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PRC Space and Missile Capabilities

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Kevin Pollpeter
Senior Research Scientist, China and Indo-Pacific Security Affairs Division, CNA

Chairmen Bartholomew and Wong and members of the Commission, thank you for inviting me back to testify before you today on the important topic of People's Republic of China (PRC) space and missile capabilities. Space and missile technologies are central to the PRC's efforts to build strategic deterrent and conventional warfighting capabilities. Since its inception in 1956, the PRC space and missile program has stressed "self-reliance" (自立更生) in developing its space and missile programs. Despite this adherence to relying on its own abilities, foreign assistance has played an instrumental role in advancing China's space and missile program.

In fact, despite far-reaching US export control restrictions on space and missile technologies, the PRC has become a world leader in these technologies in terms of quantity and quality. In 1999, the US Congress passed legislation that prohibited the launch of satellites manufactured with US components on PRC rockets. Additional legislative action was taken in 2011 when Congress voted to restrict bilateral contacts between NASA and China, ending most forms of contact between them.[1]

Multiple factors account for China's success. Its extensive and expanding relationship with Russia has played an instrumental role in advancing know-how and providing technologies. However, these efforts have been necessary but insufficient in accounting for China's progress in space and missile technologies. Just as important to China's success has been a techno-nationalist approach to science and technology that has resulted in long-term planning, ample funding, a commitment to reforming its program management system, and the recruitment of a younger and better-educated workforce. As a result, China's space and missile programs are an example of the limitations of "decoupling" in preventing China's rise as a technological power.

China's space and missile capabilities

The People's Liberation Army (PLA) has a large inventory of ground-, air-, surface-, and subsurface launched ballistic and cruise missiles (See Table 1). The majority are short-range ballistic missiles (SRBMs) that are most likely for use in a Taiwan contingency but also include an inventory of

[1] "Why NASA and China Don't Collaborate in Space," *Wall Street Journal*, https://www.wsj.com/video/series/wsj-explains/why-nasa-and-china-dont-collaborate-in-space/8C34E693-469B-484E-B4C5-12AEEB6D2B2F.

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medium-range ballistic missiles (MRBMs), such as the DF-21 with a range of 1,500–2,000 km, and the DF-26, with a range of 3,000+ km that gives the PLA the ability to strike targets as far as Guam.

The PLA's inventory of ground attack and antiship cruise missiles (ASCMs) includes the DF-10 and DF-100 ground attack cruise missiles with ranges of 1,500 and 2,000 km, respectively. The PLA's ASCM inventory includes the YJ-83, which has a range of 185 km, and the YJ-62, with a range of 277 km, as well as the supersonic, surface-launched Russian SS-N-22/SUNBURN, with a range of over 200 km.[2] The PLA has also deployed the YJ-18 ASCM that was described in 2016 by the Defense Department as a "significant step forward in China's surface anti-surface warfare capability."[3] These missiles can be launched from surface ships and submarines, have a range of 537 nm, and can reach speeds of Mach 3.[4] Additional submarine-launched ASCMs are the Russian SS-N-27, with a range of 222 nm, and the YJ-82, with a range of 37 km. In addition to surface and subsurface launched ASCMs, China has air-launched ASCMs. These include an air-launched version of the YJ-83, as well as the YJ-12, which can deliver a 500 kg warhead at speeds up to Mach 3 and a range of 300 km.[5]

China has also deployed hypersonic weapons that can travel at least five times the speed of sound. The PRC fielded the DF-17 hypersonic glide vehicle in 2020, which the Defense Department assesses as having the potential to transform the PLA's missile force.[6] Although "primarily a conventional platform," the DF-17 "may be equipped with nuclear warheads."[7] In July 2021, the PLA tested a hypersonic glide vehicle and an orbital bombardment system that the Defense Department assesses is probably intended to become an advanced nuclear delivery system.[8]

The PLA's missile inventory presents several challenges to the US military (see Table 2). The most common US antiship missile (ASM), the Harpoon ASCM with a range of 130 km, is out-ranged by most PLA ASMs, allowing PLA Navy ships to fire their ASMs in relative safety from distances well beyond the range of US surface-fired ASMs.[9] Although the air-launched version of the Harpoon can alleviate the range deficit, it places a reliance on US aircraft carriers that are likely a main target for PLA war planners. The range deficit will be ameliorated by the introduction of an antiship version of the land-attack Tomahawk cruise missile and the introduction of larger numbers of the long-range antiship missiles (LRASMs). The Maritime Strike Tomahawk has a range of over 1,600 km, and the LRASM has a range of 560 km, but these ranges are still shorter than the PLA's DF-21D and DF-26 ballistic missiles and the CJ-10 cruise missile. Moreover, the

[2] US-China Economic and Security Review Commission, *2015 Report to Congress*, Nov. 2015, 362-363.
[3] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2016*, 27.
[4] Michael Pilger, *China's New YJ-18 Antiship Cruise Missile: Capabilities and Implications for US Forces in the Western Pacific*, US-China Economic and Security Review Commission, Oct. 28, 2015, 2; US-China Economic and Security Review Commission, *2015 Report to Congress*, Nov. 2015, 356.
[5] "China's Anti-ship Missiles YJ-12 and YJ-100 Revealed," *Missile Threat*, Feb. 4, 2015, http://missilethreat.com/chinas-anti-ship-missiles-yj-12-yj-100-revealed/.
[6] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2022*, 83.
[7] *Military and Security Developments Involving the People's Republic of China 2022*, 65.
[8] *Military and Security Developments Involving the People's Republic of China 2022*, 98.
[9] Vitaliy O. Pradun, "From Bottle Rockets to Lightning Bolts," *Naval War College Review*, Oct. 18, 2010, 25.

