellite for a foreign client since 1999. Since these initial launches, China has provided launch services for Chinese-made satellites to Bolivia, Nigeria, Pakistan, and Venezuela, and has signed contracts for additional launches for Belarus, Laos, Sri Lanka, and Venezuela. For foreign-made satellites, China has provided launch services to Argentina, Ecuador, Indonesia, Luxembourg, and Turkey and signed contracts for future launch services with Algeria, Belarus, Congo, Laos, and Sri Lanka.[55]

Figures on the cost of Chinese launches are scarce. According to one source, however, the costs were in one case lower than those of Arianespace, the leading European launch company.[56] A spokesperson for the China Great Wall Industry Corporation, which handles the contracting of China's commercial launch services, predicted that going forward its launches will be offered at the same price level as those of U.S. company SpaceX, an emerging low-cost leader in the field.[57] Previously, officials from China's space industry had stated that they could not beat SpaceX's price.[58] China's

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*These figures include launches of Chinese government satellites and satellites owned by state-owned enterprises. If these are excluded, China's market share is lower, but still only surpasses 15 percent in 2011 and 2012. Additionally, data sources on the commercial launch market differ slightly; this assessment uses the highest totals reported. If the lower totals are used, China's market share still surpasses the 15 percent target in 2011 and 2012, while falling short of this number the other years. For complete market share data see: Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 21–22.

integration of its commercial and military launch infrastructures is expected to provide cost-saving effects as well, as it provides both sectors with synergies in economies of scale, "experience effects" such as increased reliability and fewer failures, and the ability to utilize modular designs.* [59]

Satellite Exports

In an attempt to increase its share of the global satellite market, China has focused on exporting commercial satellites to developing countries. Beyond valuing the revenues provided by satellite exports, China views the selection by international buyers of its satellites over Western-made ones as another indicator of the overall strength of its space industry.[60] As a relatively late entrant to the commercial satellite field, China set the goal of capturing 10 percent of this market by 2015.[61] Although data on all global commercial satellite sales are not available, China's share of geosynchronous Earth orbit satellite contracts, which represent the vast majority of commercial satellites,[62] increased from 2007 to 2013 but only achieved 10 percent in 2011 and 2012.[63]

China also likely values commercial satellite exports because these domestic-made satellites help increase demand for Chinese launch services, as they lack U.S.-made components and are thus free of restrictions that would otherwise prevent their launch on Chinese rockets.

China has exported communication satellites to Bolivia, Nigeria, Pakistan, and Venezuela and an imagery satellite to Venezuela. Moreover, China has signed contracts to provide communications satellites to Belarus, Laos, and Sri Lanka and an additional remote sensing satellite to Venezuela. In the face of stiff competition from international satellite builders, Beijing probably relied on a combination of technology transfer and preferential financing to secure these deals.[64]

Political and Diplomatic Benefits

Like other space powers, China uses its space program to enhance its international prestige and influence. Analysis of authoritative Chinese documents indicates Beijing believes successful space activities, particularly human spaceflight, provide important geo-strategic benefits, such as bolstering China's international image, promoting a role for China on the world stage commensurate with what it sees as its growing international status, and increasing China's ability to influence international policy generally and international space policy specifically.[65] For example, as China moves from a regional to global PNT service provider, Beijing could use the Beidou system as leverage to obtain more influence over PNT-related decisions in international and regional organizations such as the International Telecommunications Union,[66] the International Committee on Global Navigation Satellite Systems, the Asia-Pacific Economic Cooperation forum, and the International Civil Aviation Organization.

*Modular designs are constructed using an approach that divides a product into parts that can be connected or combined in different ways.

The CCP also uses China's space program to rally public support, a move indicative of the party's larger strategy to legitimize itself by convincing the Chinese people it is delivering economic growth and a better quality of life while restoring China to its "rightful" place as a world leader following the country's so-called "century of humiliation" from the mid-19th to the mid-20th centuries. Mr. Pollpeter explains:

> *The CCP is now communist in name only, and its continued legitimacy is predicated on delivering economic and nationalistic benefits in an informal social contract with its citizens: the CCP agrees to increase the standard of living and develop China into an internationally respected country, and the people agree not to rebel. By developing a robust space program and participating in high-profile activities such as human spaceflight and lunar exploration, the CCP can demonstrate that it is the best provider of material benefits to the Chinese people and the best organization to propel China to its rightful place in world affairs*.[67]

China collaborates with other countries on a range of bilateral and multilateral space activities, including satellite development, space exploration, human spaceflight, space object surveillance and identification, and space R&D.[68] Many of these engagements are designed to facilitate China's acquisition of new technologies from technologically-advanced states and to promote the export of China's space technologies to states with space programs lagging behind its own.[69] Others are intended to help China achieve a level of space situational awareness that enables the PLA's offensive and defense space missions and supports China's orbital debris detection, mitigation plans, and operations.

Asia Pacific Space Cooperation Organization (APSCO)

With its headquarters located in Beijing, APSCO is China's primary entity for multilateral cooperation on space. China led the founding of the formal, membership-only organization in 2008 as a successor to the Asia-Pacific Multilateral Cooperation in Space Technology and Applications organization.[70] Aside from China, APSCO has seven other member countries,* all of which have less advanced space programs than that of China. APSCO members hold conferences, engage in joint training efforts, and cooperate on multilateral research and development projects.† [71] These efforts allow China to position itself as a purveyor of space technology and expertise to lesser-developed states; China has, for example, donated ground systems and will provide remote sensing data to other member countries.‡ [72] China's leaders also likely use Beijing's

*APSCO's member countries are China, Bangladesh, Iran, Mongolia, Pakistan, Peru, Thailand, and Turkey. Indonesia is a signatory state but not yet a full member. Asia-Pacific Space Cooperation Organization, "APSCO Member States"; APSCO, "Convention of the Asia-Pacific Space Cooperation Organization," October 28, 2005.

†Ongoing multilateral research and development projects in APSCO include a remote sensing data sharing platform, earth observation and communications satellites, a space observation network, and satellite navigation technology. APSCO, "Programs."

‡These donations have included a data broadcasting system for China's Fengyun meteorological satellites to several member countries and a receiving station for remote sensing data to Thailand. Remote sensing data from China's Gaofen, Ziyuan, Fengyun, and Haiyang satellites

Continued

central role in APSCO to promote the export of its space technology and services in order to gain support for its space goals in the Asia Pacific region, as well as to obtain supplementary data and geographic coverage for its space situational awareness efforts.

China-Brazil Cooperation

China and Brazil have cultivated a strong cooperative relationship in space-related endeavors, particularly through joint satellite development and space launches. China and Brazil signed their first space cooperation agreement in 1984, and four years later embarked on the $300 million China-Brazil Earth Resources Satellites project to jointly develop two advanced remote sensing satellites.[73] Both countries contributed technologies for the service and payload modules of these satellites. China and Brazil extended the program and launched three additional satellites between 1999 and 2014,[74] with a sixth satellite slated for launch in 2016.[75] In addition to serving China's environmental and scientific missions, the satellites likely have provided the PLA with enhanced resolution of terrestrial strategic targets.[76] The project also probably helped Beijing lay the groundwork for its most advanced Earth observation satellite, the Gaofen series, which has military applications (see "Space-based C4ISR Capabilities" later in this section for more details on this satellite series).[77]

China-Russia Cooperation

Despite a break in cooperation between 1958 and 1997, China maintains a long-running comprehensive space relationship with Russia, its oldest space partner. In 1997, China and Russia established a space cooperation subcommittee within their bilateral prime ministers' dialogue, which resulted in the opening of a Chinese space program office in Russia and a corresponding Russian office in China, as well as collaboration on a range of human spaceflight and space exploration activities.[78] Future cooperative activities in space could include joint rocket engine development and a joint Russia-China space station, or Russia's participation in China's future space station, planned for completion around 2022.[79]

Through its space cooperation with Russia, China is able to gain valuable knowledge from one of the world's top space powers to advance its own space technology development, particularly in the area of launch vehicles—a technology critical for China's space-based C4ISR and counterspace capabilities. China also uses its space relationship with Russia to increase the geographic reach of its satellite coverage. In 2014, China and Russia signed agreements on expanding cooperation of their respective satellite navigation systems, Beidou and the Global Navigation Satellite System (GLONASS), to include building monitoring stations in each other's countries.

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will be provided to member countries. Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 24–25.

China-Ukraine Cooperation

China cooperates with Ukraine on a range of space issues. From 2001 to 2015, the two countries followed three consecutive five-year programs guiding their cooperation on large-scale space projects.[80] Under the 2006 to 2010 program, China and Ukraine collaborated on 29 long-term projects, including remote sensing satellites, space weather satellites, and space rocketry. In 2012 China and Ukraine agreed to collaborate on more than 50 additional joint projects in the areas of Earth observation and rocket and satellite technology development, including the Ionosat space system, marking a significant increase in space cooperation over previous years.* The two countries continue to discuss potential opportunities for space collaboration; future joint ventures could include engine manufacturing projects and exploratory missions to the Moon and Mars.[81] In March 2015 Ukraine's ambassador to China stated his expectation that a fourth five-year program would be approved later in the year, suggesting that bilateral space cooperation has proceeded despite the ongoing conflict in Ukraine.[82]

China likely applies technical expertise gained from Ukraine in its development of next-generation launch vehicles. Ukraine, a former Soviet republic, inherited a wealth of knowledge in ballistic missiles and launch vehicles from the Soviet Union when it dissolved in 1991.[83]

China-Europe Cooperation

Joint space cooperation between China and Europe is thriving, particularly in the areas of space science, space exploration, and human spaceflight. As long as conditions remain ripe for collaboration, China and Europe will remain motivated to cooperate in order to advance their domestic agendas: China generally seeks access to Europe's advanced space technology to improve its own space capabilities, while Europe seeks greater cooperation primarily in order to compensate for the reduced funding of the European Space Agency and to facilitate greater economic ties between China and Europe.[84]

In the mid- to late-2000s, China extracted important gains from the relationship through its early co-development work on Europe's Galileo satellite navigation network, resulting in the most divisive point in bilateral space relations to date. Europe had initially invited China to participate in the project in order to draw more funding, expand Galileo's access to the Chinese market, and distance itself from the United States for political reasons. Europe declined China's continued participation in the project, however, primarily due to concerns over the dual-use nature of satellite navigation and questions regarding China's plans for its own Beidou satellite navigation system.† The project likely provided Beijing with

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* Ionosat is a type of Earth observation satellite in the Earth's ionosphere designed primarily for scientific purposes, disaster relief, and space weather monitoring. Yuzhnoye Design Office, "Ionosat."

