SECTION 2: WEAPONS, TECHNOLOGY, AND EXPORT CONTROLS

Abstract

China's rapid military modernization over the past two decades shows it has not only been successful as a "fast follower" but also is now leading in several technologies as it seeks to "leapfrog" the United States to achieve dominance in the military domain. The United States and China are engaged in a de facto arms competition, and the People's Liberation Army (PLA) is preparing for the possibility of open confrontation. If China overtakes longstanding areas of U.S. advantage in undersea warfare and space and establishes a decisive lead in artificial intelligence (AI), the balance of power in Asia and worldwide could be dramatically altered. But whether China will become the world's defense technology leader remains an open question, depending on how speedily it resolves its own inadequacies in areas such as human capital and certain manufacturing technologies. One potential accelerant of Beijing's efforts is its relationship with Russia. Russia may have no choice but to share its most valuable defense technologies with China, particularly those relevant to undersea warfare, as it becomes increasingly isolated from the world due to its war in Ukraine.

Key Findings

- The Chinese Communist Party (CCP) aspires to transform China from a "fast follower" into a world leader in defense technologies. Party leaders frame this drive to catch up and surpass the United States in key warfighting domains in terms of the needs for self-reliance in critical technologies and a shift from a model based on copying foreign technologies to one of original innovation.
- China's military-industrial complex produces a variety of quality modern weapons systems that increasingly enable the PLA to challenge the balance of power in the Asia Pacific region. China is also pursuing a space-based nuclear weapon that has the potential to threaten the U.S. homeland with a new global strike capability, and it is developing frontier technologies that could lead to a paradigm shift in warfighting. It does so in spite of the fact that its domestic defense industry is dominated by state-owned monopolies and plagued by inefficiency.
- China is already a world leader in missile and space technologies, and tighter U.S. export controls are unlikely to have an effect on future Chinese innovation in these areas. China's huge inventory of conventional ballistic, cruise, and hypersonic missiles already limits the United States' ability to operate freely

within the second island chain.* Beijing's pursuit of space-based nuclear weapons and potential development of low-yield warheads could also complicate U.S. deterrence by offering the PLA greater flexibility to threaten or engage in limited nuclear use against U.S. forces in the region.

- China has made significant strides in submarine technology over time and is heavily investing in anti-submarine warfare (ASW) capabilities to erode the longstanding U.S. advantage in undersea warfare. Current limitations China faces in undersea warfare technologies include quieting technologies for manned nuclear submarines and propulsion systems for small undersea vehicles. Russian technological assistance could, however, decisively affect how quickly China catches up to the United States in this area.
- China's military-civil fusion program has made rapid progress in AI for defense applications by leveraging commercial advances. Investment and procurement patterns suggest the PLA aims to use AI-enabled weapons systems to counter specific U.S. advantages and target U.S. vulnerabilities.
- U.S. export controls toward China have expanded substantially, though they now face significant obstacles to enforcement. Military-civil fusion presents a unique challenge to export controls, requiring a renewed focus on dual-use technologies, particularly in current multilateral regimes, which focus mainly on preventing the spread of military technologies that currently exist rather than preventing the development of new ones.
- Current investment restrictions are insufficient to stem the flow of U.S. and foreign technology, expertise, and capital into China's defense sector. Capital and technology flows are often accompanied by technical expertise, managerial acumen, and business networks—factors much more difficult to contain to intended end users. These intangible benefits can help Chinese firms build operational capabilities that are not covered under current screening mechanisms and into which the U.S. government has limited visibility.

Recommendations

The Commission recommends:

- Congress hold hearings to evaluate the potential for establishing a single export licensing system. Such a system would integrate the Commerce Control List, the dual-use technology licensing system managed by the U.S. Department of Commerce's Bureau of Industry and Security, and the U.S. Munitions List, the armaments licensing system managed by the U.S. Department of

*According to the U.S. Department of Defense (DOD), the first island chain consists of the islands spanning from "the Kurils, through Taiwan, to Borneo." The second island chain begins in Japan, travels south through the Northern Mariana Islands, Guam, Palau, and ends off the northern coast of West Papua. The first and second island chains are not officially demarcated and are the subject of debate regarding their boundaries. U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China: 2020 Annual Report to Congress*, 2020, 73; Wilson Vorndick, "China's Reach has Grown; So Should the Island Chains," *Center for Strategic and International Studies*, October 22, 2018.

State's Directorate of Defense Trade Controls. In evaluating a single licensing system, Congress should consider:

- ○ Whether a single licensing system could improve the enforcement of export controls targeting specific end users, particularly those in jurisdictions with poor transparency into corporate ownership and commercial affiliations, such as China;
- ○ The potential commercial impact of combining the licensing systems, including how to reduce the compliance burden on industry without compromising national security;
- ○ Which technologies to include in a combined system and how to integrate appropriate technical expertise to scope evolving controls on dual-use emerging and foundational technologies;
- ○ Where such a system should be housed within the U.S. government and how to establish effective coordination between different agency stakeholders; and
- ○ How to provide the Department of State and other relevant agencies with appropriate information and authorities to advocate for multilateral export controls that advance U.S. security, foreign policy, and economic competitiveness.

- Congress provide the Committee on Foreign Investment in the United States (CFIUS) the authority to review investments in U.S. companies that could support foreign acquisition of capabilities to attain technological self-sufficiency or otherwise impair the economic competitiveness of the United States, including:
  - ○ Investments in technology areas prioritized in potential adversaries' industrial policies, such as China's 14th Five-Year Plan, Made in China 2025, and other related initiatives;
  - ○ Investments in U.S. firms that have received funding from the U.S. Departments of Defense, Commerce, Energy, and other U.S. government funding for projects critical to national security and competitiveness; and
  - ○ Other investments that may provide privileged access to expertise, business networks, and production methods critical to maintaining U.S. economic and technological competitiveness.
- Congress establish a risk matrix framework to evaluate the national security threat posed by electronic products imported from the People's Republic of China. To eliminate or mitigate risks identified in the threat matrix evaluation, Congress should consider the use of all trade tools, including tariffs.
- Congress request an evaluation, to be completed within 180 days by the Government Accountability Office, of the effectiveness of recently imposed semiconductor export control regulations in preventing China from either acquiring or developing the capacity to manufacture certain advanced semiconductors. The report should include an assessment of the extent of cooperation received from key allied governments, as well as both U.S. and foreign-based companies, and an evaluation of China's efforts to circumvent these controls or to negate their effectiveness by developing its own indigenous capabilities. This assess-

ment should be prepared for public release but may include a classified annex. The report should be updated annually.