LRASM is air launched, which again places a focus on naval aviation and aircraft carriers (see Figure 1).[10]

Similarly, the longer ranges of PLA air-launched ASCMs gives the PLA Air Force and PLA Navy aviation units the ability to launch their missiles from well beyond the defensive ranges of US air defense systems. The US anti-air missiles SM-2 and Sea Sparrow with their ranges of less than 170 km, for example, are out-ranged by PLA ASCMs, which can have ranges of several hundred kilometers.

With a reliance on ballistic and cruise missiles, the PLA has come to realize what the US military has realized for some time: long-range power projection requires space-based command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) capabilities. Space-based C4ISR can provide remote sensing to identify targets and conduct battle damage assessments, navigation to guide precision munitions, and communication to connect and integrate the actions of multiple services into joint operations.

With more than 500 operational satellites now in orbit, the PRC has the second-largest fleet of satellites in orbit behind the United States. Over 200 are remote-sensing satellites, including electro-optical, synthetic aperture radar, and signals intelligence satellites. The PRC also has over 60 communication satellites and is planning to build a megaconstellation consisting of nearly 13,000 communication satellites.[11] In 2020, the PRC established Beidou, a global satellite navigation system. When taken together, the elements of this space-based C4ISR architecture, when combined with airborne, maritime, and ground-based C4ISR systems, will form the basis of a system to locate, track, and target US military assets.

China is also developing a wide range of counterspace technologies that are intended to threaten adversary space systems from ground to geosynchronous orbit.[12] These include direct-ascent kinetic-kill vehicles, co-orbital satellites, directed-energy weapons, jammers, and cyber capabilities.[13] In 2007, China destroyed one of its weather satellites with a direct-ascent KKV. According to the Director of National Intelligence, "the PLA has an operational ground-based antisatellite (ASAT) missile intended to target low-Earth-orbit satellites, and China probably intends to pursue additional ASAT weapons capable of destroying satellites up to geosynchronous orbit."[14] The PLA is also expected to deploy a ground-based laser system for use against satellites in low-Earth-orbit by 2020.[15]

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[10] Dmitry Filipoff, "Fighting DMO, Pt. 2: Anti-Ship Firepower and the Major Limits of the American Naval Arsenal," CIMSEC, Feb. 27, 2023, https://cimsec.org/fighting-dmo-pt-2-anti-ship-firepower-and-the-major-limits-of-the-american-naval-arsenal/#:~:text=The%20amount%20of%20LRASM%20inventory,for%20the%20Navy%20so%20far.&text=The%20Air%20Force%27s%20inventory%20is,numbers%20slightly%20less%20than%20100.

[11] Andrew Jones, "China to Begin Constructing Its Own Megaconstellation Later This Year," *Space News*, Mar. 28, 2023, https://spacenews.com/china-to-begin-constructing-its-own-megaconstellation-later-this-year/.

[12] Dan R. Coats, *2019 Worldwide Threat Assessment of the U.S. Intelligence Community*, 2019, p. 17.

[13] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2016*, 37.

[14] Coats, *2019 Worldwide Threat Assessment of the U.S. Intelligence Community*, 17.

[15] Patrick M. Shanahan, "Remarks by Acting Secretary Shanahan at the 35th Space Symposium, Colorado Springs, Colorado," Apr. 9, 2019, https://dod.defense.gov/News/Transcripts/Transcript-View/Article/1809882/remarks-by-acting-secretary-shanahan-at-the-35th-space-symposium-colorado-sprin/.

Table 1. PRC missile inventory

Missile	Type	Deployment Mode	Range (kilometers)	Number of Launchers
DF-15 (CSS-6)	SRBM	Road-Mobile	600-850+	More than 200 launchers More than 600 missiles
DF-11 (CSS-7)	SRBM	Road-Mobile	300-60	
DF-16 (CSS-11)	SRBM	Road-Mobile	700+	
DF-21 (CSS-5)	MRBM	Road-Mobile	1,500-1750+	Approximately 350 launchers
DF-17 (CSS-22)	MRBM	Road-Mobile	1,000-3,000	
DF-26 (CSS-18)	IRBM	Road-Mobile	3,000+	
DF-4 (CSS-3)	ICBM	Transportable	5,500+	10 to 15
DF-5A (CSS-4 Mod 2)	ICBM	Silo	12,000+	About 20
DF-5B (CSS-4 Mod 3)	ICBM	Silo	12,000+	
DF-31 (CSS-10)	ICBM	Road-Mobile	7,000-11,000	Approximately 20-25+
DF-41 (CSS-20)	ICBM	Road-Mobile	UNK	16+
JL-2 (CSS-N-14)	SLBM	Submarine and ship Launched	7,000+	48
JL-3 (CSS-NX-20)	SLBM	Submarine and ship Launched	10,000	UNK
DH-10 (CJ-10)	LACM	Ground	1,500	More than 100 launchers More than 300 missiles
DF-100 (CJ-100)	LACM	Air	2,000	UNK
YJ-83	ASCM		180	UNK