† The European Space Agency provided the additional rationale that legal restrictions prohibited China's involvement, following Galileo's change from public-private funding to public only. Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 28–30.

essential technology and experience needed for the development of Beidou.[85] Beidou satellites even use frequencies previously allocated to Galileo, which EU and Chinese diplomats jointly negotiated for in the early 2000s.[86]

China-Venezuela Cooperation

China and Venezuela have a robust space partnership. In 2005, the two countries signed a memorandum of understanding on space technology cooperation and established a special joint subcommittee on technology, industry, and space. Since then, China has built and launched two satellites for Venezuela, the Venesat-1 communications satellite in 2008 and the VRSS–1 remote sensing satellite in 2012. China also is helping Venezuela build small satellites, supplying Venezuela's space industry with Chinese technology, and training Venezuelan engineers.[87]

China's Counterspace Program

China is pursuing a broad and robust array of counterspace capabilities, which includes direct-ascent antisatellite missiles, co-orbital antisatellite systems, computer network operations, ground-based satellite jammers, and directed energy weapons. China's nuclear arsenal also provides an inherent antisatellite capability.

During a conflict, China likely would employ a combination of "hard attacks," which use kinetic methods to cause permanent and irreversible destruction of a satellite or to ground support infrastructure, and "soft attacks," which use nonkinetic methods to temporarily affect the functionality of a satellite or ground systems. PLA writings suggest Beijing prefers soft attacks to hard attacks because they are less likely to escalate a conflict, are less likely to broaden a conflict to include other countries, do not create debris that could damage its own satellites, and offer Beijing plausible deniability. However, Beijing almost certainly would conduct hard attacks in response to an adversary's kinetic strikes on China's satellites or when Beijing determined a crisis had progressed to the point where destructive attacks were needed and that it could accept reciprocal retaliation from or an escalation by an adversary.[88]

Direct-Ascent Antisatellite Missiles

China has tested two direct-ascent antisatellite missiles: the SC–19 and the larger DN–2. Direct-ascent antisatellite missiles are designed to disable or destroy a satellite or spacecraft using one of several possible kill mechanisms, such as a kinetic kill vehicle.* The missiles typically are launched against pre-selected targets, as they must either wait for the target satellite to pass overhead within a certain distance from the launch site, or target a stationary satellite within range of the launch site. Unlike co-orbital antisatellite systems (discussed later in this section), direct-ascent antisatellite missiles do not establish a persistent presence in space, enter into long-term orbits, or loiter to await commands to engage a target.[89]

*A kinetic kill vehicle is a maneuverable platform with the ability to detect, track, and undergo guidance to a target and destroy it through the force of a direct collision.

China destroyed an aging Chinese weather satellite using its SC–19 direct-ascent antisatellite missile in January 2007 following two non-destructive tests of the missile in 2005 and 2006. The 2007 test demonstrated China's ability to strike satellites in low Earth orbit, where the majority of the United States' approximately 549 satellites reside, including about 30 military and intelligence satellites. During a discussion of the test in 2015, General John Hyten, commander of U.S. Air Force Space Command, said: "It was a significant wakeup call to our entire military . . . until that singular event, I don't think the broader military realized that that is something [we will] have to worry about." [90] If China began series production of the SC–19 after the successful 2007 test, China could already have sufficient numbers of the missile to attack all U.S. military and intelligence satellites in low Earth orbit.

China conducted additional SC–19 tests in 2010, 2013, and 2014. In each test, the SC–19 intercepted a mock warhead launched by a ballistic missile rather than a satellite. The targets were not in orbit, so any debris generated by the interceptions quickly fell back to Earth.[91] Although China has called these tests "land-based missile interception tests," [92] available evidence suggests they were indeed antisatellite tests. Regarding the most recent test in 2014, Assistant Secretary of State for Arms Control, Verification, and Compliance Frank Rose said, "Despite China's claims that this was not an [antisatellite] test; let me assure you the United States has high confidence in its assessment, that the event was indeed an [antisatellite] test." [93]

The non-debris-generating nature of the tests suggests China may have gained a better appreciation of the diplomatic costs of debris-generating antisatellite tests as well as the long-term consequences of such tests for China's own space assets. China received worldwide criticism for creating more than 3,400 pieces of debris during its 2007 antisatellite test, and this debris continues to threaten the space systems and astronauts of all nations, including China. More than half of the debris could still be in orbit in 2027.[94] Not all experts agree, however: according to Mr. Cheng, China may have avoided debris-generating tests since 2007 for other reasons such as changes to its testing needs, and evidence linking the shift to the previous diplomatic response is lacking.[95]

In May 2013, China fired its new DN–2 rocket into nearly geosynchronous Earth orbit, marking the highest known suborbital launch since the U.S. Gravity Probe A in 1976 and China's highest known suborbital launch to date. Beijing claims the launch was part of a high-altitude scientific experiment; however, available data suggests China was testing the ballistic missile component of a new high-altitude antisatellite capability. The nature of the test indicates China is developing an antisatellite capability to target satellites in medium Earth orbit, highly elliptical Earth orbit, and geosynchronous Earth orbit.[96] Although the DN–2 is technically capable of reaching U.S. Global Positioning System (GPS) satellites, it would likely be better suited for strikes on U.S. ISR satellites.* [97]

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*There are over 30 GPS satellites in orbit, distributed across multiple planes, and many more than the four required for a "position fix" are overhead at any given time. Numerous successful direct-ascent antisatellite missle attacks would thus be required to achieve results of military

Continued

Based on China's research, development, and acquisition timelines for previous ballistic missile and antisatellite programs, China could operationally deploy the DN–2 in the 2020–2025 timeframe.

Table 1: Summary of Direct-Ascent Antisatellite Tests

Date	Orbital Debris	Missile	Notes
July 2005	No	SC–19	Rocket test
February 2006	No	SC–19	Failed intercept and destruction of an orbital target
January 2007	Yes	SC–19	Successful intercept and destruction of an orbital target
January 2010	No	SC–19	Successful intercept and destruction of a suborbital target
January 2013	No	SC–19	Successful intercept and destruction of a suborbital target
May 2013	No	DN–2	Rocket test
July 2014	No	SC–19	Successful intercept and destruction of a suborbital target

Sources: Commission analysis and judgments based on the following sources: U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, April 2015, 14; Frank Rose (Assistant Secretary of State, Bureau of Arms Control, Verification, and Compliance), "Written Remarks Delivered to the Federation of American Scientists" (Washington, DC, February 20, 2015); U.S.-China Economic and Security Review Commission, *Hearing on China's Space and Counterspace Programs*, written testimony of Richard Fisher, February 18, 2015; U.S.-China Economic and Security Review Commission, *Hearing on China's Space and Counterspace Programs*, written testimony of Kevin Pollpeter, February 18, 2015; Bill Gertz, "Stratcom: China Continuing to Weaponize Space with Latest Anti-Satellite Missile Shot," *Washington Free Beacon*, August 13, 2014; Brian Weeden, "Through a Glass, Darkly: Chinese, American, and Russian Anti-Satellite Testing in Space" *Secure World Foundation*, March 17, 2014; Brian Weeden, "Anti-Satellite Tests in Space—The Case of China," *Secure World Foundation*, August 16, 2013; Craig Murray, "China Missile Launch May Have Tested Part of a New Antisatellite Capability," *U.S.-China Economic and Security Review Commission*, May 22, 2013; Xinhua, "China Carries out Land-Based Mid-Course Missile Interception Test," January 28, 2013; Greg Kulacki, "Is January Chinese ASAT Testing Month?" *Union of Concerned Scientists*, January 4, 2013; and Xinhua (English ed.), "China Conducts Test on Ground-Based Midcourse Missile Interception," January 11, 2010.

Co-orbital Antisatellite Systems

Co-orbital antisatellite systems have not been a significant concern for the United States since the collapse of the Soviet Union. However, China's recent space activities indicate that it is developing co-orbital antisatellite systems to target U.S. space assets. These systems consist of a satellite armed with a weapon such as an explosive charge, fragmentation device, kinetic energy weapon, laser, radio frequency weapon, jammer, or robotic arm. Once a co-orbital satellite is close enough to a target satellite, the co-orbital satellite can deploy its weapon to interfere with, disable, or destroy the target satellite. Co-orbital satellites also may intentionally crash into the target satellite.[98]

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utility. ISR satellites, by contrast, are relatively few in number and are thus somewhat more vulnerable, although the changing velocity and altitude inherent to their highly elliptical orbit would complicate targeting. Brian Weeden, "Through a Glass, Darkly: Chinese, American, and Russian Anti-Satellite Testing in Space," *Secure World Foundation*, March 17, 2014.

Co-orbital antisatellite systems provide several advantages over current direct-ascent antisatellite missiles, including their ability to be used to target satellites in every orbital regime, generate less debris, conduct attacks without geographic limitations, and limit escalation, as many co-orbital attack options are reversible and offer plausible deniability. Additionally, co-orbital satellites would pose significant warning challenges for the U.S. Intelligence Community because they could be launched into orbit long before an attack.[99]

Since 2008, China has tested increasingly complex space proximity capabilities. Although these capabilities have legitimate applications for China's manned space program, the dual-use nature of the technology and China's secrecy surrounding the tests suggest China also is using the tests to develop co-orbital counterspace technologies.