Introduction

This section evaluates China's pursuit of advanced defense technologies. It begins with an assessment of Chinese leaders' ambition to become a dominant military power and their efforts over time to improve the research, development, and acquisition process for modern weapons. It then assesses China's progress in mastering advanced defense technologies across three domains: undersea warfare, missile and space capabilities, and AI. Finally, the section assesses current U.S. and multilateral export controls and investment restrictions to determine whether they are adequately stemming the flow of U.S. and foreign technology, expertise, and capital to China's defense sector. The section draws on the Commission's April 2023 hearing on "China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment Screening Regimes," consultations with experts, and open source research and analysis.

China's Drive for Defense Innovation

In just a few decades, the PLA has transformed itself from a technologically backward military to one that is capable and seeking to contest the United States' military superiority.*[1] An important element of this transformation has involved changes to China's system for developing modern and innovative weapons, which has benefited from ample state funding and China's systematic theft of foreign technology.[2] As Christian Curriden, a defense analyst at RAND Corporation, testified before the Commission, this system has inefficiencies but is also capable of producing highly sophisticated weapons systems that threaten the United States and allied forces throughout the Indo-Pacific.[3] More generally, China is attempting to transition from being a "fast follower" of the United States and other advanced militaries to a dominant military power by making its weapons development system capable of original innovation.[4]

China Invests in Modern Defense Technologies to Counter U.S. Advantages

China's leaders have focused on modernizing the PLA in order to counter overwhelming U.S. military advantages in the Indo-Pacific and to build capabilities commensurate with the global power China seeks to be. Senior CCP officials have historically recognized that the PLA's past technological backwardness would make it an ineffective fighting force in the event of a conflict with the United

*The Commission assessed in its 2020 Annual Report to Congress that Beijing's view of strategic competition with the United States reflects an intention to surpass U.S. military capabilities, not simply to achieve parity. This drive for superiority has been especially pronounced in the space domain, where the Commission's 2019 Annual Report assessed that China "aims to catch up to and eventually surpass other spacefaring countries in terms of space-related industry, technology, diplomacy, and military power." For more, see U.S.-China Economic and Security Review Commission, Chapter 1, Section 1, "A Global Contest for Power and Influence: China's View of Strategic Competition with the United States," *2020 Annual Report to Congress*, December 2020, 31, 35, 56, and U.S.-China Economic and Security Review Commission, Chapter 4, Section 3, "China's Ambitions in Space - Contesting the Final Frontier," *2019 Annual Report to Congress*, November 2019, 359.

States.*[5] Past CCP leaders Jiang Zemin and Hu Jintao both supported initiatives to expand China's limited capacity for defense-relevant research and development (R&D) and oversaw changes to China's military strategy that highlight information technology and other modern weapons technologies as the key to winning a regional war over Taiwan.†[6] They also presided over Central Military Commission (CMC) efforts to invest in modern air, space, missile, and command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) capabilities throughout the 1990s and early 2000s.[7] PLA strategists and technicians focused their efforts on countering a more developed adversary's qualitative advantages in an "asymmetric" manner, sometimes through the use of new technologies and at other times through the PLA's own quantitative advantages.[8] Particular areas of focus in the PLA's early approach to asymmetric warfare included counterattacking an adversary's stealth, cruise missile, and helicopter capabilities while also defending itself from an enemy's precision strikes, electronic warfare, and reconnaissance.[9]

The PLA has spent the last several decades honing asymmetric capabilities and strategies that could be used in a war where both sides employed modern information technology.[10] According to Elsa Kania, an adjunct senior fellow at the Center for a New American Security, PLA strategists have more recently studied how AI and other technologies can be used to gain decisive advantages in wartime decision-making and processes.[11] For instance, Lieutenant General Liu Guozhi, the director of the CMC Science and Technology Commission, claimed in 2017 that AI will not only "accelerate the process of military transformation" but also lead to "a profound revolution in military affairs."[12] As part of this new focus, Ms. Kania notes that PLA leaders have developed the concept of "hybrid intelligence," blending human and machine intelligence through techniques such as the use of brain-computer interfaces.[13] Ms. Kania observes that this concept is being realized through new programs, including projects intended to promote human performance enhancement, such as the use of "intelligent autonomy" in weapons, with command exercised through brain-machine integration enabled

*The United States' success during the Gulf War taught Chinese leaders the importance of developing a modern, space-based C4ISR system in order to become a world-class military conducting joint force and expeditionary operations. Mike Dahm, "China's Desert Storm Education," *U.S. Naval Institute*, March 2021; John Costello and Joe McReynolds, "China's Strategic Support Force: A Force for a New Era," in Phillip C. Saunders et al., eds., *Chairman Xi Remakes the PLA: Assessing Chinese Military Reforms*, National Defense University, February 22, 2019, 440.

†In 1993, Beijing issued its first "military strategic guidelines," a set of principles encompassing China's military strategy for building long-term competitive capabilities, rather than preparing for U.S. or Soviet attacks on China's borders as had historically been the case. The 1993 military strategic guidelines were Beijing's response to U.S. technological capabilities exhibited in the 1990–1991 Gulf War, which some PLA strategists believe triggered a "revolution in military affairs," revealing a new model of war. In his speech on the 1993 guidelines, then General Secretary Jiang identified the focal point of China's strategy as deterring Taiwan from declaring independence. While the guidelines did not specify China's primary strategic opponent, they revealed that this opponent was no longer the Soviet Union and had changed based on "major changes in the strategic threat." The guidelines also noted that the most important geographic focus for China's military planning, known as the "primary strategic direction," would be China's southeast, toward Taiwan. By leaving the new strategic opponent the PLA would likely face unstated, Chinese leaders avoided naming the United States directly while tacitly acknowledging that a conflict over Taiwan would likely require the PLA to also fight the United States. Tai Ming Cheung, *Innovate to Dominate: The Rise of the Chinese Techno-Security State*, Cornell University Press, 2022, 143, 147–149; M. Taylor Fravel, *Active Defense: China's Military Strategy since 1949*, Princeton University Press, 2019, 183–184.