YJ-62	ASCM		400	UNK
YJ-12	ASCM		400	UNK
SS-N-22	ASCM		200+	UNK
SS-N-27b	ASCM		220-300	UNK

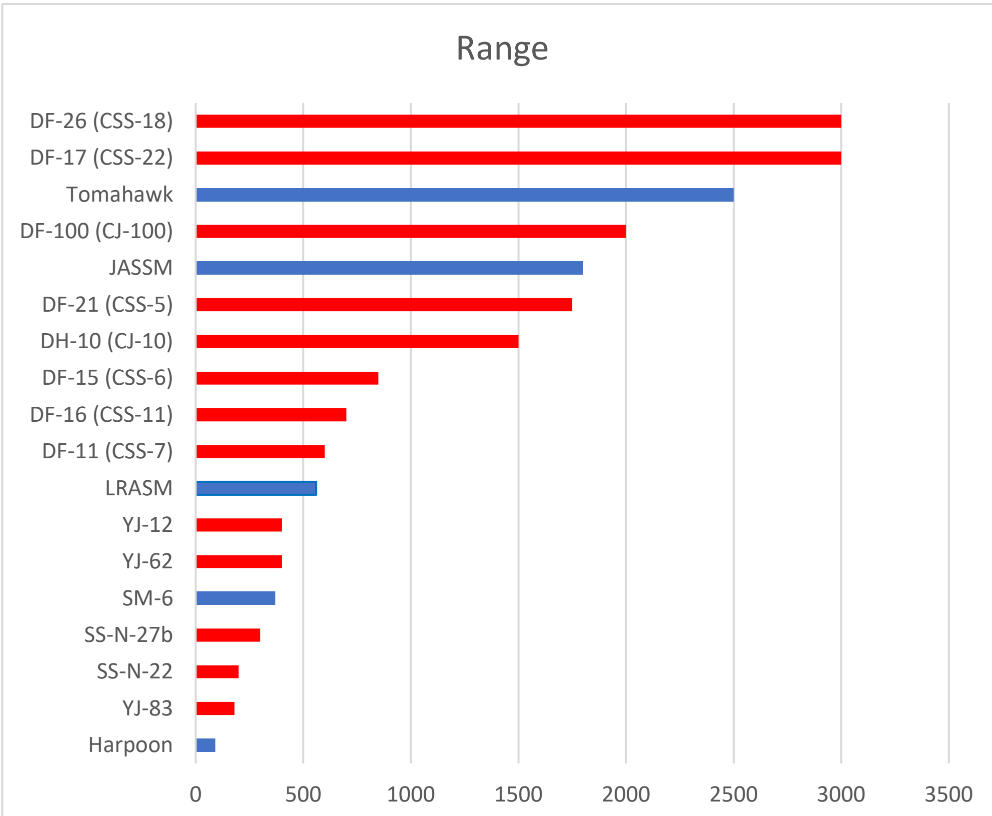
Source: Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2020* and Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2022*, Defense Intelligence Ballistic Missile Analysis Committee, *Ballistic and Cruise Missile Threat*, 2020, https://media.defense.gov/2021/Jan/11/2002563190/-1/-1/1/2020%20BALLISTIC%20AND%20CRUISE%20MISSILE%%2020THREAT_FINAL_2OCT_REDUCEDFILE.PDF; "YJ-12," Missile Defense Advocacy Alliance, Dec. 2022, https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/yj-12/; US-China Economic and Security Review Commission, *2015 Report to Congress*, Nov. 2015, 362-363.

Table 2. US missile force

Missile	**Type**	**Deployment Mode**	**Range (kilometers)**	**Number**
Minuteman III	ICBM	Silo	13,000	400
Trident DF	SLBM	Submarine-launched	12,000	UNK
Tomahawk	Land attack cruise missile	Sea, submarine-launched	1,250-2,500	UNK
AGM-158 JASSM	Land attack cruise missile	Air	370	~5,000
AGM-158B JASSM-ER	Land attack cruise missile	Air	1,000	UNK
LRASM	ASCM	Air	560	UNK
AGM-84 Harpoon	ASCM	Ship/Air	92.6-280 km	UNK
SM-6	ASM/Antiair	Ship	370.4	UNK

Source: "Missiles of the United States, Center for Strategic and International Studies, Mar. 3, 2021, https://missilethreat.csis.org/country/united-states/; "LGM-30G" Minuteman III," US Air Force, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104466/lgm-30g-minuteman-iii/; "JASSM/JASSM-ER," July 30, 2021, https://missilethreat.csis.org/missile/jassm/; "Department of Defense Fiscal Year (FY) 2023 Budget Estimates," April 2022, https://www.secnav.navy.mil/fmc/fmb/Documents/23pres/WPN_Book.pdf.

Figure 1. Comparison of US and PRC missile ranges



Source: Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2020* and Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2022*, Defense Intelligence Ballistic Missile Analysis Committee, *Ballistic and Cruise Missile Threat*, 2020, "YJ-12," Missile Defense Advocacy Alliance, Dec. 2022, https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/yj-12/; US-China Economic and Security Review Commission, *2015 Report to Congress*, 362-363; "Missiles of the United States, Center for Strategic and International Studies; "LGM-30G" Minuteman III;" "JASSM/JASSM-ER," July 30, 2021, "Department of Defense Fiscal Year (FY) 2023 Budget Estimates."