- During a manned space mission in September 2008, China's Shenzhou 7 spacecraft deployed the BX–1, a miniature imaging satellite, which then positioned itself into an orbit around the spacecraft. The activities of the BX–1 may have been designed to test a dual-use on-orbit inspection capability for future inspector satellites. In addition to aiding China with maintenance of its satellites, inspector satellites could approach U.S. satellites in orbit to collect detailed images and intelligence on them. Moreover, at one point the BX–1 passed within 45 kilometers of the International Space Station, apparently without prior notification, suggesting it may have been simulating a co-orbital antisatellite attack.[100]

- In June 2010, China launched the SJ–12 satellite. Over the next two months, the satellite conducted a series of maneuvers and came within proximity of the SJ–6F, an older Chinese satellite that was placed into orbit in 2008. The activities of the SJ–12 may have been designed to test a co-orbital antisatellite capability, such as on-orbit jamming. Moreover, during its maneuvers, the SJ–12 apparently bumped the SJ–6F, causing it to drift slightly from its orbital regime. This activity suggests China also could have used the test to demonstrate the ability to move a target satellite out of its intended position by hitting it or attaching to it.[101]

- In July 2013, China launched a rocket carrying the CX–3, SY–7, and SJ–15 satellites, one of which was equipped with a robotic arm for grabbing or capturing items in space. Once all three were in orbit, the satellite with the robotic arm grappled one of the other satellites, which was acting as a target satellite.[102] The satellite with the robotic arm then changed orbits and came within proximity of a separate satellite, the SJ–7, an older Chinese satellite that was orbited in 2005.[103] Robotic arms can be used for civilian missions such as satellite repair, space station construction, and orbital debris removal; they also can attach to a target satellite to perform various antisatellite missions.[104]

Computer Network Operations

Chinese military doctrine and the integration of computer network operations, electronic warfare, and counterspace reflected in certain Chinese military organizations and research programs indicate the PLA during a conflict would attempt to conduct computer network attacks against U.S. satellites and the ground-based facilities that interact with U.S. satellites.[105] According to one Chinese author:

> *A military satellite cannot connect with the Internet. Therefore, some people think "hackers" cannot attack a satellite's command and control [system]. But in actuality, the microwave antenna of the satellite control is open, so one can intercept satellite information through technological means and seize the satellite's command and control [system]. Using this as a springboard to invade the enemy's independent network systems is entirely possible.*[106]

If executed successfully, such attacks could significantly threaten U.S. information superiority, particularly if they are conducted against satellites with sensitive military and intelligence functions. For example, access to a satellite's controls could allow an attacker to damage or destroy the satellite; deny, degrade, or manipulate its transmissions; or access its capabilities or the information, such as imagery, that can be gained through its sensors.

Chinese hackers likely have been responsible for several computer network operations against U.S. space assets, though the U.S. government has not publicly attributed any of them to China. If responsible, China likely used these intrusions to demonstrate and test its ability to conduct future computer network attacks and to perform network surveillance.

- In October 2007 and July 2008, cyber actors attacked the Landsat-7, a remote sensing satellite operated by the U.S. Geological Survey, resulting in 12 or more minutes of interference on each occasion. The attackers did not achieve the ability to command the satellite.[107]
- In June and October 2008, cyber actors attacked the Terra Earth Observation System satellite, a remote sensing satellite operated by NASA, resulting in two or more minutes of interference on the first occasion and nine or more minutes of interference on the second occasion. In both cases, the responsible parties achieved all steps required to command the satellite but did not issue commands.[108]
- In September 2014, cyber actors hacked into the National Oceanographic and Atmospheric Administration's (NOAA) satellite information and weather service systems, which are used by the U.S. military and a host of U.S. government agencies. NOAA stopped the transmission of satellite images to the National Weather Service for two days while it responded to the intrusion and "sealed off data vital to disaster planning, aviation, shipping, and scores of other crucial uses," according to a U.S. media report citing a discussion with NOAA officials.[109] The U.S. government has not publicly attributed the attack to any country or actors; however, then Congressman Frank Wolf stated, "NOAA told me it was a hack and it was China."[110]

Moreover, China's large-scale, state-sponsored theft of intellectual property and proprietary information through cyber espionage has enabled future space and counterspace operations by filling knowledge gaps in China's space R&D, providing insight into U.S. space plans and capabilities, and helping to identify vulnerabilities in U.S. space systems.

In May 2015, Pennsylvania State University disclosed that two separate groups of cyber actors had been sifting through the computers of its engineering school for more than two years. The University is also home to a separate lab that specializes in aerospace issues and works primarily for the U.S. military. Although the lab's networks are reportedly separate from those of the engineering school, the length of the breach raises the possibility that the hackers may have entered the lab's networks as well, according to a source familiar with the U.S. government investigation of the intrusions, as cited in a U.S. media article. This source also alleged that China sponsored at least one of the groups, while the other is believed to be state-sponsored as well.[111]

Earlier in June 2014, Crowdstrike, a private U.S. cybersecurity firm, published a report providing detailed technical information regarding the activities of a Chinese cyber threat group, which Crowdstrike refers to as "Putter Panda." According to the report, the group supports China's space surveillance mission and is subordinate to the Third Department of the PLA General Staff Department, widely believed to be China's premier organization responsible for signals intelligence collection and analysis. Crowdstrike assesses that Putter Panda since 2007 has targeted "government, defense, research, and technology sectors in the United States, with specific targeting of space, aerospace, and communications." [112]

Moreover, Mandiant, a U.S. cybersecurity firm, has responded to multiple incidents in which at least six distinct China-based threat actors have compromised aerospace and defense companies both in the United States and other countries. These threat groups, which Mandiant assesses most likely are associated with the Chinese government, have targeted the sector since at least 2006, and frequently steal sensitive data from their victims. Stolen files include human resources records, internal business communications, marketing and sales documents, and test results and other product information pertaining to the development and operation of missile systems and military and civilian satellite technology for both communications and location tracking.[113]

Ground-Based Satellite Jammers

Since the mid-2000s, China has acquired a number of foreign and indigenous ground-based satellite jammers, which are designed to disrupt an adversary's communications with a satellite by overpowering the signals being sent to or from it. The PLA could employ jammers to degrade or deny U.S. military systems' access to GPS and most satellite communications bands if they are operating within a few hundred kilometers of China.[114] GPS is particularly easy to jam because the signals are weak; as a result, even low-power jammers can deny or degrade the acquisition of a GPS signal over long distances. Although China's employment strategy for its ground-based jammers is unknown, Mr. Pollpeter posits that "given the relatively small size and long range of GPS jammers, [the strategy] could consist of [placing] a series of vehicle-mounted jammers . . . at intervals within the theater of operations to provide overlapping jamming zones." [115]

Directed Energy Weapons

China has been committing substantial resources to R&D for directed energy weapons, including those that could be used for antisatellite missions, since at least the 1990s. Directed energy weapons can deliver concentrated energy, atomic, or subatomic particles along a line-of-sight trajectory at or near the speed of light to damage or destroy equipment, facilities, and personnel.

By 2006, China had at least one ground-based laser designed to damage or blind imaging satellites.[116] At low energies, lasers can blind or damage a satellite's optical sensors; at high energies, lasers can cause physical damage to satellites.

In 2006, China fired a high-powered laser at a U.S. satellite, resulting in a temporary degradation to the satellite's functionality. Although it is unclear whether China fired the laser to determine the location of the satellite * or to "dazzle" it, China's test demonstrated a significant new capability that it almost certainly has continued to develop and improve over the last nine years.[117]

Additionally, China is researching radio frequency weapons, which are designed to damage or destroy electronic components of satellites by either overheating or short-circuiting them. Radio frequency weapons can be surface-based, space-based, or employed on missiles; they are thus useful in achieving a wide spectrum of effects against satellites in all orbits.[118] Although China's progress in this area is unknown, such weapons could feasibly be deployed in the next five to ten years.

Nuclear Weapons

China's nuclear arsenal provides an inherent antisatellite capability, as China could detonate a nuclear warhead in low Earth orbit using a ballistic missile. The electromagnetic pulse generated by the blast would destroy unshielded satellites † that are in line of sight of the explosion, and the resulting persistent radiation environment would slowly damage unshielded satellites in low Earth orbit as they pass through the area. Although the blast would not directly affect satellites in higher orbits, the radiation could impede their communications with ground stations. China likely would only consider using nuclear weapons in space during an ongoing nuclear war, given that the detonation would also affect China's satellites as well as those of other countries.[119]

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* Satellite laser ranging is used to precisely determine a satellite's location by measuring the distance from a ground station to a satellite based on the time an ultra-short laser pulse fired from the ground takes to reach and be reflected back from the satellite. Yousaf Butt, "Satellite Laser Ranging in China," *Union of Concerned Scientists Technical Working Paper*, January 8, 2007.

† Physical shielding using sheets of aluminum, sometimes supported by other materials, reduces the risk to satellites of damage from micrometeoroid and orbital debris impact. Colin Schultz, "How Do You Shield Astronauts and Satellites from Deadly Micrometeorites?" *Smithsonian.com*, June 28, 2013.

China's Space-Based C4ISR Modernization

China's initial C4ISR modernization efforts focused on developing a robust and secure terrestrial network of fiber optic cables, mobile radios, datalinks, and microwave systems. In the mid-2000s, however, China shifted the emphasis of its C4ISR modernization program to expanding and enhancing the country's space-based infrastructure. China had approximately 142 operational satellites in orbit as of September 1, 2015, compared to about 10 in 2000 and 35 in 2008.* Approximately 95 of these satellites are owned and operated by Chinese defense organizations, including the PLA, the Ministry of Defense, and various entities under the state-owned space industry conglomerates.[120]

Intelligence, Surveillance, and Reconnaissance

China is fielding sophisticated satellites that feature electro-optical (EO), synthetic aperture radar (SAR), and electronic reconnaissance (ELINT) sensors. EO sensors passively detect light images of maritime and ground-based targets. Although EO sensors can achieve the highest resolution of these types, they are adversely affected by poor weather conditions and cannot image at night. SAR sensors use a microwave transmission to create images of maritime and ground-based targets. They tend to have lower resolution than EO sensors but can image during night or day and in all weather conditions. ELINT sensors detect electronic signal emissions and then determine emitter locations.[121]

Combining these varying capabilities is crucial for locating and tracking a moving target. A study by authors affiliated with the PLA Navy Aerospace Engineering Academy illustrates the importance of integrating the information obtained from ISR satellites for long-range antiship ballistic missile (ASBM) strikes:

> *During the process of planning [to use] the fire power of an ASBM, [there is a need] for obtaining reliable target intelligence information for guiding the missile attack. This could be achieved by integrating EO imaging satellites, SAR imaging satellites, ELINT satellites, naval ocean surveillance satellites, mapping resource satellites, and highly accurate commercial remote sensing satellite imagery, which could be purchased on the international market. Through the integration of the data obtained via a number of different satellites, and with the addition of processing and data fusion, [one could] guarantee missile guidance requirements for all types of target information for a long-range ASBM strike.*[122]

China's major military-relevant ISR satellites are the Yaogan, Shijian, Gaofen, and Haiyang, each of which is examined in detail in the following paragraphs. China also has a large number of imaging and remote sensing satellites that are owned and operated by civilian or commercial entities. Given the PLA's central role in the development, launch, and operations of all of China's satellites,

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* For comparison, the United States has approximately 549 active satellites in orbit and Russia has approximately 131 active satellites in orbit. Union of Concerned Scientists, "UCS Satellite Database."

these civilian and commercial satellites likely contribute to the PLA's C4ISR efforts whenever it is technically and logistically feasible for them to be so utilized,[123] and they would probably be directly subordinate to the PLA during a crisis or conflict.