by cloud infrastructure.[14] Through such investments in advanced military and frontier technologies, she argues, the PLA is seeking to create "technological surprise"* for the United States and achieve paradigm-shifting advances in warfare.[15]

Under General Secretary of the CCP Xi Jinping, China is seeking to both "catch up and leapfrog" the United States in the military realm amid an increasingly tense strategic competition between the two powers and greater urgency to become self-reliant in key technologies.[16] Xi has pledged to make the PLA a world-class military by the middle of the 21st century, a term which itself is a moving target and which Chinese state media have increasingly linked to the idea of military innovation.[17] He has also tried to ready the PLA for this task by launching a far-reaching reorganization of the armed forces as well as the broader system responsible for PLA armaments and innovation.†[18] Xi has also spoken consistently of the need to accelerate defense modernization through investments in innovative defense technologies, making independent innovation an important element of "Xi Jinping Thought on a Strong Military."‡[19] At the 20th Party Congress in October 2022, for example, Xi stated his government's intention to "implement major projects to develop defense-related science and technology, weaponry, and equipment, and move faster to translate scientific and technological advances into combat capabilities."§[20] Although the PLA's capabilities today

*Technological surprise occurs when the performance of new tools of warfare contravenes expectations and produces strategic effects, the latter of which may be large enough to decisively win a conflict. Technological surprise can be created by an adversary's debut of an unexpected capability or by the unanticipated performance of one's own technology. For more, see Con Crane, "The Danger of Technological Surprise: Expect the Unexpected or Suffer the Consequences," *U.S. Army War College: War Room*, January 6, 2022; Mark F. Cancian, "Avoiding Coping with Surprise in Great Power Conflicts," *Center for Strategic and International Studies*, 2018, 37.

†These changes included the dismantlement of the notoriously corrupt General Armaments Department, efforts to consolidate the state-owned defense conglomerates that dominate China's defense industry, and the decision to make the CMC Science and Technology Commission an independent CMC organ. As in other policy areas, Xi has also made himself the chair of key bodies that make and coordinate decisions regarding China's defense technology requirements. In addition to his role as chairman of the CMC, Xi leads the CMC Leading Small Group for the Deepening of Reforms in Defense and the Armed Forces, the CMC Military-Civil Fusion Development Commission, and the 995 Leading Small Group. Christian Curriden, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment Screening Regimes*, April 13, 2023, 2–4; Tai Ming Cheung, *Innovate to Dominate: The Rise of the Chinese Techno-Security State*, Cornell University Press, 2022, 47–48; Nis Grünberg, "The CCP's Nerve Center," *Mercator Institute for China Studies*, July 1, 2021; Tai Ming Cheung, "Keeping Up with the Jundui: Reforming the Chinese Defense Acquisition, Technology, and Industrial System," in Phillip Saunders et al., eds., *Chairman Xi Remakes the PLA: Assessing Chinese Military Reforms*, National Defense University Press, 2019, 598, 602–603; Joel Wuthnow and Phillip C. Saunders, "Introduction Appendix: Central Military Commission Reforms," in Phillip Saunders et al., eds., *Chairman Xi Remakes the PLA: Assessing Chinese Military Reforms*, National Defense University Press, 2019, 30; Joel Wuthnow and Phillip C. Saunders, "Introduction: Chairman Xi Remakes the PLA," in Phillip Saunders et al., eds., *Chairman Xi Remakes the PLA: Assessing Chinese Military Reforms*, National Defense University Press, 2019, 6.

‡"Xi Jinping Thought on a Strong Military" are official formulations representing Xi's policy guidance on military development. *People's Liberation Army Daily*, "Xi Jinping Thought on a Strong Military Questions and Answers" (习近平强军思想学习问), September 14, 2022. Translation; Joel Wuthnow and Phillip C. Saunders, "Introduction: Chairman Xi Remakes the PLA," in Phillip C. Saunders et al., eds., *Chairman Xi Remakes the PLA*, National Defense University, February 22, 2019, 1–24, 15; Chinese Communist Party Member Network, *Study Platform: Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era: Xi Jinping Thought on a Strong Military* (学习平台: 习近平新 时代中国特色社会主义思想: 习近平强军思想). Translation.

§Chinese military commentators have similarly called for greater investment in defense technology and efforts to boost self-sufficiency. For instance, one PLA Navy rear admiral argued in 2016 that "despite the fact that the Navy's strength, weapons and equipment continue to improve, we have weaknesses at the technological level. Our researchers have made breakthroughs in many fields, and what we need now is the government's determination and investment, otherwise the Navy will lag behind others." More recently, in 2023, a researcher from the Academy

reflect the success of long-running efforts by previous CCP leaders to modernize the armed forces, Xi's approach to defense technology modernization has emphasized long-term planning, an effort to transition to a model of original innovation, and the appropriation of civilian talent for defense innovation under the country's military-civil fusion strategy.[21]

China's Concept of a "World-Class Military" and the Role of Technological Advancement

In 2017, Beijing announced its goal to build the PLA into a "world-class" military by the mid-21st century, overcoming remaining shortfalls in the force's capabilities to establish China firmly among the ranks of the world's leading militaries.[22] This objective is guided by CCP leaders' view that China is approaching the "world's center stage" and represents the military component of a multifaceted goal to establish China's leading global position in every important element of national power.[23] Beijing views a world-class PLA as surpassing the world's other militaries in strength and prestige, especially the U.S. Armed Forces, and being capable of preventing other countries from resisting China's pursuit of its national goals.[24]

China has identified the technological advancement of its military capabilities as an essential part of becoming a world-class military.[25] For example, one 2018 *PLA Daily* article asserted that "building a world-class army in an all-round way is inseparable from the support of modernization of weapons and equipment."[26] Noting that the future of technological competition will be intense and complex, the *PLA Daily* warned that "the road to leapfrog development of weaponry and equipment construction has a long way to go."[27] It urged the military to address foreign countries' "stranglehold" on "key and core technologies" and to make indigenous breakthroughs in those same areas.[28] A November 2022 state media article noted that in order to be successful in future conflicts, the PLA must pay close attention to changes in technology and improve its ability to win "informationized and intelligentized wars" in tandem with its transformation into a world-class military.[29] The use of AI in weapons systems has become a central focus of China's military reform in recent years and will be a major aspect of its efforts to build a world-class military.[30]