The PRC space and missile industry

China's space industry is led by two large state-owned enterprises: the China Aerospace Science and Technology Corporation, focused on space and launch vehicle technologies, and the China Aerospace Science and Industry Corporation, focused on missiles. China's strictly top-down approach to space technology innovation is now beginning to change with the rise of a commercial space industry. China has between 120–150 commercial space companies offering a range of products and services, including satellite and rocket manufacturing and launch services. China's commercial space market is still developing, however, with most companies established since 2014.[16]

The PRC government appears to have encouraged the development of the commercial space industry for several reasons. First, the government intends for private capital to supplement government space efforts.[17] Proponents of commercial space also argue that the efficiencies brought about by market forces better position the private sector to innovate. It does not appear, however, that the PRC government is prepared to allow a commercial space industry to supplant the state-owned sector. PRC regulations characterize the commercial sector as a supplement to, not a replacement for, China's state-owned sector. Nevertheless, commercial space entities could become important players in China's space technology supply chain, even if they are not replacing the state-owned sector's role as the prime contractor.[18]

The dual-use nature of space technologies

A distinctive feature of space technologies is their dual-use nature. Satellite imagery can be used in both urban planning and to collect intelligence on an adversary. Satellite navigation can be used to navigate city streets as well as to guide missiles. The dual-use aspect of space technologies can make determining a country's true intention for acquiring space technologies difficult and complicates the enforcement of export controls. Technologies exported on the pretext of non-military use can be diverted for defense applications or to organizations conducting defense R&D and manufacturing.[19] Here, I discuss three areas of dual-use space technologies in more depth.

Space situational awareness

Like air traffic control systems, space situational awareness (SSA) systems provide knowledge of activities in the space domain that can be used to better control spacecraft and ensure their safe operation. SSA, also called space domain awareness (SDA), can also provide militaries with the intelligence to conduct offensive counterspace operations. China has, or is developing, a range of SDA technologies, including domestic, space-based, seaborne, and foreign-based space monitoring stations consisting of optical systems, laser range finders, radio telescopes, and a potential space radar.[20]

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[16] "Developments in China's Commercial Space Sector," National Bureau of Asian Research, Aug. 24, 2021, https://www.nbr.org/publication/developments-in-chinas-commercial-space-sector/.
[17] Luo Heng, Zhao Feng, and Liang Tang, "Research on the Development Status of US Commercial Space" (美国商业航天发展态势研究), Aerospace China (中国航天), no. 4 (2017): p. 8.
[18] "Developments in China's Commercial Space Sector."
[19] Cate Cadell and Ellen Nakashima, "American Technology Boosts China's Hypersonic Missile Program," *Washington Post,* Oct. 17, 2022, https://www.washingtonpost.com/national-security/2022/10/17/china-hypersonic-missiles-american-technology/.
[20] Kristin Burke, "China's Space Situational Awareness Capabilities for Beyond GEO," China Aerospace Studies Institute, Sept. 2022, https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/CASI%20Articles/2022-09-12%20China%27s%20Space%20Situational%20Awareness%20Capacity%20For%20Beyond%20GEO.pdf.

Rendezvous and proximity operations

Rendezvous and proximity operations (RPO) refer to "a spacecraft intentionally maneuvering to dock or operate in close proximity to a target space object" and have several peaceful uses.[21] These include the potential to service, repair, and monitor the health of spacecraft. These same technologies can also be used to collect intelligence against spacecraft and to maneuver toward and attack satellites. China has conducted a number of RPO since 2010. According to the Secure World Foundation, the PRC has "not conducted an actual destructive intercept of a target, and there is no proof that [RPO] technologies are definitively being developed for counterspace use as opposed to intelligence gathering or other purposes.[22] However, the dual-use nature of these technologies, coupled with PRC writings on the strategic value of attacking US space assets, strongly indicates that these technologies are militarily relevant.

Space debris removal and planetary defense

Space debris removal and planetary defense have important dual-use applications, including counterspace and SDA functions. According to China's 2021 space white paper, China will improve its space debris monitoring system, cataloguing database, and early warning services and will "study plans for building a near-Earth object defense system, and increase the capacity of near-Earth object monitoring, cataloguing, early warning, and response."[23]

China is developing space debris removal and planetary defense capabilities that could improve its military capabilities. In a demonstration of potential offensive RPO capabilities, in January 2022, the PRC SJ-21 satellite towed a defunct Beidou-2 satellite into a graveyard orbit to move it out of the way of operational satellites.[24] PRC researchers are also exploring the use of lasers to remove space debris.[25] In terms of SDA, China is building a network of radars that can detect asteroids that could threaten the Earth. The second stage of this radar network is scheduled to be completed in 2025 with a detection range out to 10 million kilometers, which would extend its SDA capabilities well beyond the Moon.[26]

The PRC approach to space and missile innovation[27]

China's success in space and missile technologies can be attributed to a techno-nationalist approach that treats science and technology as a competition between states and a determiner of