Yaogan Satellites

The Yaogan series of satellites, the first of which was launched in 2006, serves as the core component of China's maritime ISR architecture. Chinese state-run press claims the satellites are used to conduct scientific experiments and carry out land surveys, among other functions.[124] Because the series is owned and operated by the PLA, however, it likely is used primarily for broad area maritime surveillance in support of the PLA's efforts to detect, track, and target foreign ships, such as U.S. carrier strike groups. China to date has launched 37 Yaogan satellites,[125] including EO, SAR, and ELINT variants.[126]

Shijian Satellites

China's Shijian series of satellites, the first of which was launched in 1971, is owned and operated by China's Academy of Space Technology. The Shijian satellites have a variety of configurations and missions. Although some have been used for strictly civilian purposes, such as crop breeding,* many appear to be military ISR satellites based on their suspected payloads, their orbital characteristics, and the secrecy surrounding their launches. Some Shijian satellites likely feature ELINT sensors used by the PLA for broad area maritime surveillance. Others probably are equipped with infrared sensors to detect ballistic missile launches in support of a future early warning system.[127] According to Mr. Pollpeter, the development of such a system could indicate a change in China's nuclear posture:

> *The deployment of a space-based ballistic missile early warning system may also signal a change in China's nuclear doctrine from "no first use" to "launch on warning." China's current nuclear force doctrine relies on retaliating only after a nuclear first strike from an opponent. A "launch on warning" system would make China's nuclear force more survivable since China would have warning that an attack is imminent, but would also present the possibility for false warnings, which could be catastrophically destabilizing during a conventional conflict*.[128]

Gaofen Satellites

The Gaofen series of EO/SAR satellites, the first of which was launched in 2013, features China's first high-definition satellite and first satellite capable of sub-meter resolution; the series also

* According to Mr. Pollpeter, "the Shijian-8 was the world's first satellite devoted to crop breeding. Seeds were placed in the satellite and then exposed to the higher radiation levels of space in the hopes that genetic mutations [might] occur. The seeds were then removed from the satellite after it returned to Earth and grown." Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 77.

incorporates several design innovations. According to Beijing, the Gaofen-1 "has been used in land resource investigation, mineral resource management, atmospheric and water environment quality monitoring, and natural disaster emergency response and monitoring," and its imagery has supported "tens of national ministries and agencies, local governments, research institutions, universities, enterprises and organizations in China." [129] China also employed the Gaofen-1 to assist in the search for missing Malaysian airliner MH370 in 2014, demonstrating its ability to conduct broad maritime surveillance that could be useful for the PLA. China launched the second Gaofen in 2014 and two more in 2015, and is expected to launch as many as four more by 2016.[130]

Haiyang Satellites

The Haiyang series of satellites, the first of which was launched in 2002, is owned and operated by the State Oceanic Administration. The series primarily supports China's civilian and scientific organizations involved in monitoring the characteristics of the ocean environment, including pollution, topography, wind fields, surface temperatures, and currents. The fact that the State Oceanographic Administration oversees China's maritime law enforcement organizations, however, suggests these satellites also play a role in monitoring and enforcing China's maritime claims in the East and South China seas. Indeed, in 2012 a Chinese official said future Haiyang satellites will be used to monitor the disputed Senkaku Islands and Scarborough Reef. To date, China has launched three Haiyang satellites (two of which are operational) and plans to launch five more by 2020.[131]

Remote Sensing Commercial Satellites and Microsatellites

China launched the four-satellite Jilin-1 constellation in October 2015. These have been described as the country's first "self-developed" remote sensing satellites intended for commercial use and were reportedly developed by a company subordinate to a research institution of the Chinese Academy of Sciences.[132]

Since 2000, China has launched at least 28 microsatellites*, including Chuangxin/Banxing, Fengniao, Naxing, Tiantuo, and Xinyan types, most of which belong to civil users.[133] China launched Tiantuo-2, which carries four video cameras for data transmission and live tracking of moving objects on Earth, in September 2014.[134] Most recently, China reportedly launched 20 microsatellites assembled by universities and research institutes in September 2015.[135] Although their small size often limits their capabilities, microsatellites are significantly cheaper and easier to develop and manufacture than larger satellites that serve similar functions. Microsatellites also have lower observable signatures than larger satellites, making them harder for an adversary to track in space.[136]

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* "Microsatellites" are satellites with a mass between 10 and 100 kilograms. Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 23.

Positioning, Navigation, and Timing

In December 2012, China's Beidou regional satellite navigation system* became fully operational. Using 19 satellites and a network of ground stations, Beidou provides subscribers, including the PLA, with 24-hour regional position, navigation, and timing (PNT) services. Unlike other PNT systems, Beidou offers a short message service that can accommodate up to 120 Chinese characters per transmission. Beidou reportedly provides positioning accuracies of 10 meters or better, depending on the location, for civilian users. In comparison, GPS has 31 satellites and can provide positioning accuracies of several meters, depending on the location, for civilian users.† China intends to construct thousands of additional ground stations and launch additional satellites to improve Beidou's positional accuracies within China.[137]

Beijing plans to expand the Beidou constellation from 19 to 35 satellites by 2020 in order to provide global coverage. If successful, China will become the third country in the world after the United States and Russia to field an independent global satellite navigation system. China launched its 18th and 19th Beidou satellites in July 2015.[138]

China's Satellite Navigation Office has emphasized Beidou's importance to the PLA and to China's commercial interests, stating the system meets the "demands of China's national security, economic development, technological advances and social progress . . . safeguard[s] [China's] national interests . . . enhance[s] [China's] comprehensive national strength . . . promote[s] the development of [China's] satellite navigation industry . . . make[s] contributions to human civilization and social development . . . [and] serve[s] the world and benefit[s] mankind." [139]

Although Beidou has a wide and growing range of civilian applications that will benefit China's economic development,‡ China developed its indigenous PNT system primarily for military purposes. Prior to the deployment of Beidou, most PLA units used GPS for positioning and maneuver and most PLA precision weapon systems used GPS for guidance. The PLA has considered this dependence on a foreign PNT system to be a strategic vulnerability since at least the mid-1980s. These fears were exacerbated during the 1995–1996 Taiwan Strait Crisis. According to a retired PLA general, the PLA concluded that an unexpected disruption to GPS caused the PLA to lose track of some of the ballistic missiles it fired into the Taiwan Strait during the crisis. He then said that "it was a great shame for the PLA . . . an unforgettable humiliation. That's how we made up our mind to develop our own global [satellite] navigation and positioning system, no matter how huge the cost. Beidou is a must for us. We learned it the hard way." [140]

The PLA in the early 2000s began to gradually incorporate Beidou into its ground, air, and naval forces, and by the late 2000s

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* The regional Beidou system, which China refers to as Beidou-2, grew out of an earlier satellite constellation, known as Beidou-1. Beidou-1 provided limited position, navigation, and timing services in China and a small portion of East Asia but served primarily as a developmental platform for future projects.

† Beidou and GPS provide higher positional accuracies for the PLA and U.S. military, respectively.

‡ Civilian applications include road transport, aviation, shipping and rail transport, science, surveying and mapping, geophysics, telecommunications, financial services, and social activities.

was using Beidou for positioning and maneuvering, friendly force tracking,* and secure communications. Public information about China's incorporation of Beidou into its weapons systems is scarce, but China almost certainly is equipping its ballistic and cruise missiles to operate with both GPS and Beidou. If this is true, PLA operators could switch to Beidou to guide a missile to its target if GPS were (1) denied by the United States during a conflict or (2) deemed unusable by PLA commanders due to operational security concerns. Additionally, the availability of Beidou would allow China to attack an adversary's access to GPS without disrupting the PLA's own capabilities.[141]

China is attempting to make the Beidou system more prevalent in its domestic economy in order to compete with GPS, which dominates 95 percent of market share for satellite navigation products in China due to its earlier introduction, better known brand name, superior accuracy, and cheaper receiver costs. By 2020, China aims to gain 70–80 percent of the domestic satellite navigation market, which is estimated to reach $65 billion. To achieve this goal, China has announced several measures to encourage or force its citizens to adopt Beidou, including the requirement that, in order to receive transportation certificates, all new heavy trucks manufactured in any of nine Chinese provinces must be equipped with Beidou. Already more than 50,000 Chinese fishing boats—many of which are supporting China's efforts to advance its maritime claims—have been equipped with the system.[142]

Beijing has also taken several steps to promote Beidou to countries throughout Asia, where it currently occupies only 1 percent of the market, and to position the service to break into the global PNT market in 2020.

- China released the technical specifications of Beidou's open signal to allow for the production of ground receivers and offers free Beidou service for civilian and commercial users throughout Asia.[143]
- China has reached agreements with Brunei, Laos, Pakistan, and Thailand to provide Beidou for government and military customers at heavily subsidized costs. These agreements include provisions allowing Beijing to build satellite ground stations in each country; the stations will be used to increase Beidou's range and signal strength.[144] China already has built three ground stations in Thailand, and plans to build more than 220 additional stations in the country. According to a senior Chinese industry official involved in the development of Beidou stations in Thailand, "with these stations, Beidou could better service local customers and will be able to gradually squeeze GPS's market share."[145] China ultimately aims to build a vast network of ground stations throughout Asia.
- China reportedly is pursuing various cooperative arrangements involving Beidou with other countries, including Israel, Malaysia, Mexico, North Korea, Russia, Singapore, and Sweden.[146]

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* Beidou provides automatic position reporting back to PLA command and control centers, allowing the PLA to constantly monitor the location of PLA units as well as Beidou-equipped Chinese fishing boats. U.S. Office of Naval Intelligence, *The PLA Navy: New Capabilities and Missions for the 21st Century*, 2015, 22.