In recent years, the Chinese leadership has pushed to accelerate the timeline for achieving world-class status. Despite initially laying out the goal of the PLA reaching a world-class standard by mid-century in 2017, Xi has in his recent speeches indicated a desire to shorten this timeline without setting a specific date.[31] During both the 20th Party Congress in October 2022 and the 14th National People's Congress in March 2023, for example, Xi urged the PLA to reach world-class standards "more quickly."[32]

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of Military Sciences argued that China should develop indigenous weapons systems in light of Western sanctions on high-tech components already implemented against the Russian military in response to its unprovoked war in Ukraine. Amber Wang, "China Urged to Speed Up Self-Reliance in Military Tech as Western Sanctions Render Old Model 'Unsustainable,'" *South China Morning Post*, April 11, 2023; Zhao Lei, "PLA Officer: Navy Needs More Punch," *China Daily*, March 21, 2016.

China's Concept of a "World-Class Military" and the Role of Technological Advancement—*Continued*

Zhao Xun, a researcher at Beijing's Academy of Military Sciences, asserted that this desire to increase the military's technological capabilities more rapidly has been driven by a perception in China of the West as "suppress[ing] and contain[ing] the development of our country's hi-tech industries," arguing further that "the old path of following and imitating others for the development of our military's weapons and equipment has become unsustainable."[33] Zhao also asserted that the PLA must secure technological chokepoints—including raw materials, essential components, and various electromechanical products—"as soon as possible" in order to ensure self-sufficiency.[34]

Long-Term Planning and Resources for Defense Innovation

According to Tai Ming Cheung, a professor at the University of California, San Diego, China has made such rapid progress in recent decades thanks largely to consistent policy support and ample resourcing.*[35] According to Dr. Cheung, five-year plans constitute the primary policy framework for Chinese defense modernization.[36] The 14th Five-Year Plan for National Economic and Social Development (2021–2025) vowed to "accelerate weapons and equipment modernization, focus on independent innovation and original innovation in defense S&T, speed up the development of strategic cutting-edge technologies, and speed up weapons and equipment upgrades," among other things.†[37] The PLA, Chinese defense industry state-owned enterprises (SOE), and provinces also operate on the basis of complementary five-year plans that outline near-term defense science and technology development goals.[38]

In addition to the five-year plans, several other key plans, strategies, and programs define the equipment and technologies China will prioritize in future defense acquisition. These include:

- *The Weapons and Equipment Development Strategy (WEDS)* and its corresponding *Weapons and Equipment Construction Plans (WECPs)*, which encompass the "detailed nuts and bolts" of program management, the types of weapons to be designed and developed, funding requirements, and the allocation of funds, purchasing plans, and maintenance plans.[39] These planning documents are developed by the CMC's Equipment Develop-

*According to Dr. Cheung, China's defense-related R&D is likely well funded, but actual figures are not released by Chinese authorities and are likely supported by parts of the state budget separate from the defense budget. Tai Ming Cheung, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment Screening Regimes*, April 13, 2023, 11.

†Another important five-year plan is the 13th Defense Science, Technology, and Industry Five-Year Plan (2016–2020), which was focused on developing high-tech weaponry and leveraging civilian innovation for defense purposes. Its tasks included facilitating "leapfrog development" of weapons and military equipment, optimizing the structure of the defense industry, promoting civil-military integration, and boosting exports of Chinese weapons. There is no publicly available information about its successor, the 14th Defense Science, Technology, and Industry Five-Year Plan, which should be in force from 2021 to 2025. Tai Ming Cheung, Barry Naughton, and Eric Hagt, "China's Roadmap to Becoming a Science, Technology, and Innovation Great Power in the 2020s and Beyond: Assessing Its Medium- and Long-Term Strategies and Plans," *University of California Institute on Global Conflict and Cooperation*, 10.

ment Department and come in one-, five-, or ten- year variants, with the WEDS having both national-level and service-level variants.[40] Although the detailed contents of the WEDS and WECPs are unknown because they are classified documents, Dr. Cheung observes that they likely specify the acquisition of various offensive, asymmetric, and advanced technologies such as precision-guided munitions, antiship ballistic missiles, anti-satellite weapons, cyber weapons, stealth aircraft, hypersonic missiles, and supercomputers.[41]

- *The Defense Medium- and Long-Term Science and Technology Development (DMLP) Plan*, which focuses on defense-related basic research and creating conditions for long-term innovation.[42] DMLP initiatives aim to build up the defense innovation system within China, create incentives for domestic innovation, increase channels for investment in defense-related technology, improve technology transfer from foreign sources, leverage civilian innovation, and cultivate a science- and technology-literate workforce.[43] The DMLP has prioritized research related to nuclear energy, new energy, aerospace, aviation, information technology, ship building, and ocean engineering.[44]
- *The New High-Technology Project*, or *995 Project*, focuses on advanced, strategic weapons systems the PLA refers to as "trump card" capabilities.[45] Nicknamed after the accidental bombing of the Chinese Embassy in Belgrade in May 1999, the 995 Project is a long-term plan rarely spoken about in public that has reportedly driven programs related to stealthy, supersonic, and long-range strategic bombers, next-generation fighter jets, new missiles, and electronic countermeasures.[46] The DF-21D antiship ballistic missile and different types of unmanned aerial vehicles have reportedly been produced under the 995 Project.[47] The 995 Project is likely guided by five-year planning cycles.[48]
- *The Science, Technology, and Innovation 2030 (STI 2030) Major Projects program*, a long-term initiative launched in 2015 that is focused on mastering key technologies.[49] The STI 2030 program covers at least 16 megaprojects that include aircraft engines and combustion turbines, technologies for deep-sea exploration and stations, quantum communications and computing, neuroscience and brain-related research, cybersecurity, deep-space exploration and in-orbit spacecraft, clean and efficient use of coal, smart power grids, space-earth integrated information networks, intelligent manufacturing and robotics, and key new materials research and applications.[50] General Secretary Xi has described the STI 2030 program as needed to help China "capture the science and technology strategic commanding heights."[51]