[21] Kaitlyn Johnson, "Key Governance Issues in Space," Center for Strategic and International Studies, Sept. 2020, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/200901_Johnson_GovernanceInSpace_WEB.pdf.
[22] Brian Weeden and Victoria Samson, "Global Counterspace Capabilities," Apr. 2021, https://swfound.org/media/207162/swf_global_counterspace_capabilities_2021.pdf, 1-2.
[23] PRC State Council Information Office, *China's Space Program: A 2021 Perspective*, Jan. 28, 2022, https://english.www.gov.cn/archive/whitepaper/202201/28/content_WS61f35b3dc6d09c94e48a467a.html
[24] Andrew Jones, "China's Shijian-21 Towed Dead Satellite to a High Graveyard Orbit," *Space News*, Jan. 27, 2022, https://spacenews.com/chinas-shijian-21-spacecraft-docked-with-and-towed-a-dead-satellite/.
[25] Matt Williams, "China Has a Plan to Clean Up Space Junk with Lasers," Phys.org, Jan. 17, 2018, https://phys.org/news/2018-01-china-space-junk-lasers.html.
[26] Andrew Jones, "Chinese Asteroid-Detection System Enters New Phase of Construction," Feb. 19, 2023, https://www.space.com/china-asteroid-detection-system-construction-progress.
[27] This section is taken, in part, from Kevin Pollpeter, "Innovation in China's Space Industry: Overcoming Decoupling," *Asian Security*, (forthcoming).

the fates of nations. Reflecting this, China takes outer space as a domain of strategic competition.[28] PRC leader Xi Jinping, for example, has stated that space technologies have become an important representation of a country's technological level and capability,[29] and has called space technology a "sharp weapon" (国之利器) in international competition.[30] A variety of factors, however, are responsible for China's success in space and missile technologies.

Long-term planning

China manages its space program goals through a series of short-, medium-, and long-term plans that mandate goals—and funding—well beyond the traditional one-year increments of the US budgeting system. Medium-term planning is administered through a series of five-year plans (FYPs). China is currently in the 14th FYP, which covers the period from 2021 to 2025.

Long-term planning governs China's space goals over a 10- to 15-year period. The Medium- and Long-Term Plan for Science and Technology Development that governed overall science and technology work from 2006–2020, for example, established 16 "megaprojects" that set long-term project-based technology objectives across a number of sectors, of which four involved space.[31] The 13th FYP plan extended the megaproject approach, setting objectives to the year 2030.[32] Space also figures prominently in other national industrial strategies. It is one of the 10 "major sectors" for development under the Made in China 2025 plan,[33] one of seven strategic emerging industries,[34] and one of nine sectors listed for priority under the 14th FYP.[35]

Systems engineering

An often-overlooked factor for the success of China's space and missile programs has been a commitment to establishing a modern program management system. Space programs can be large, complex endeavors that require vast numbers of personnel and organizations working on different systems and whose work must be coordinated, scheduled, and provided with technical data. Beginning in the 1990s, the PRC space program reinvigorated its chief commander and chief designer program management system that entrusted the authority of overall program management to one person. Priority was given to hiring a younger workforce familiar with modern R&D and manufacturing techniques and moving more senior engineers into advisory

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[28] The State Council Information Office of the People's Republic of China, *China's National Defense in the New Era*, 2019.

[29] "Make Science and Technology Innovation the Primary Driver of China's Space Development (把科技创新作为中国航天发展第一动力), ScienceNet.cn (科学网), http://news.sciencenet.cn/htmlnews/2020/11/449208.shtm.

[30] "Use a New Era of Space Spirit to Develop a Strong Space Power" (以新时代的航天精神建设航天强国) *Seeking Truth* (求实), May 21, 2018, http://www.qstheory.cn/dukan/hqwg/2018-05/21/c_1122853891.htm.

[31] Sun Laiyan, "China Space Development Strategy and Key Areas" (中国航天的发展战略和重点领域), *Aerospace China* (中国航天), Jan. 2007, 7.

[32] Central Committee of the Communist Party of China, *The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020)*, 2016, http://en.ndrc.gov.cn/newsrelease/201612/P020161207645765233498.pdf.

[33] "State Council Issues 10 Major Areas of "Made in China 2025" (国务院部署 "中国制造2025"10大领域), PRC Central People's Government, Mar. 26, 2015, http://www.gov.cn/zhengce/2015-03/26/content_2838613.htm.

[34] "China Underscores Development of Strategic Emerging Industries,' *China Daily*, Nov. 4, 2020, https://www.chinadaily.com.cn/a/202011/04/WS5fa214d2a31024ad0ba82fe6.html.

[35] "PRC Civilian Economic and Societal Development 14th Five-year Plan and 2035 Long-term Goals (中华人民共和国国民经济和社会发展第十四个五年规划和2035年远景目标纲要), PRC Central People's Government, Mar. 13, 2021, http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm.

roles. A system of quality assurance and testing was established, and a system of standards was enacted to ensure uniformity of the manufacturing process.[36]

Foreign assistance

The success of China's space and missile technologies raises concerns of the role of foreign technology and know-how in advancing China's space and missile programs. Since its inception in 1956, China's space program has relied heavily on foreign technology and know-how, especially Soviet and later Russian assistance. China continues to leverage foreign technology and know-how to advance its space program through a combination of cooperative activities, technology theft, and foreign inspiration.

Cooperative activities. The space industry's desire for foreign technology is reflected in its international cooperative activities, especially those conducted with Russia and Ukraine. Although the exact nature of China's space relationship with these countries is difficult to determine, their scope and duration indicates the potential for significant transfer of technology and know-how.