Additionally, according to official Chinese press citing an interview with the spokesperson for Beidou, "the Beidou satellite navigation system will tap into opportunities brought by the Belt and Road Initiative,* and will engender further cooperation with other satellites. ... During the process, China will step up cooperation with researchers working with other satellite navigation systems." [147]

- In November 2014, Beidou won approval from a United Nations' maritime body that sets standards on international shipping, joining GPS and Russia's GLONASS as the only navigational systems recognized for operations at sea. This formal recognition could help to further promote Beidou's use around the world by boosting brand awareness and signaling that Beidou can achieve its stated accuracy.[148]

Communications

China in 2000 began launching dedicated military communications satellites to provide secure voice and data communications for PLA users. Today, the PLA operates at least four communications satellites: Chinasat-1A, Chinasat-2A, Chinasat-20A, and Chinasat-22A. To meet bandwidth or geographic requirements or add resilience, the PLA could leverage communications satellites owned by China's civilian agencies or Chinese-controlled telecommunications corporations, as well as communication satellites owned by international corporations.[149]

China's commercial communications satellites include the Apstar-7, which is owned and operated by a Hong Kong-based subsidiary of the state-controlled China Satellite Communication Company. From 2012 to 2014, the U.S. Department of Defense (DOD) leased the Apstar-7's services to satisfy satellite communications requirements from U.S. Africa Command.[150] Following media and Congressional scrutiny of the deal, however, DOD did not renew the lease for 2015. According to Doug Loverro, DOD's deputy assistant secretary for Space Policy: "Working with [the Office of the Secretary of Defense], U.S. Africa Command has made significant progress over the last year in moving DOD [satellite communication] leases from the Chinese Apstar system to other commercial satellite providers in the region. We have already transitioned over 75 percent of the Apstar bandwidth to other satellites, and our intent is to be completely transitioned by May of [2014]." [151]

China plans to launch the world's first experimental quantum communications † satellite in 2016. This technology could eventu-

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* China's Silk Road Economic Belt initiative is aimed at enhancing economic and cultural integration between China and Central Asia. The land-based Silk Road Economic Belt has a maritime counterpart, the "21st Century Maritime Silk Road," which will run from China's coast through Southeast Asia and the Indian Ocean to Africa and the Mediterranean Sea. Together, they are commonly referred to as the "One Belt, One Road" initiative. For more information on the initiative, see Chapter 3, Section 1, "China and Central Asia."

† Quantum communications, a subset of quantum information science, refers to the transmission of a quantum state (i.e., using quantum data rather than bits) from one place to another. A quantum communication network's key characteristic is its use of the quantum key distribution method which is, in theory, unbreakable—any attempt to intercept the encryption key would alter the physical status of the data (otherwise in a state of "superposition," existing in two states at the same time) and trigger an alert to the communicators. Quantum communication has thus far been limited to short distances due to the technological difficulty in maintaining the quantum data's fragile state over a long distance. Giuseppe Vallone et al., "Experimental

ally enable the PLA to instantaneously send, receive, and decipher messages around the world using a virtually unbreakable encryption key to provide secure electronic transmission of sensitive information.[152]

China also has announced plans to launch its first communications satellite that uses electric propulsion around 2020, following previous demonstrations of this technology by the Unites States, Russia, Europe, and Japan.[153] By using electric-powered engines instead of chemical propellant, such satellites will allow China to launch larger payloads at a fraction of the cost of traditional launch vehicles and improve communications satellites' lifespan from 15 to 20 years. The main drawback of this technology will be the longer time required to bring a satellite into orbit—up to eight months instead of several weeks.[154] According to a deputy chief designer of China's communications satellites at the China Academy of Space Technology, the technology will also be important for future manned spaceflight missions, including China's future space station around 2022.[155] The PLA could eventually use the technology to launch more advanced remote sensing ISR satellites into high Earth orbit, as well as for military missions in deep space.[156]

China's network of military communication satellites will be assisted by its Tianlian data relay satellite constellation, which was completed in 2012. As China orbits relay-capable satellites,* the Tianlian constellation will reduce the time the PLA must wait to receive data from its ISR satellites and thus enhance its ability to provide near-real-time ISR data to locate, track, and target U.S. ships operating in the Western Pacific. Without a data relay system, Chinese satellites must wait until they come into view of ground stations in China before sending ISR data, potentially causing a time lag of up to several hours and thus reducing the PLA's ability to receive time-sensitive intelligence on mobile targets.[157] Mr. Pollpeter explains:

> *A remote sensing satellite at an altitude of 600 [km], such as China's Yaogan series, can communicate with ground stations at a range of around 2,800 km. Beyond this range, they must retain their data until they come in range of a ground station. With the use of data relay satellites operating in geosynchronous [Earth] orbit above ISR satellites, an ISR satellite can transmit its data to a data relay satellite, which will then transmit the data to a ground station. In this way, time-sensitive data and communications can be immediately downloaded to a ground station for processing. They can also be used to assist with data transmission from launch vehicles to ground stations and can transfer data between aircraft, space tracking ships, and other craft*.[158]

Satellite Quantum Communications," *Physical Review Letters* 15:4 (July 20, 2015): 1; Yu Dawei, "In China, Quantum Communications Comes of Age," *Caixin*, February 6, 2015; Stephen Chen, "China to Launch Hack-Proof Quantum Communication Network in 2016," *South China Morning Post* (Hong Kong), November 4, 2014; and Michael A. Nielsen and Isaac L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, 2000, 14.

*The number of China's current ISR satellites that are relay-capable is unknown. However, China almost certainly will add this capability to all of its future ISR satellites.

China's Space Launch Capabilities

Since approximately 2000, China has significantly enhanced its ability to launch military, civilian, and commercial satellites. China conducted 83 known space launches from 2010 to 2014, only 10 fewer than the United States during this period (see Table 2).[159] This growth is expected to continue as China expands and improves its ground-based space infrastructure and launch vehicles.

Table 2: Chinese versus U.S. Space Launches, 2010–2014

	2010	*2011*	*2012*	*2013*	*2014*
Chinese Launches (Satellites Deployed)	15 (20)	19 (18)	19 (25)	14 (17)	16 (19)
U.S. Launches (Satellites Deployed)	15 (41)	19 (39)	16 (35)	20 (85)	23 (110)

Note: Estimates of the number of space launches and satellites deployed vary by source due to a number of judgment decisions involved in the calculations, such as how to determine the ownership of a satellite company belonging to a certain country, whether to count objects as satellites or as space junk, and whether to include small satellites that can separate from an object already in orbit. For the number of new Chinese satellites deployed since 2010 by type, see U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, May 8, 2015, 70.

Source: Jonathan McDowell (Astrophysicist, Harvard-Smithsonian Center for Astrophysics), interview with Commission staff, June 17, 2015.

China has eight Long March (LM) liquid-fuel space launch vehicles that provide lift capacities ranging from light- to heavy-lift and the capability to deploy payloads at altitudes ranging from low Earth orbit to geosynchronous Earth orbit. These vehicles consist of the LM–2C, LM–2D, LM–2F, LM–3A, LM–3B, LM–3C, LM–4B, and LM–4C. China has conducted more than 205 launches since its first rocket flew in 1970.[160]

In tandem with efforts to upgrade its current launch vehicles, China is developing a new generation of liquid-fuel rockets designed to meet the country's future launch requirements. Once operational, this new generation—which will consist of the LM–5, LM–6, and LM–7—will substantially increase China's payload capacity while offering improved reliability, increased flexibility, and reduced costs.[161] China conducted the debut launch of the LM–6, reportedly using a safer and more efficient liquid propellant, in September 2015. The rocket carried 20 microsatellites and will primarily be used to launch microsatellites in the future, according to state-run media.[162]

The LM–5 will be one of the largest and most powerful space launch vehicles in the world and will more than double the size of payloads China can launch into low Earth orbit and geosynchronous Earth orbit. Although China publicly advertises the LM–5 as beneficial to its human spaceflight program, the rocket likely will also launch advanced C4ISR satellites, space station modules, and potentially reusable orbital vehicles that could be used for counterspace and ISR missions. The first LM–5 launch, which has been repeatedly delayed by manufacturing issues, could occur by the end of 2015.[163]

China also is conducting preliminary research on a super-heavy-lift launcher—the LM–9—that could be used to send large payloads, such as a manned lunar lander, to the Moon; the LM–9 also would be capable of launching into deep outer space. According to a senior rocket engineer at the China Aerospace Science and Technology Corporation, which is responsible for producing China's LM series, "estimates show the LM–5 will have to use four launches to fulfill a manned mission to the Moon while the LM–9 will need only one." [164]

In addition to these liquid-fuel launch vehicles, China is developing at least three types of solid-fuel rockets: the LM–11, the Kuaizhou, and the Feitian. China successfully conducted the inaugural launch of the LM–11, the largest of the developmental solid-fuel rockets, in September 2015.[165] China has tested the smaller Kuaizhou rocket twice, most recently in November 2014, and revealed the existence of the similarly-sized Feitian at China's Zhuhai Airshow in November 2014.[166] Solid-fuel rockets lack the payload capacity of liquid-fuel rockets but are cheaper to manufacture, simpler to operate, and can be released with less preparation. Furthermore, the launchers are transportable or "road-mobile," meaning they do not rely on fixed launch structures and are thus less vulnerable to attack. China likely is developing these new solid-fuel launch vehicles to put microsatellites into orbit on short notice. Such a capability would allow the PLA to rapidly replace or augment its satellite deployments in the event of any disruption in coverage during a conflict.[167]

China debuted the Yuanzheng-1, described by a Chinese state-run media outlet as an "independent aircraft" or "space shuttle bus" that is "installed on [a] carrier rocket with the ability of sending one or more spacecraft into different orbits in space," in March 2015.[168] The spacecraft, more accurately described as a type of potentially reusable orbital transfer vehicle (termed a "space tug" if reusable or an "upper stage" if expendable),* [169] uses a small thrust engine with a 6.5-hour lifetime and will be utilized with Long March-3A, 3B, and 3C vehicles primarily to insert Beidou satellites into medium Earth orbit and geostationary Earth orbit. In both the March 2015 launch and a second in July 2015, Yuanzheng-1 was used to successfully deploy Beidou satellites. As it can reportedly transfer multiple spacecraft into separate orbits, the vehicle has the potential to improve the efficiency of China's space launches.[170]

China's Civilian Space Activities

Although it lacks a designated civilian space program, China since the mid-1990s has incrementally developed a series of ambitious space exploration programs, ostensibly for civilian purposes, with high-level backing and sustained financial support. China already has achieved milestones that few other countries have reached, including sending a manned mission to space and conducting a soft landing of a spacecraft on the Moon. However, China

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*An orbital transfer vehicle (OTV) is defined as "a propulsion system used to transfer a payload from one orbital location to another—as, for example, from low Earth orbit to geostationary Earth orbit. Orbital transfer vehicles can be expendable or reusable . . . a reusable OTV is sometimes called a space tug." Joseph Angelo, *Dictionary of Space Technology*, Routledge, 2013, 286.

is still largely catching up to the two premier space powers, the United States and Russia, which accomplished these feats decades ago. Nonetheless, China has made rapid progress in developing its space capabilities—exceeding regional rival space programs such as those belonging to Japan and India—and is gradually closing the technological gap with the United States and Russia.[171]

Nearly all of the technologies used in China's civilian space activities also have military applications and are therefore dual-purpose, as is the case with other countries' space programs. Alanna Krolikowski, Princeton-Harvard China and the World Program postdoctoral fellow at Harvard University, explained to the Commission:

> *Particular items of commercial space hardware can be repurposed for defense applications with only minor modifications. These items include entire systems, such as launch vehicles, which can launch both civil-commercial and defense payloads. They also include sub-systems, such as sensors and robotic arms on spacecraft, which can in some measure be applied or adapted to intelligence or counterspace missions. Finally, dual-use technologies also include many smaller components, such as radiation-hardened electronic elements*.[172]

Human Spaceflight

China's human spaceflight program is one of the country's largest and most technologically-advanced projects, involving some 3,000 organizations and several hundred thousand personnel.[173] China is only the third country behind the United States and Russia to have independently launched a human into space.