Emphasis on Original Innovation and Self-Reliance

Chinese leaders have also stressed the importance of China's weapons development system becoming truly innovative and less reliant on Western sources of technology that could be disrupted for political or military purposes. China is seeking to move from an "absorption-based model" of defense innovation—whereby Chinese firms copied, stole, and reverse engineered other countries' technolo-

gies—to one where these firms are developing novel technologies.*[52] In his 20th Party Congress speech, Xi claimed China had "joined the ranks of the world's innovators" with advances in basic research, original innovation, core technologies,† and emerging strategic industries.[53] By standard measures of inputs to and outputs from innovation, China is indeed rapidly catching up to the United States, with major increases in infrastructure devoted to R&D, patents, and Chinese authors' standing in citation indices.[54]

Official claims and metrics likely overstate China's capabilities in original innovation, however. First, China's R&D expenditures have historically skewed toward applied research rather than basic research, and its gains tend to be in "process innovation" or realizing breakthroughs in production efficiency.[55] Second, China has historically struggled to catch up in technologies that require integrating different disciplines, such as internal combustion engines.[56] Third, the monopolistic nature of major state-owned defense conglomerates can also slow adoption of research breakthroughs due to a lack of incentives for innovation (for more, see the next subsection on "China's Research, Development, and Acquisition (RDA) System").[57] More broadly, because China's policy system incentivizes the pursuit of easily measurable metrics of performance, this creates a situation where proxies for innovation such as patenting and potentially R&D expenditure are often inflated and less likely to reflect true quality than they would in a market economy.[58]

As it emphasizes its progress toward a model of original innovation, Beijing is trying to identify "chokepoints" in the imported technologies used in weapons systems and dual-use infrastructure that the United States and other countries could potentially cut off, aiming to replace them with domestic alternatives.‡[59] Xi has consistently emphasized the importance of technological self-reliance in core and defense-related technologies, most recently interrupting a "Two Sessions" delegate from the Xuzhou Construction Machinery Group in March 2023 to ask whether all the chips it used in its cranes were domestically produced.[60] Recognition of these vulner-

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*Chinese state-sponsored hackers have reportedly stolen designs and other information for a variety of U.S. weapons systems, including the Aegis Ballistic Missile Defense System, the F-35 Lighting II Joint Strike Fighter, the Littoral Combat Ship, and electromagnetic railguns. Independent analysts have noticed striking similarities between the U.S. F-22 Raptor and Chinese J-20 fighter, the U.S. F-35 and the Chinese Shenyang J-31 fighters, the U.S. MQ-9 Reaper drone and the Chinese Caihong-class unmanned aerial vehicle, and the U.S. C-17 Globemaster III and the Chinese Y-20 transport aircraft, which were likely facilitated by espionage. Ellen Ioanes, "China Steals U.S. Designs for New Weapons, and It's Getting Away with 'the Greatest Intellectual Property Theft in Human History,'" *Business Insider*, September 24, 2019; Sam LaGrone, "Report: China Hacked Two Dozen U.S. Weapon Designs," *USNI News*, May 28, 2013.

†Chinese media and state planning documents describe "core technologies" as encompassing a broad range of technologies across many sectors. According to one *Global Times* article, for example, there are around two dozen of these core technologies, "including rockets, batteries, robots, 3D printing, biological innovative medicine and satellites." In China's National Medium- and Long-Term Program for Science and Technology Development (2006–2020), which identifies mastering core technologies in the information industry and manufacturing as top priorities, specific core technologies in the information industry include integrated circuits and key components, major software, high-performance computers, broadband mobile telecommunications, and next-generation internet. Xie Jun, "Chinese Manufacturing Industry Leaders Call for Focus on Core Technologies," *Global Times*, December 26, 2021; China's State Council, *National Medium- and Long-Term Program for Science and Technology Development (2006–2020)*, 2006, 22. Translation.

‡In 2018, China's state-run newspaper *Science and Technology Daily* published a series of articles on 35 different Chinese technological import dependencies, ranging from aviation design software to photo-lithography machines for microchips. Ben Murphy, "Chokepoints: China's Self-Identified Strategic Technology Import Dependencies," *Center for Security and Emerging Technology*, May 2022, 1–2, 6–9.

abilities has been a key driver of China's dual circulation strategy to reduce dependency on foreign technology, increase domestic consumption, and increase foreign reliance on China.[61] China's 14th Five-Year Plan, released in December 2021, also places self-sufficiency at the core of national development and prioritizes advancements in sectors such as AI, critical materials, advanced manufacturing, aerospace, and agricultural machinery.[62]

Leveraging Civilian Ingenuity for Defense Innovation

Defense technology innovation in China increasingly relies on the contributions of civilian companies and universities under the auspices of China's military-civil fusion (MCF) strategy.*[63] According to Ms. Kania, MCF is "an incredibly consequential component of Beijing's agenda to catch up with and surpass the United States," particularly in domains such as space, cyberspace, and the deep seas as well as in strategic technologies like AI and quantum information science.[64] MCF was elevated to a national-level strategy in 2014, and in 2017 a central national commission known as the Central Commission for Military-Civil Fusion Development was established to oversee its implementation.†[65]

Today, many Chinese government ministries and agencies implement MCF by developing criteria to identify companies best equipped to supply the PLA or modify university curricula to serve defense needs.[66] At the same time, numerous local governments have established MCF demonstration bases, where companies can apply for or are chosen for an MCF designation.[67] This enables them to receive government support, become vendors for the PLA, and form partnerships with MCF-designated research institutions.[68] Chinese universities are also important contributors to MCF, with many conducting research with defense applications and some even hosting what the Australian Strategic Policy Institute (ASPI) has called "transfer centers" to facilitate the development of technology for MCF.[69]

China's Research, Development, and Acquisition System

The PLA relies on a fairly top-down, centralized, and uncompetitive research, development, and acquisition (RDA) system to acquire weapons for its forces.[70] According to Mr. Curriden, China's RDA system has made noteworthy progress over the last 30 years in various technologically complex fields such as hypersonic vehicles and