Russia. China's longest and most substantive space cooperation partner is Russia. After a rupture in relations in 1960, China-Russian space cooperation was restarted in the 1990s. In 1997, the two countries signed an agreement to establish a regular dialogue between their premiers. According to the China National Space Administration, the two countries cooperated on over 100 projects between 2001–2016.[37] Most recently, cooperation was continued with an agreement covering the years 2018–2022. This agreement was described as a significant step forward, covering launch vehicles, rocket engines, space planes, lunar and deep space exploration, Earth remote sensing, space electronic components, satellite navigation, and satellite communications.[38]

Ukraine. Ukraine appears to have been a substantial source of foreign technology and know-how for the PRC space program before the Russian invasion of Ukraine in 2022. Ukraine inherited a substantial amount of the former Soviet Union's space industry on which Ukraine based its cooperation with China, especially related to ballistic missiles and launch vehicles. Beginning in 1995, China has cooperated with Ukraine under the Space Cooperation Subcommittee Mechanism of the Sino-Ukrainian Cooperation Commission. China-Ukraine space cooperation is organized around five-year agreements dating at least to 2006.[39] Cooperation involved a variety of topics,

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[36] See Kevin Pollpeter, "Organization as Innovation: Instilling a Quality Management System in China's Human Spaceflight Program," in Tai Ming Cheung, ed., Forging China's Military Might: A New Framework for Assessing Innovation, (Bethesda: John Hopkins University Press, 2014), 212–240.

[37] "China-Russia Space Cooperation Has Entered a New Stage of Major Strategic Cooperation" (中俄航天合作已转入重大战略合作新阶段)," *Sputnik News*, Sept. 6, 2016, https://sputniknews.cn/russia_china_relations/201609061020681762/.

[38] Wu Yan, "China-Russia Space Cooperation is Broad (中俄航天领域合作空间广阔)," *People's Daily*, Apr. 17, 2018, http://world.people.com.cn/n1/2018/0417/c1002-29930025.html and "Notice on Soliciting Project Proposals for the 'China-Russia Space Cooperation Program 2018-2022' (关于征集《2018-2022年中俄航天合作大纲》项目建议的通知)," Northwestern Polytechnical University School of Astronautics (西北工业大学航天学院), Mar. 24, 2017, https://hangtian.nwpu.edu.cn/info/1371/10283.htm.

[39] "Ukrainian-Chinese Working Group on Space Cooperation Held Meeting in Yuzhnoye Sdo," Nov. 29, 2019, https://www.yuzhnoye.com/en/press-center/news/copy_news_669.html and "Ukraine, China to Expand Space Cooperation Program Until 2015 With New Large-scale Projects," *Kyiv Post*, Sept. 12, 2013, http://www.kyivpost.com/content/business/ukraine-china-to-expand-space-cooperation-program-until-2015-with-newlarge-scale-projects-329268.html.

including rocket engines, new materials, and additive technologies.[40] Although unknown, it is likely that space cooperation between the two countries was halted with the Russian invasion of Ukraine. It is also possible that China's tacit support given to Russia for its invasion of Ukraine will curtail or stop further cooperative efforts.

Technology theft. A second avenue of approach for China is illegal technology transfer. As the leading space power, the United States is likely a major target for PRC collection efforts. An examination of the US Department of Commerce's Bureau of Industrial Security website reveals a number of space-related export control violation cases involving China. A common item in space-related export control violation cases is radiation-hardened computer chips. This likely reflects not only China's overall challenge with developing high-end computer chips but also its challenges with developing computer chips suitable for use in the space environment. The higher radiation levels of outer space can degrade electronic components and affect the life of spacecraft, and the lack of more effective radiation-hardened chips may be one factor in Chinese spacecraft having had shorter service lives than US spacecraft.[41]

Foreign inspiration. A third category of technology and know-how transfer is "inspiration"—basing designs on the knowledge that something has been done or been done in a certain way. Inspiration allows countries to know the realm of the possible. These similarities have raised accusations that China is leveraging the capabilities of the US commercial sector as a "fast follower" in space innovation.[42] Similar to SpaceX, China's space industry is developing a number of partially reusable space launch vehicles. The Long March 6 and Long March 8 launch vehicles developed by China's state-owned space sector, as well as the Hyperbola 2 and Zhuque 2 launch vehicles being developed by the commercial space launch companies iSpace and Landspace, respectively, are planned to be partially reusable.[43] In November 2022, the China Academy of Launch Technology announced that the Long March 9 super heavy lift rocket would be redesigned to accommodate a reusable first stage.[44] A partially reusable first stage would offer a significant advantage over its US counterpart, the Space Launch System.

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[40] "China's CPMIEC to Expand Space Cooperation with Ukraine," Russia & CIS Military Weekly, Aug. 7, 2009, and "Yuriy Boyko, Vice Prime Minister of Ukraine for Ecology, Natural Resources, Energy and Space," Space News, Nov. 25, 2013, http://www.spacenews.com/article/features/38347profile-yuriy-boyko-vice-prime-minister-of-ukraine-for-ecologynatural; and "Ukraine, China to Prepare Space Cooperation in April," China Defense Mashup, Mar. 22, 2012, http://www.chinadefense-mashup.com/ukraine-china-to-prepare-space-cooperation-in-april.html; "Ukraine, China Approve Updated Bilateral Program of Space Cooperation Until 2020," *Interfax-Ukraine*, Nov. 27, 2017; and "Ukrainian-Chinese Working Group on Space Cooperation Held Meeting in Yuzhnoye Sdo," Nov. 29, 2019, https://www.yuzhnoye.com/en/press-center/news/copy_news_669.html.