China's human spaceflight program consists of three phases. In phase one (1992–2005), China launched several unmanned Shenzhou spacecraft to develop technologies necessary for its first manned spaceflights in 2003 and 2005. In phase two (2005–2013), China conducted both manned and unmanned docking maneuvers between the Shenzhou spacecraft and the Tiangong-1 space lab. In phase three, scheduled for completion by 2022, China plans to launch a permanent manned space station into orbit.[174]

- China has conducted 10 Shenzhou missions and plans to conduct the 11th in 2016. The Shenzhou spacecraft, which was designed by the China Academy of Space Technology, weighs approximately 7.8 tons and measures about 8.86 meters in length, and is able to support up to three people for up to seven days. It consists of three sections: an orbital module, a descent module, and a propulsion module.[175]
- China launched the Tiangong-1 space lab into orbit in 2011. The lab, which was developed by the China Academy of Space Technology, weighs approximately 8.5 tons and has an area of about 15 cubic meters, allowing it to hold up to three astronauts. China is expected to launch the follow-on to the Tiangong-1, the Tiangong-2, in 2016.[176] Following the Tiangong labs, China plans to launch a permanent manned space station in several phases beginning with an experimental

"core module" in 2018. Two additional modules are scheduled for launch in 2020 and 2022.[177] At 60 tons, the space station will be similar in size to the United States' first space station, Skylab, which was launched in the 1970s; it will be much smaller than the approximately 450-ton International Space Station, which is operated by the United States and Russia.[178] China expects to complete its space station launch around 2022, while the International Space Station is currently scheduled to complete its mission and be deorbited in 2024, potentially leaving China with the world's only active space station.[179]

Table 3: China's Human Spaceflight Missions

Spacecraft	Launch Date	Flight Time	Purpose
Shenzhou-1	November 20, 1999	21 hours	Test
Shenzhou-2	January 10, 2001	7 days	Test
Shenzhou-3	March 25, 2002	8 days	Test
Shenzhou-4	December 30, 2002	7 days	Test
Shenzhou-5	October 15, 2003	21 hours	Manned (1 crew)
Shenzhou-6	October 12, 2005	4+ days	Manned (2 crew)
Shenzhou-7	September 25, 2008	2+ days	Manned (3 crew); Extravehicular activity
Tiangong-1	September 29, 2011	36 months (ongoing)	Prototype space lab
Shenzhou-8	November 1, 2011	16 days	Unmanned docking
Shenzhou-9	June 16, 2012	14 days	Manned (3 crew) docking
Shenzhou-10	June 11, 2013	15 days	Manned (3 crew) docking

Source: Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 46.

Lunar Exploration Program

China's space experts proposed a lunar exploration program in 1991, and Beijing approved the first lunar orbiting mission in 2004.[180] According to the State Administration of Science, Technology, and Industry for National Defense, the program is a "major strategic decision by the CCP Central Committee, State Council, and Central Military Commission taking a broad look at [China's] overall modernization and construction by grasping the world's large [science and technology (S&T)] events and promoting [China's] space enterprise development, promoting [China's] S&T advancement and innovation, and improving [China's] comprehensive national power." [181]

China's lunar exploration program consists of three phases involving the Chang'e spacecraft and several lunar landing vehicles.

- In phase one (2004–2007), the Chang'e-1 and the Chang'e-2 spacecraft orbited the Moon to map the lunar surface. The missions also tested China's ability to control objects in deep space.

- In phase two (2007–2014), the Chang'e-3 spacecraft landed a lunar vehicle on the Moon. The vehicle deployed a rover, designated "Jade Rabbit," * to study the lunar surface and analyze its soil. Jade Rabbit has far exceeded its expected lifespan of three months; after mechanical failures throughout the mission, the rover was still communicating with Earth as of July 2015 despite being unable to move.[182] With the successful landing of the Chang'e-3, China became only the third country behind the former Soviet Union and the United States to conduct a soft landing on the Moon and the first to do so since 1976. Later in the second phase, China employed the Chang'e-5 spacecraft to test technologies required to retrieve and return a lunar sample to Earth.[183]
- In phase three, China plans to send a rover to the Moon and bring it back to Earth after it collects soil samples. The mission, scheduled for 2017, will use the Chang'e-6 spacecraft and be launched from China's new Wenchang launch center on Hainan Island.[184]
- In a potential fourth phase, China announced in September 2015 that it would send the Chang'e-4 spacecraft—originally designed as a backup for Chang'e-3—to land on the moon's "dark side" before 2020, which China would be the first nation to accomplish. The stated objective of this mission is to study geological conditions on the dark side, which could eventually lead to the placement of a radio telescope for use by astronomers.† [185]

Jeffrey Plescia, the chairman of NASA's Lunar Exploration Analysis Group, compared the lunar programs of China and the United States:

> *China has had a well-developed, focused plan, and they are using incremental steps to [carry out] lunar exploration. I would guess that, given the pieces they have tested, [they] have a high probability of success [in phase three]. . . . They are demonstrating that they have the technical capability [to conduct] the most sophisticated deep-space activities. They have a program, and they can keep to the schedule and accomplish mission goals on time. [By comparison] the United States has been floundering around for decades, trying to figure out what to do.*[186]

* Jade Rabbit is equipped with a set of cameras to analyze the lunar surface and a robotic arm to gather samples of lunar soil. It has less than 16 percent of the mass of NASA's Mars rovers. Kevin Pollpeter, *China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States* (Prepared for the U.S.-China Economic and Security Review Commission by the University of California Institute on Global Conflict and Cooperation, March 2, 2015), 58–59.

† The far side or "dark side" of the moon is an ideal location for sensitive instruments, as radio transmissions from Earth are unable to reach it. Associated Press, "China Sets Its Space Exploration Sights on the Dark Side of the Moon," September 14, 2015.

Although China's lunar program is motivated primarily by prestige and scientific objectives, China also may seek to use the program to exploit the Moon's natural resources. Chinese analysts have noted that the Moon contains large amounts of 14 elements in particular, including iron, titanium, and uranium, that could be useful for economic development. Helium-3—of which the Moon has 1–5 million tons—appears to be of specific interest to the analysts, who estimate that 100 tons of the element could supply all of the Earth's energy requirements for one year, and that the revenue derived would make the endeavor economically feasible.[187] Importantly, exploitation of helium-3 for energy production would require the design and production of a commercially-viable nuclear fusion reactor, a technology not yet demonstrated by any nation. Should fusion power become available, however, helium-3 provides the most promising fuel and is almost entirely unavailable on earth.[188]

Beijing has not approved a plan to send humans to the Moon. In its 2011 white paper on space, however, Beijing acknowledged it is "researching the critical technologies for manned lunar exploration," and it began a feasibility study that same year for a manned mission to the Moon with a potential launch date of 2020, 2025, or 2030.[189]

Mars Exploration

Although Beijing has not approved a mission to Mars, top Chinese scientists have expressed interest in a Mars exploration program,[190] and China's defense industry and the Chinese Academy of Sciences are conducting studies on the feasibility of landing a robotic rover on the planet.[191] Moreover, the China Aerospace Science and Technology Corporation's debut of a full-size Mars rover model at the 2014 Zhuhai Airshow suggests China has begun preliminary research into the necessary technology for such a mission.[192]

U.S.-China Space Cooperation

Limited U.S.-China space cooperation began in the late 1970s, when the two countries signed a space exchange agreement and a memorandum of understanding on space technology cooperation.[193] U.S.-China cooperative space activities increased between 1990 and 1999, when the United States looked to China for satellite launch services. Following the loss of the space shuttle Challenger in 1986, which effectively ended the United States' plan to launch future military and commercial satellites aboard space shuttles, the United States faced a shortage of satellite launch facilities and began contracting launches out to other countries, including China. During this period, China launched a total of 19 U.S.-manufactured commercial satellites. Cooperation ended in 1999 when Congress passed a law prohibiting the launch of U.S. satellites by China, following revelations that several U.S. companies involved in the Chinese launches had illegally transferred potentially sensitive military information to China and that China had stolen classified information on advanced U.S. nuclear weapons technology.[194]

Since this decision, aside from limited instances of cooperation, U.S.-China space relations have stagnated due to ongoing U.S. government concerns about China's efforts to illicitly procure U.S. space technology.* Washington also remains wary of China's intentions as a growing space power, particularly with respect to China's lack of transparency regarding its intentions in space and China's focus on developing counterspace capabilities to restrict U.S. freedom of movement in space.

Despite tensions in the U.S.-China space relationship, events prior to 2011 suggested new momentum in bilateral space cooperation. The United States and China held several high-level visits from 2004 to 2010: the administrator of the China National Space Administration visited NASA in 2004, and the NASA administrator visited the Agency in 2006 and 2010.[195] A joint statement produced during President Obama's visit to China in 2009 expressed that "China and the United States look forward to expanding discussions on space science cooperation and starting a dialogue on human spaceflight and space exploration."[196] In January 2011 the Obama Administration also invited a Chinese delegation to visit NASA headquarters and other NASA facilities later that year to reciprocate for the NASA administrator's "productive" 2010 visit to China.[197]

In November 2011, however, Congress, based on concerns regarding China's efforts to illegally acquire U.S. space technologies, passed a prohibition against NASA conducting a range of activities with China. The law states:

> *None of the funds available by this Act may be used for the National Aeronautics and Space Administration (NASA) or the Office of Science and Technology Policy (OSTP) to develop, design, plan, promulgate, implement, or execute a bilateral policy, program, order, or contract of any kind to participate, collaborate, or coordinate bilaterally in any way with China or any Chinese-owned company unless such activities are specifically authorized by a law enacted after the date of enactment of this Act*.[198]

The law further applies this limitation to "any funds used to effectuate the hosting of official Chinese visitors at facilities belonging to or utilized by NASA." It only allows for NASA to engage in "activities which NASA or OSTP have certified pose no risk of resulting in technology transfer, data, or other information with national security or economic security implications to China or a Chinese-owned company," requiring the certification to be submitted to Congress 14 days beforehand.[199] Language added in 2013 requires that these activities also "not involve knowing interactions with officials who have been determined by the United States to have direct involvement with violations of human rights."[200] Under this law, NASA's administrator has still been able to meet with Chinese counterparts in China and in official multilateral settings, and visits by Chinese nationals to NASA facilities are permitted if certified and presented to Congress as required.[201] The law has notably disallowed participation by Chinese astronauts in missions to

* Among China's most effective methods for acquiring sensitive U.S. technology are cyber espionage; witting and unwitting collection by Chinese students, scholars, and scientists; joint ventures; and foreign cooperation. For more information on the subject, see the U.S.-China Economic and Security Review Commission, *2014 Report to Congress*, November 2014, 294–299.

the International Space Station, though China's noninvolvement in the program predates 2011.* [202] Additionally, a ban mistakenly placed by NASA officials on Chinese scientists' participation at an international NASA conference in 2013 was misattributed to the law.[203] China's pursuit of enhanced bilateral space cooperation has included efforts to persuade the United States to lift these restrictions, with a 2013 commentary in state-run *PLA Daily* specifically calling for the removal of the "'Wolf Clause'† that bans China-U.S. space cooperation," terming it "a huge roadblock in terms of bilateral cooperation and mutual benefits." [204]

Bilateral Space Activities beyond NASA

Although the recent Congressional regulations place strict limitations on collaboration between NASA and the Chinese space industry, the United States and China since 2012 have expanded their cooperation on space activities that do not involve NASA.