*MCF is a strategy to leverage the capabilities of civilian sectors and commercial innovation to drive military development through a combination of policies and government-supported mechanisms. Under Xi, MCF implementation has pursued three broad goals: spinning on, spinning off, and defense mobilization. "Spinning on" refers to facilitating transfers between the defense and civilian sectors to improve the sophistication of China's military technology, particularly in dual-use sectors such as information and electronics (including AI), aerospace, aviation, and shipbuilding. "Spinning off" refers to driving technological innovation and economic growth, including by declassifying military patents and eroding entrenched state-owned enterprise (SOE) monopolies in defense production. Defense mobilization refers to creating cohesion in industry and academia working with and in support of military objectives, for instance so the PLA can use commercial equipment and civilian infrastructure. (For further discussion, see U.S.-China Economic and Security Review Commission, Chapter 3, Section 2, "Emerging Technologies and Military-Civil Fusion - Artificial Intelligence, New Materials, and New Energy," in *2019 Annual Report to Congress*, November 2019).

†The Chinese government has censored mentions of MCF since 2018, likely to evade efforts to place participating civilian entities on the Entity List or other restrictions. Such opacity makes quantifying civilian contributions to the PLA's defense innovation efforts difficult, but the strategy is presumably still in full force. Matt Ho, "Has China Gone into Stealth Mode with Its Military-Civil Fusion Plans?" *South China Morning Post*, June 5, 2020.

carrier-based aviation, demonstrating that the PLA is "clearly capable of producing innovative and advanced platforms."[71] Still, the RDA system suffers from numerous inefficiencies and bureaucratic obstacles related to the monopolistic structure of the defense industrial base, all of which may constrain Beijing's ability to innovate rapidly in the future.[72]

Key Decision-Making Bodies Identify China's Defense Technology Requirements

Decisions about China's defense requirements are made at the top of the political system and coordinated through a series of subordinate bodies below.[73] The CMC sits atop the RDA system's hierarchy as the leading policymaking body regarding China's defense requirements, and it oversees subordinate bodies related to coordination, implementation, and advanced research.[74] One of the most important of these bodies from the perspective of defense modernization is the leading small group in charge of the aforementioned 995 Project's implementation, guiding the development of some of China's advanced strategic weapons systems.[75] Another is the CMC Science and Technology Commission, which guides China's defense-related scientific research and promotes indigenous innovation and MCF.[76] A third is the CMC Equipment Development Department, which handles armaments research and the development, testing, and procurement of systems.[77] Separate from the CMC chain of command, the State Council is responsible for leading the State Administration for Science, Technology, and Industry for National Defense (SASTIND), which manages China's defense industrial apparatus by drafting regulations, standards, and long-term plans that state-owned and private enterprises are required to follow.[78]

Key Organizations Developing China's Weapons Technology

China's RDA process involves a constellation of military, state, and civilian actors. These include China's enormous defense SOEs, Chinese universities, defense-related laboratories, and civilian nonstate enterprises participating in MCF.

China's Defense SOEs

Most of the PLA's major weapons systems and technologies are produced by the country's state-owned defense conglomerates, which vary by sector and often own dozens of subsidiaries.*[79] China's defense industrial sector is closed to outside competition, allowing these SOEs to monopolize defense contracting, with competitive bidding and tendering only taking place for noncombat support equip-

*These include Aviation Industry Corporation of China Limited (AVIC) and Aero Engine Corporation of China Limited (AECC) in the aviation sector; China Aerospace Science and Technology Corporation Limited (CASC) and China Aerospace Science and Industry Corporation Limited (CASIC) in the missile and space sector; China State Shipbuilding Corporation Limited (CSSC) in the maritime sector; China North Industries Group Corporation Limited (NORINCO) and China South Industries Group Corporation Limited (CSGC) in the armaments and ordnance sector; China Electronics Technology Group Corporation Limited (CETC) and China Electronics Corporation Limited (CEC) in the electronic and information technology sector; and China National Nuclear Corporation Limited (CNNC) in the nuclear technology sector. These companies are owned by the State-Owned Assets and Administration Commission of the State Council (SASAC), but their business operations are supervised by SASTIND. Peter Wood and Alex Stone, "China's Ballistic Missile Industry," *BluePath Labs for China Aerospace Studies Institute*, 2021, 5.

ment such as logistics supplies.[80] According to Courtney Weinbaum, a senior management scientist at RAND Corporation, the CCP may direct defense SOEs to prioritize and invest in specific weapons systems or research areas, and Party leaders frequently serve in leadership roles on the boards of these enterprises.[81] According to analysis by the Center for Strategic and International Studies, top Chinese military and civilian leaders also participate in "extra oversight mechanisms" to guide the development of specific weapons deemed a national priority.[82]

Civilian Universities with Strengths in Science and Technology

China's civilian universities are vital sources of talent and research for the country's military advancements, playing a significant role in MCF.[83] According to ASPI, as of 2019, there are 61 Chinese civilian universities supervised by SASTIND, the agency that manages China's defense industrial apparatus.[84] Many civilian universities conduct classified defense research, host state-affiliated laboratories, support state-sponsored espionage, or train the future personnel of the PLA and defense SOEs.[85] Among the most important are the "Seven Sons of National Defense,"* a grouping of elite Chinese public universities with deep ties to the military and defense industry.†[86] More than 10,000 students from these seven universities, or 30 percent of their total employed graduates, obtain jobs in the defense research sector annually, with defense SOEs focusing on aircraft, missiles, warships, armaments, and military electronics constituting their top employers.[87]

Defense-Related State Laboratories

China's system of defense research laboratories, likely managed by both SASTIND and the CMC Equipment Development Department, conducts research involving defense and dual-use technologies.[88] These labs may be hosted at SOEs, civilian universities, or PLA institutions, and focus heavily on areas such as military aerospace, maritime warfare, and ground warfare.[89] For example, the National Key Laboratory of Aerodynamic Design and Research based at Northwestern Polytechnical University is reportedly helping to create a new generation of advanced military and civilian aircraft, helicopters, and unmanned aerial vehicles and is known to conduct research collaboration with at least four different PLA military units.[90] A March 2023 report by DC-based research contractor BluePath Labs studying a subset of defense-related labs known as "defense science and technology key state laboratories" found significant evidence of their collaboration with universities, companies, and research institutions in the United States, Europe, Australia, and Japan.[91]

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*These seven universities include the Beijing Institute of Technology, Beihang University, Harbin Engineering University, Harbin Institute of Technology, Nanjing University of Aeronautics and Astronautics, Nanjing University of Science and Technology, and Northwestern Polytechnical University. Alex Joske, "The China Defence Universities Tracker," *Australian Strategic Policy Institute*, November 25, 2019.