[41] "Summary Of Major US Export Enforcement, Economic Espionage, and Sanctions-Related Criminal Cases (January 2016 to The Present: Updated November 2019)," US Department of Justice, November 2019 and "Summary of Major US Export Enforcement, Economic Espionage, and Sanctions-Related Criminal Cases (January 2015 to January 19, 2018)," US Department of Justice, Jan. 2018.

[42] "Developments in China's Commercial Space Sector," *National Bureau of Asian Research*, Aug. 24, 2021, https://www.nbr.org/publication/developments-in-chinas-commercial-space-sector/.

[43] Andrew Jones, "China Sets Targets for Smart, Recoverable and Reusable Launch Vehicles," *Space News*, November 26, 2020, https://spacenews.com/china-sets-targets-for-smart-recoverable-and-reusable-launch-vehicles/ and Andrew Jones, "China Rolls Out Long March 8 Rocket for Weekend Test Flight," Space News, December 18, 2020, https://spacenews.com/china-rolls-out-long-march-8-rocket-for-weekend-test-flight/.

[44] Andrew Jones, "China Scraps Expendable Long March 9 Rocket Plan in Favor if Reusable Version," *Space News*, Nov. 9, 2022, https://spacenews.com/china-scraps-expendable-long-march-9-rocket-plan-in-favor-of-reusable-version/.

Conclusions

China's space and missile programs are a case study in how China has been able to overcome US isolation to become a world-leading technological power. Indeed, the near-total ban on space cooperation between the two countries since the late 1990s demonstrates the ability of the PRC to innovate in this critical area. The recognition of space as an important strategic military capability and an element of national prestige has committed China's leadership to devote attention and funding to the development of its space and missile programs.

Despite this isolation, China's space and missile programs are not only closing the gap with the United States but are also increasingly innovative. The US Director of National Intelligence assesses that "China is developing innovative systems in all space technology areas," and "that by 2030 will achieve world-class status in all but a few."[45] The PRC has deployed the world's first antiship ballistic missile (ASBM), the DF-21D MRBM, with a range of 1,500–2,000 km, giving the PLA the ability to attack ships east of Taiwan, as well as the DF-26 ASBM.[46] China's emphasis on developing hypersonic glide vehicles has resulted in China surpassing the United States. According to Mark Lewis, the Pentagon's former director of defense research and engineering for modernization, "By almost any metric that I can construct, China is certainly moving out ahead of us [in hypersonics]."[47] The development of an orbital bombardment system will provide the PLA with true global strike capabilities.

China's progress in space and missile technologies has several implications for the United States in terms of export control enforcement and military security.

Implications for export control enforcement

US export controls have had limited effect on PRC access to space technologies

Although determining the exact role and importance of the innovative factors propelling the advancement of China's space and missile programs is difficult because of secrecy issues and the inability to physically examine launch vehicles, missiles, and satellites, it is evident that China's success cannot be attributed to just one factor. Foreign assistance in its many forms has been critical to its success; however, China's space and missile programs would not have been successful if they had not also been well-funded, committed to improving their program management, and attracting a well-educated and competent workforce.

As a result, efforts to isolate China technologically or to "decouple" the United States and China may have been effective over the short- to medium-term but have been less effective over the long-term. Although each industrial sector has its own characteristics that influence the effectiveness of export controls, China's ability to access foreign space technology through both

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[45] "Chinese Space Activities Will Increasingly Challenge US Interests Through 2030," Office of the Director of National Intelligence, April 2021, https://www.dni.gov/files/ODNI/documents/assessments/NICM-Declassified-Chinese-Space-Activities-through-2030--2022.pdf.

[46] Jordan Wilson, *China's Expanding Ability to Conduct Conventional Missile Strikes on Guam*, US-China Security and Economic Review Commission, May 10, 2016, 4 https://www.uscc.gov/sites/default/files/Research/Staff%20Report_China%27s%20Expanding%20Ability%20to%20Conduct%20Conventional%20Missile%20Strikes%20on%20Guam.pdf and "SinoDefence Air and Space," Sept. 4, 2015, https://sinodefence.com/2015/09/04/pla-missiles-in-3-sept-parade/.

[47] US Defense Department, *Military and Security Developments Involving the People's Republic of China 2020*, p. 56 and Robert Burns, "More security? US vs. China in 'Super-Duper' Missiles Race," *Christian Science Monitor*, May 20, 2020, https://www.csmonitor.com/USA/Military/2020/0520/More-security-US-vs.-China-in-super-duper-missiles-race.

legitimate and illegal means indicates that US attempts to restrict space- and missile-related technology transfers have been limited by the willingness of other states to share technology with China and the porousness of US export control enforcement. US efforts to constrain China's space program have likely only limited the speed of PRC progress rather than halted it.

PRC role as a leading space power may make it less reliant on foreign technology

The next 10 years may prove to be telling for the future of the PRC space and missile programs. As they close the technological gap with the United States and approach the technological edge of space and missile technologies, the PRC space and missile programs must increasingly rely on their internal abilities to advance. As a result, access to foreign technology may become less important for the PRC.