- In 2012, the U.S. Geological Survey of the Department of the Interior agreed to provide imagery from its two Landsat satellites to the Center for Earth Observation and Digital Earth of the Chinese Academy of Sciences, apparently continuing China's use of Landsat imagery since 1986. Importantly, in 2008 current and archived Landsat imagery going back to 1972 had also become available online for free to users who register with the U.S. Geological Survey. These satellites image the Earth continuously and cover each point on Earth once every 16 days, and the Chinese Academy of Science reportedly uses this imagery for its research on Chinese environmental and land-use issues. Although the Landsat imagery is not sufficient to support time-sensitive military operations, the PLA could use it for map making and broad area analysis of trends in terrestrial infrastructure.[205]
- In 2014, the Space Studies Board of the U.S. National Academy of Sciences' National Research Council and the National Space Science Center of the Chinese Academy of Sciences held the first "Forum for New Leaders in Space Science." The goals of the forum are to: (1) "identify and highlight the research achievements of the best and brightest young scientists currently working at the frontiers of their respective disciplines"; (2) "build informal bridges between the space-science communities in China and the United States"; and (3) "enhance the diffusion of insights gained from participation in the Forum to the larger space-science communities in China and the United States." [206] Despite its collaborative spirit, the forum may present opportunities for Chinese participants to collect information, whether wittingly or unwittingly, on sensitive U.S. technology on behalf of the Chinese government and military.

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*In August 2015 a Houston company announced it had negotiated an agreement to carry a Chinese DNA experiment on the International Space Station, but as a commercial deal involving a U.S. business rather than a U.S. government entity, the law does not apply. Leonard David, "US-China Space Freeze May Thaw with Historic New Experiment," *Space.com*, August 21, 2015; and Eric Berger, "For the First Time Chinese Research to Fly on NASA's Space Station," *Houston Chronicle*, August 3, 2015.

†The commentary referred to the initiation of the November 2011 National Defense Authorization Act clause by then Congressman Frank Wolf.

- In late 2014, Beijing asked the U.S. Air Force to send warnings of potential satellite collisions directly to China's space operators. In the past, such information was routed from the U.S. Air Force to the U.S. State Department, passed to China's Ministry of Foreign Affairs, and finally conveyed to China's space operators—a lengthy sequence. Mr. Cheng, assessing the likely reasons for this step, stated:

  [The PLA] is most likely acting . . . to remove an unnecessary link in the chain of information, especially important since conjunction data is perishable. . . . [Additionally, China] may be [attempting] to double-check [its] own data: What are the Americans seeing that [it is] not? This may be partly a matter of [image] resolution, and partly a possible source of intelligence. There was a brouhaha a few years back where [the United States was] reporting in [its] space catalogs European satellites that the Europeans denied existed.[207]

Moreover, in late June 2015, the United States and China held the seventh round of the Strategic and Economic Dialogue in Washington, DC. The U.S. State Department spokesperson announced that the dialogue produced several areas for further space cooperation between the State Department and China:

- The United States and China stated their intention to "establish regular bilateral government-to-government consultations on civil space cooperation." As an inaugural step in these consultations, the two countries held the first "U.S.-China Civil Space Cooperation Dialogue" in China in September 2015. At this meeting U.S. and Chinese officials exchanged information on space policies and on national plans related to space exploration, and discussed cooperation opportunities related to space debris, satellite collision avoidance, civil Earth observation, space sciences, space weather, and civil satellite navigation systems.[208] As stated in the June announcement, the two countries additionally plan to hold "exchanges on space security matters under the framework of the U.S.-China Security Dialogue before the next meeting of the Security Dialogue."
- The two sides reaffirmed that avoiding orbital collisions serves their common interest in exploring and using outer space for peaceful purposes, noting that further consultation is needed on the process for resolving an "orbital close approach" and that such a consultation should aim to ensure timely resolution to reduce the probability of accidental collisions. The two countries determined to "continue bilateral government-to-government consultations on satellite collision avoidance and the long-term sustainability of outer space activities as part of the U.S.-China Civil Space Cooperation Dialogue."
- The two sides determined to undertake, among other projects, a joint project in "space security" within the East Asia Summit, the Association of Southeast Asian Nations Regional Forum, or another multilateral framework in the Asia-Pacific region, as part of their larger goal to "enhance communication and coordination" within these fora.[209]

U.S.-China Space Endeavors: Risks vs. Rewards

Although the United States and China continue to pursue opportunities to collaborate on space endeavors, such cooperation is not without its potential hazards. Mr. Cheng advised the Senate Committee on Commerce, Science, Technology, and Transportation that the United States should proceed with caution as it considers expanding space cooperation with China:

> *While the United States should not avoid cooperation with any country out of fear, at the same time, it is vital that cooperation occur with full understanding and awareness of whom we are cooperating with, and that such cooperation serve American interests. In the case of [China], the combination of an opaque Chinese space management structure, a heavy military role in what has been observed, and an asymmetric set of capabilities and interests raise fundamental questions about the potential benefits from cooperation between the two countries in this vital arena.*
>
> *To this end, it is essential to recognize a few key characteristics of China's space program. First, that China possesses a significant space capability in its own right, and therefore is not necessarily in need of cooperation with the United States. Too often, there is an assumption that [China] is still in the early stages of space development, and that we are doing them a favor by cooperating with them. Second, that the Chinese space program is closely tied to the [PLA]. . . . Therefore, any cooperation with [China] in terms of space must mean interacting, at some level, with the PLA. Third, that the Chinese space program has enjoyed high-level political support, is a source of national pride, and is therefore not likely to be easily swayed or influenced by the United States, or any other foreign actor. These three issues, in combination, suggest that any effort at cooperation between the United States and [China] will confront serious obstacles, and entail significant risks.*[210]

Other observers have suggested it is possible for the United States to improve space cooperation with China while also protecting U.S. security interests and supporting the U.S. space program's development. In his testimony to the Commission, Philip Saunders, director of the Center for the Study of Chinese Military Affairs of the Institute for National Strategic Studies at the National Defense University, argued, "there are other areas such as many scientific applications and manned space flight where the United States can share information and experiences without compromising national security and can benefit from growing Chinese investments in space capabilities and China's potential contributions to international space cooperation."[211]

Implications of China's Space and Counterspace Programs for the United States

China's improving space capabilities are challenging U.S. superiority in the information and space domains. A senior official at the PLA's Academy of Military Science underscored China's ambition to rival the world's top space powers following China's 2007 antisatellite test: "[If there is going to be] a space superpower, it's not going to be alone. . . . It will have company."[212] In 2013, Central Military Commission Chairman and Chinese President Xi Jinping said "the dream of space flight is an important part of the strong country dream" and "the space dream is an important component of realizing the Chinese people's mighty dream of national rejuvenation."[213]

Space activities are critical to the United States' technological advancement, scientific discovery, security, and economic growth. As outlined in the Obama Administration's 2010 *National Space Policy*, the utilization of space has transformed every aspect of U.S. society, and the benefits of space permeate daily life in the United States:

> *Satellites contribute to increased transparency and stability among nations and provide a vital communications path for avoiding potential conflicts. Space systems increase our knowledge in many scientific fields, and life on Earth is far better as a result. The utilization of space has created new markets; helped save lives by warning us of natural disasters, expediting search and rescue operations, and making recovery efforts faster and more effective; made agriculture and natural resource management more efficient and sustainable; expanded our frontiers; and provided global access to advanced medicine, weather forecasting, geospatial information, financial operations, broadband and other communications, and scores of other activities worldwide. Space systems allow people and governments around the world to see with clarity, communicate with certainty, navigate with accuracy, and operate with assurance.*[214]

Space capabilities also have enhanced U.S. security and have been a key element of warfighting for more than 30 years—to the extent that U.S. national security is now dependent on the space domain. According to the joint DOD–Intelligence Community *National Security Space Strategy*, published in 2011:

> *Space capabilities provide the United States and our allies unprecedented advantages in national decision-making, military operations, and homeland security. Space systems provide national security decision-makers with unfettered global access and create a decision advantage by enabling a rapid and tailored response to global challenges. Moreover, space systems are vital to monitoring strategic and military developments as well as supporting treaty monitoring and arms control verification. Space systems are also critical in our ability to respond to natural and man-made disasters and monitor long-term environmental trends.*[215]

The United States' sustained success in integrating space capabilities into its military operations has encouraged China to pursue a broad and robust array of counterspace capabilities to deny, degrade, deceive, disrupt, or destroy U.S. space systems and their supporting infrastructure. This program includes direct-ascent antisatellite missiles, computer network operations, ground-based satellite jammers, and directed energy weapons. China also appears to be developing co-orbital antisatellite systems, which have not been a significant concern for the United States since the fall of the Soviet Union.

China already has demonstrated its ability to strike U.S. satellites in low Earth orbit. As China's developmental counterspace capabilities become operational, China will be able to hold at risk U.S. national security satellites in every orbital regime. According to General Hyten, commander of U.S. Air Force Space Command, the loss of U.S. space capabilities would send the U.S. military "back to World War Two . . . back to industrial age warfare." [216]

Beijing also recognizes that command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) modernization is central to its "preparation for military struggle" and is rapidly expanding its space-based C4ISR assets accordingly. China currently has approximately 142 operational satellites in orbit, more than 97 percent of which have been launched since 2000 and 75 percent since 2008. In addition to serving China's economic goals, this modernization program is designed to improve the PLA's ability to command and control its forces; monitor global events and track the military activities of the United States and other potential adversaries; and increase the range at which Beijing can use conventional missile systems to place U.S. ships, aircraft, and bases at risk.