†Because of these deep links to the military industrial complex, ASPI argues that "it would be more accurate to describe them as defense universities than as civilian universities." Alex Joske, "The China Defence Universities Tracker," *Australian Strategic Policy Institute*, November 25, 2019, 6.

Civilian Nonstate Enterprises Participating in MCF

Civilian nonstate enterprises participating in MCF have increasingly become important contributors to China's military modernization, making the greatest impact in the research phase of the RDA cycle and in the realm of AI (for more, see "Artificial Intelligence: China Leverages AI for Military Use" in this section.)[92] Compared to other phases, research is less likely to be classified and often involves hardware and knowhow that are not explicitly military related.[93] Early-stage research is also less likely to put Chinese civilian nonstate enterprises in direct competition with SOEs, which enjoy administrative monopolies in certain fields of defense production.[94] Additionally, China's civilian enterprises face fewer restrictions in accessing sensitive foreign technologies and knowhow than Chinese defense contractors.[95] Civilian nonstate enterprises have yet to become significantly involved in the process of defining technical specifications and operational requirements of PLA weapons or in quality control, as these steps involve more classified information.[96] Similarly, the PLA's maintenance, support, and servicing of military equipment is largely carried out by the military units themselves rather than by enterprise.[97] Nonetheless, MCF may provide inroads for China's commercial sector to become more involved in this aspect of military procurement, as the PLA has acquired some AI-enabled predictive maintenance and logistics solutions through civilian sources.[98]

Although Ms. Kania assesses that MCF is "starting to gain traction," civilian enterprises still face significant barriers to full integration with China's defense sector.[99] China's military industrial complex has deeply embedded inefficiencies that make integration of civilian firms challenging, even with extensive pressure and support from the central government.[100] Because of the high degree of compartmentalization within the defense production establishment, breakthroughs in facilitating MCF in one domain, such as AI, do not guarantee that civilian enterprises will readily be integrated in other fields, like aviation.[101] Long approval times for military production licensing, at six months or more, have also inhibited civilian enterprises' participation in MCF initiatives.[102] Moreover, a lack of intellectual property (IP) protections has reportedly discouraged some firms from sharing technology with the PLA or defense SOEs.[103] Like the implementation of other Chinese industrial and economic development policies, however, China's government has been adapting guidance on MCF implementation as the strategy evolves.[104] Chinese government agencies are taking steps to overcome obstacles and increase the channels for commercial ties to the PLA.[105]

China's RDA Process in Comparative Perspective

The Chinese and U.S. acquisition systems have several parallels, but there are also major differences stemming from the legacy structure of China's state-owned defense conglomerates.* One similarity

*Where many of China's state-run sectors undertook market reforms in the 1980s and 1990s and began adopting more market-based practices through corporatizing SOEs and forming joint ventures with foreign investors, China's armaments production remained largely concentrated in a small number of machine-building ministries responsible for specific defense sectors until 1993. Additionally, foreign firms were unlikely to invest in China's defense sector, so China's defense production did not benefit from market practices or technical knowhow shared through foreign

between the Chinese and U.S. acquisition processes is that both systems tend to take more than a decade to develop and produce new weapons systems.[106] As Mr. Curriden noted in his testimony, it took nearly 17 years for China's Y-20 transport aircraft to gain initial operational capability, while its high-profile carrier-borne J-15 fighter jet took between 11 and 13 years to gain initial operational capability.[107] U.S. and Chinese defense firms are also similar in their overall size.[108] Of the top 20 defense firms in the world ranked by defense-related revenue, the United States possesses eight, while China has seven.[109]

China's Five-Step Research, Development, and Acquisition Process

As in the United States, China's RDA process can be described in five discrete steps:[110]

1. The *comprehensive feasibility study stage*, whereby a PLA institution, university, or defense enterprise researcher conducts a study to determine the requirements for a new weapons system, assess lifecycle costs, and inform a future R&D contract.[111]
2. The *project design stage*, during which the entity that won the contract validates designs and models for the given weapons system and makes initial prototypes.[112]
3. The *engineering and development stage*, whereby the PLA produces technical designs for the weapon and builds and evaluates test models, potentially revising designs on the basis of testing.[113]
4. The *experiment and design finalization stage*, during which PLA units and specialized testing centers conduct tests with the new weapons system to evaluate performance and reliability.[114]
5. The *batch production stage*, during which the contractor produces the weapon in batches.[115] Once a system enters production, the process may repeat itself to develop an incrementally improved version of the same system.[116]

For some weapons platforms, only small numbers of the new product are initially produced and distributed to operational PLA units for further testing, and their input can result in changes in future versions.[117] Mr. Curriden notes that in some cases, such as the Type 98 tank or the Type 052 destroyer, the first version of the platform was so unsatisfactory that the PLA purchased only a relatively small number, opting to wait for improvements before ordering large numbers.[118]

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partnerships (China's defense industry did, however, obtain many weapons systems from Russia). Even after defense-related production was corporatized from state ministries, it remained highly compartmentalized, exacerbating redundant production and limiting potential for research breakthroughs to be shared across firms. Richard Bitzinger, "Reforming China's Defense Industry," *Journal of Strategic Studies* 39:5–6, September 2016, 764–770; Andrew Szamosszegi and Cole Kyle, "An Analysis of State-Owned Enterprises and State Capitalism in China," *Capital Trade* (prepared for the U.S.-China Economic and Security Review Commission), October 26, 2011, 72, 83; Wanda Tseng and Markus Rodlauer, "China: Competing in the Global Economy," *International Monetary Fund*, 2003, 79; Evan Medeiros et al., "A New Direction for China's Defense Industry," *RAND Project Air Force*, 2005, 11–22.