US may need to place more emphasis on monitoring PRC exports of space and missile technologies

As its space and missile technologies become more advanced, the PRC may become more likely to export sensitive technologies and services to countries of concern. In a reversal of decades-long practice, the PRC is supplying electronic components to the Russian space industry.[48] On January 23, 2023, the US Department of the Treasury sanctioned Spacety, a PRC-based manufacturer of small satellites, for providing satellite imagery to Russia's Wagner Group.[49]

Expansion of PRC commercial space industry complicates export control enforcement

On the other hand, the expansion of the PRC commercial space industry increases the number of actors who may try to acquire export-controlled items. The increased number of actors either acquiring foreign technology directly or through their subsidiaries may make monitoring and enforcement of export control laws increasingly difficult.

Implications for US military security

PRC emphasis on missiles is ushering in an emerging competition in missiles and space technologies

China's development of long-range cruise and ballistic missiles and hypersonic weapons has the potential to usher in a new stage of warfare in which missile power replaces air power as the determining factor in warfare. In doing so, missile power places an even greater emphasis on long-range reconnaissance and the role of space technologies. As a result, future maritime warfare will be decided by two main factors: weapon range and C4ISR capabilities.[50] This dynamic is seen in

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[48] State Council Information Office, *China's Space Activities in 2016*, Dec. 27, 2006, http://www.scio.gov.cn /zfbps/32832/Document/1537024/1537024.htm; State Council Information Office, "Joint Communique From the 21st Regular Meeting Between the Prime Ministers of China and Russia" (中俄总理第二十一次定期会晤联合公报), *People's Daily*, Nov. 9, 2016, http://politics.people.com.cn/n1/2016/1109/c1001-28845796.html.
[49] Andrew Jones, "U.S. Sanctions Chinese Satellite Firm for Allegedly Supplying SAR Imagery to Russia's Wagner Group," *Space News*, Jan. 27, 2023, https://spacenews.com/u-s-sanctions-chinese-satellite-firm-for-allegedly-supplying-sar-imagery-to-russias-wagner-group/.
[50] Wayne P. Hughes, *Fleet Tactics and Coastal Combat*, (Annapolis: Naval Institute Press, 2000), 721.

an emerging competition in missiles and space technologies, called here the "US-China reconnaissance-strike competition."[51]

PRC expansion of nuclear arsenal complicates US nuclear deterrence

The PRC has a relatively small intercontinental ballistic missile (ICBM) force consisting of tens of silo-based and road-mobile missiles. This force will likely grow as the PRC's nuclear arsenal increases to a projected 1,500 warheads by 2035.[52] The PRC's nuclear arsenal presents more challenges than sheer numbers, however. According to the Defense Department, the PRC seeks to modernize, expand, and diversify its nuclear force with warheads that range from "lower-yield precision strike missiles to ICBMs with multi-megaton yields."[53]

The establishment of a more diverse nuclear force armed with precision low-yield warheads could provide the PRC more escalatory options not matched by the US nuclear arsenal with its reliance on larger warheads. This asymmetry in nuclear force employment could complicate the ability of the US to respond proportionally to PRC nuclear provocations.

Potential PRC development of nuclear "quad" complicates US nuclear deterrence

The potential development of an orbital bombardment system by the PRC may signal the intent to develop its nuclear triad into a nuclear "quad" based on land-launched nuclear missiles, submarine-launched nuclear missiles, aircraft with nuclear bombs and missiles, and space-launched hypersonic glide vehicles. The addition of a space-launched leg to the PRC nuclear deterrent appears to give the PRC a potential global first-strike capability capable of evading US missile defenses that could add a destabilizing element into US-PRC crisis management. The development of a space-based nuclear bombardment system would also violate the Outer Space Treaty's prohibition against stationing nuclear in space, which the PRC has signed.

US needs to consider the development and stockpiling of longer-range missiles and delivery systems.

The PRC focus on conventional missiles demonstrates an emphasis on precision and mass that provides the PLA with a multilayered area denial capability out to the second island chain.[54] China's development of ballistic missiles, cruise missiles, and hypersonic weapons presents a number of challenges to the US military. These include the longer ranges of PLA missiles and an inability to defend against supersonic and hypersonic missiles. Moreover, the Russian war on Ukraine and a recent wargame by the Center for Strategic and International Studies indicate that a conflict with the PRC could be resource intensive, with thousands of precision-guided munitions being used in the first weeks of the war causing significant losses of ships and aircraft.[55] If

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[51] For more on the US-PRC reconnaissance-strike competition, see Kevin Pollpeter, "The US-China Reconnaissance-Strike Competition: Missiles, Space, and Counterspace," in Tai Ming Cheung and Thomas Mahnken, eds., *The Gathering Pacific Storm, Emerging US-China Strategic Competition in Defense Technological and Industrial Development*, (Amherst: Cambria Press, 2018).

[52] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2022*, 98.

[53] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2022*, 96.

[54] US-China Economic and Security Review Commission, *2015 Report to Congress*, Nov. 2015, 355-356.

[55] Mark F. Cancian, Matthew Cancian, Eric Heginbotham, *The First Battle of the Next War: Wargaming a Chinese Invasion of Taiwan*, Center for Strategic and International Studies, Jan. 2023, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/230109_Cancian_FirstBattle_NextWar.pdf?VersionId=WdEUwJYWIySMPIr3ivhFolxC_gZQuSOQ.

accurate, this would appear to make the stockpiling of long-range missiles and weapons platforms and an acceleration of the expansion of defense production priorities.

Approved April 2023: Maryanne Kivlehan-Wise, Research Program Director
China Studies Program/ China and Indo-Pacific Security Affairs Division