China's current system of C4ISR satellites likely allows the PLA to detect and monitor U.S. air and naval activity out to the second island chain * with sufficient accuracy and timeliness to (1) assess U.S. military force posture, and (2) cue land-, maritime-, and air-based collection assets for higher fidelity and time-sensitive tracking and targeting of U.S. military assets. As China continues to field additional C4ISR satellites, the country's space-based ISR coverage almost certainly will become more accurate, responsive, and timely and could ultimately extend beyond the second island chain into the eastern Pacific Ocean and Indian Ocean.[217] Nevertheless, the U.S. Office of Naval Intelligence points out that building a complete picture of all activities—which would rely heavily on additional space-based C4ISR—could remain a "formidable challenge" for China due to the sheer size of these areas:

> *Just to characterize activities in the "near seas," China must build a picture covering nearly 875,000 square nau-*

* The first island chain refers to a line of islands running through the Kurile Islands, Japan and the Ryukyu Islands, Taiwan, the Philippines, Borneo, and Natuna Besar. The second island chain is farther east, running through the Kurile Islands, Japan, the Bonin Islands, the Mariana Islands, and the Caroline Islands. PLA strategists and academics have long asserted the United States relies primarily on the first island chain and the second island chain to strategically "encircle" or "contain" China and prevent the PLA Navy from operating freely in the Western Pacific. Open Source Center, "PRC Article Surveys China's Naval Rivals, Challenges," January 6, 2012. ID: CPP20120109671003; Bernard D. Cole, *The Great Wall at Sea* (Second Edition), Naval Institute Press, 2010, 174–176.

tical miles (sqnm) of water- and air-space. The Philippine Sea—a key interdiction area in the event of a conflict over Taiwan or in the South China Sea—expands the battle-space by another 1.5 million sqnm. In this vast space, navies and coast guards from seven regional countries as well as several globally-deploying nations combine with tens of thousands of fishing boats, cargo ships, oil tankers, and other commercial vessels.[218]

In a 2015 report sponsored by the Commission, the RAND Corporation notes that the cyber infrastructure contributing to China's maritime domain awareness could at times be limited by technical challenges associated with integrating so many new technologies and complex systems, as well as by poor coordination among intelligence organizations, operators, and decision makers:

Another potential weakness for China . . . may exist in the need to integrate all the PLA's disparate ISR capabilities and incorporate them into the targeting process. Indeed, shortcomings in China's C4ISR capabilities, which could be both organizational and technological, could hamper the speed, reduce the reliability, or otherwise diminish the effectiveness of the PLA's over-the-horizon targeting capabilities. Problems with the potential to limit the effectiveness of Chinese C4ISR and targeting could include not only technical challenges associated with integrating such a variety of new technologies and complex systems but also procedural weaknesses, such as insufficient coordination among numerous intelligence organizations, operators, and higher-level decision makers.[219]

Furthermore, although China's space-based C4ISR modernization enhances the PLA's operational capabilities, it also increases PLA vulnerabilities to U.S. deception, degradation, and denial capabilities.[220]

In addition to the implications it poses for U.S. military interests, the rapid expansion of China's space industry could also have economic consequences for the United States.

First, China's persistent global marketing of its commercial satellite and space launch services has the potential to cut into U.S. market share in these areas, though it has had little effect on established satellite manufacturers or the international launch market thus far. Although China's current effort focuses on growing its satellite exports to lower-income buyers, it almost certainly will eventually expand to higher-end markets, following a business plan similar to that of Chinese telecommunications giant Huawei. China's launch service costs compare favorably with those of Arianespace, the major European provider, and may match those of SpaceX, the low-cost leading U.S. private firm, as described earlier. In addition, according to one former European space executive, China has broken into the launch services market by offering prices at as low as three-quarters of the launches' cost, suggesting heavy government assistance on top of low initial costs will enable China to successfully compete for broader market share in the future. Furthermore, China often packages its satellite exports and launch services together, and also reaps cost and experience benefits from blending its civilian and military space infrastructure, which is expected to provide additional competitive advantages. An executive for U.S. company SpaceX, which has led a resurgence in U.S. commercial launch market share after U.S. organizations were priced out of the market until recently, stated in 2013 that the company views China as its main competition. However, in a July 2015 meeting with the Commission, the China Great Wall Industry Corporation asserted that it is unable to compete with Western counterparts due to U.S. export controls, indicating that obstacles remain despite China's cost advantages.[221]

Second, China's designation of the Beidou satellite navigation system—planned to provide global service by 2020—as "national infrastructure," and introduction of preferential policies to promote its place in China's domestic satellite navigation market, will directly impact the market share of GPS and related products within China.[222] While GPS usage provides no revenues to the United States, Beidou is also intended to foster development in downstream industries such as mobile internet applications, which may affect U.S. firms' market share in these industries.[223]

Third, U.S. International Trafficking in Arms Regulations (ITAR), altered by the FY13 National Defense Authorization Act to no longer include exports of many satellites and satellite technologies but still in force for China, have prompted many European countries and their industries to pursue "ITAR-free" exports in order to reach the Chinese market—by definition necessitating the exclusion of U.S. technologies from these products. Mr. Nurkin testified to the Commission that "concern over U.S. export controls on space-related items and confusion over which items are on the list of banned items for export and, importantly, which ones will be in the future, has led international industry, especially the European space industry, which has far less severe export guidelines for space technologies, to endeavor to design ITAR-free solutions, effectively cutting out U.S. based suppliers of ITAR-restricted items from international supply chains."[224] Mr. Nurkin suggested that export control reform should "focus on increasing protection on a small number of systems and technologies that the United States is and should be unwilling to offer on the open market" instead of focusing on the many technologies that China probably already has access to from foreign partners, particularly Europe.[225] In May 2015, General James Cartwright, former vice chairman of the Joint Chiefs of Staff, and the Honorable Sean O'Keefe, former NASA administrator, reiterated that U.S. ITAR regulations are not currently in line with the pace of technological innovation and are therefore in need of reform in order to protect the U.S. space industry's global competitiveness.[226]

China's thriving space programs have important political implications as well, most importantly in their potential to present a future challenge to the United States' position as a leading space power. China's human spaceflight program may be repeating many of the same accomplishments the United States achieved in the 1970s, but it also is tempering U.S. superiority in civilian space capabilities and lessening U.S. influence in the international space community. Roger Handberg, professor at the University of Central Florida, testified to the Commission that "psychologically, momentum appears to be moving in China's favor with the possibility of actually moving ahead of the United States over the next two decades."[227] China is gaining sway among lesser space nations by sharing space technologies, supplying training and financing for developing satellites, and providing launch services. Beijing's push into new space markets could undermine U.S. efforts to prevent countries from obtaining certain dual-use space technologies. China is developing capabilities that could allow it to compete in sending humans and other payloads to the Moon and beyond, even as the United States now depends on Russian launch vehicles and sites to send humans into space.[228]

China's new space station, slated for completion in 2022 while the deorbiting of the International Space Station is scheduled for 2024, will provide Beijing greater prestige in the international system and expand its growing space presence—concurrent with declining U.S. influence in space. Not only will China have the only space station in orbit, but it also will have the ability to choose its partners and determine the countries with which it will share technologies and experimental data. In this sense, the space station likely will serve as a diplomatic tool China can leverage to execute its broader foreign policy goals. Meanwhile, given current Congressional restrictions on U.S.-China space cooperation, the United States would not participate in China's space station program barring changes to annual appropriations legislation. For the first time in decades, the United States could be without a constant human presence in space.

Conclusions

- China has become one of the top space powers in the world after decades of high prioritization and steady investment from China's leaders, indigenous research and development, and a significant effort to buy or otherwise appropriate technologies from foreign sources, especially the United States. Although China's space capabilities still generally lag behind those of the United States and Russia, its space program is expanding and accelerating rapidly as many other nations' programs proceed with dwindling resources and limited goals.

- China's aspirations in space are driven by its judgment that space power enables the country's military modernization, drives its economic and technological advancements, allows it to challenge U.S. information superiority during a conflict, and provides the Chinese Communist Party with significant domestic legitimacy and international prestige.

- China's space program involves a wide network of entities spanning its political, military, defense industry, and commercial sectors. Unlike the United States, China does not have distinctly separate military and civilian space programs. Under this nebulous framework, even ostensibly civilian projects, such as China's human spaceflight missions, directly support the development of People's Liberation Army (PLA) space, counterspace, and conventional capabilities. Moreover, Chinese civilian and commercial satellites likely contribute to the PLA's command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) efforts whenever it is technically and logistically feasible for them to be so utilized, and they would probably be directly subordinate to the PLA during a crisis or conflict. Given the PLA's central role in all of China's space activities, U.S. cooperation with China on space issues could mean supporting the PLA's space and counterspace capabilities.

- China likely has capitalized on international cooperation to acquire the bulk of the technology and expertise needed for most of its space programs. China probably will continue to pursue close cooperation with international partners to overcome specific technical challenges and to meet its research and development objectives and launch timelines.
- Chinese analysts perceive that China's advances in space technology have become an important driver for the country's economic growth. Satellite and launch service sales provide China's defense industry with a growing source of revenue. Technology spin-offs offer competitive advantages in certain sectors, such as satellite navigation products. Exports of space technology-based products pose challenges to the United States not only due to the non-market-based nature of China's economy, but also due to military and security concerns.
- As China's developmental counterspace capabilities become operational, China will be able to hold at risk U.S. national security satellites in every orbital regime.
- China is testing increasingly complex co-orbital proximity capabilities. Although it may not develop or operationally deploy all of these co-orbital technologies for counterspace missions, China is setting a strong foundation for future co-orbital antisatellite systems that could include jammers, robotic arms, kinetic kill vehicles, and lasers.
- China is in the midst of an extensive space-based C4ISR modernization program that is improving the PLA's ability to command and control its forces; monitor global events and track regional military activities; and strike U.S. ships, aircraft, and bases operating as far away as Guam. As China continues to field additional intelligence, surveillance, and reconnaissance (ISR) satellites, its space-based ISR coverage almost certainly will become more accurate, responsive, and timely and could ultimately extend beyond the second island chain into the eastern Pacific Ocean and the Indian Ocean.
- China's rise as a major space power challenges decades of U.S. dominance in space—an arena in which the United States has substantial military, civilian, and commercial interests.

ENDNOTES FOR SECTION 2

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