There are also significant differences between the U.S. and Chinese RDA processes, however. As Mr. Curriden points out, many of these differences stem from the relationships Chinese defense firms have with the PLA and the CCP, which differ significantly from the relationship between the U.S. Department of Defense (DOD) and its suppliers.[119] Like the PLA, SOEs are important interest groups within the CCP, and their leadership positions are among those controlled by the CCP Central Committee's Organization Department.[120] These SOEs trace their origins to the 1980s and 1990s, when the CCP broke its old Stalinist command economy into distinct enterprises, and they exhibit certain problems following directly from this past:[121]

- *Monopolies:* There is little competition to win major weapons systems and defense equipment because China's defense industry is closed to outside competition, is dominated by SOEs, and allows for little crossover by these conglomerates between sectors.[122] Contracts for most military equipment are sole-sourced, while only contracts for noncombat-related equipment are subject to a competitive bidding process.[123] According to Mr. Curriden, "Attempts to introduce private actors have borne some fruit, but they have not changed the fact that, for most platforms, the PLA has only one firm to turn to as the lead integrator," and Chinese SOEs are still relatively unprofitable and less innovative than their private sector counterparts.[124]
- *Bureaucratic fragmentation:* Bureaucratic fragmentation is another significant issue, because different contractors, research institutes, and PLA units may be responsible for R&D, testing, procurement, production, and maintenance.[125] Dr. Cheung argues "that linkages among these entities tend to be ad hoc in nature with major gaps in oversight, reporting, and information-sharing."[126]
- *Weak management and quality assurance practices:* The PLA's system for overseeing defense contracts is also hobbled by inefficiencies and conflicts of interest.[127] The PLA administers oversight through the "military representative system," which stations active-duty PLA officers in factories and research institutes across the country to ensure product quality and contract execution.[128] These PLA officers, however, lack the technical expertise to rigorously monitor the activities of the contractors because they are generally recent college graduates with only limited technical training, not holders of advanced graduate degrees in scientific subjects.[129] More broadly, these military representatives are paid by the entities they are supposed to oversee instead of the PLA, a dependency that incentivizes corruption, and it is not uncommon for former military representatives to take posts at the institutions they were overseeing once they retire.[130] Another problem is that contracts for weapons systems are often vague and short and do not define the contractor's obligations or critical performance milestones, further complicating management and oversight.[131]
- *Outdated pricing regime:* China's defense industry practices a cost-plus pricing regime that guarantees 5 percent profit for

contractors on top of their incurred costs, which provides little incentive for innovating or improving efficiency.[132] According to Mr. Curriden, the PLA released several new policies in 2021 and 2022 related to military procurement and contract management, but it is unclear whether they involve a reform of the cost-plus pricing model.[133]

- *Corruption:* While there is little public reporting on corruption in the defense industry, PLA leaders have highlighted the RDA system as one of a number of high-risk areas for corruption.[134] Dr. Cheung notes one rare example of official reporting on an egregious case in which the Central Discipline Inspection Commission sent a team to investigate SASTIND for two months in 2016.[135] In the aftermath, the ministry was required to set up a "rectification program" involving 100 corrective measures, and a large number of officials were punished.[136]

Case Studies in China's Defense Technology Modernization

China's efforts to "catch up and leapfrog" the United States in defense technologies are best exemplified in three areas: missile and space capabilities, undersea warfare capabilities, and AI. These technologies have the potential to directly threaten U.S. forces in the Indo-Pacific region and in some cases could challenge strategic stability more broadly. However, the PLA is also investing considerable resources into the development of weapons in emerging technology fields, such as quantum computing,* directed energy weapons,† and magnetic accelerator cannons (rail guns), among other things.

China's Missile and Space Capabilities

According to testimony by Kevin Pollpeter, a senior research scientist at the Center for Naval Analyses (CNA), China is now a world leader in missile and space technologies in terms of quantity as well as quality.[137] China maintains the largest and most diverse missile arsenal in the world, ranging from precision-guided ballistic and cruise missiles to hypersonic weapons, all of which can be used to limit foreign military forces from operating around the second island chain.[138] China also is modernizing, expanding, and diversifying its nuclear forces, pursuing new delivery vehicles such as hypersonic glide vehicles and potentially exploring nuclear warheads of lower yields that could complicate its adversaries' missile

*China has invested in its quantum communications technologies, such as satellites, as well as its quantum computing capabilities. U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China: 2022 Annual Report to Congress*, November 29, 2022, 90, 152.

†According to the U.S. Government Accountability Office, directed energy weapons, such as lasers, "use energy fired at the speed of light" and "can produce force that ranges from deterrent, to damaging, to destructive." These weapons use high-power electromagnetic energy, including high-energy laser, millimeter wave, and high-power microwave weapons. In August 2023, the *South China Morning Post* reported that Chinese military scientists claimed they had developed a "new cooling system that allows high-energy lasers to operate 'infinitely' without any build-up of waste heat," which has been a major technological challenge in laser weapon development. The *South China Morning Post* asserted that the technology has the potential to "significantly change the face of battle by extending engagement times, increasing range and damage, and reducing logistics and costs, according to the researchers." Stephen Chen, "Chinese Military Scientists Claim to Have Achieved a 'Huge Breakthrough' on Laser Weapon Technology," *South China Morning Post*, August 11, 2023; U.S. Government Accountability Office, *Science & Tech Spotlight: Directed Energy Weapons*, May 25, 2023.

defenses and give China more options for limited nuclear use amid a broader conflict.*[139] China's space capabilities now include satellite constellations,† counterspace weapons,‡ for-profit satellite launches, human spaceflight, a long-term crewed space station, and multi-year programs that aim to explore both the Moon and Mars.[140] China also has an increasing number of commercial space companies that began operations over the last decade.[141]

China Seeks to Control Access to the Moon for Strategic Aims

Beijing is working to establish a long-term presence in space, which it seeks to accomplish by first dominating the cislunar domain, or the space between Earth and the Moon.[142] The U.S. Air Force Research Laboratory and the Defense Innovation Unit argue that cislunar space is an important domain because it will allow the United States to place its national security space assets beyond low-Earth orbit and geosynchronous orbit and to establish infrastructure that will enable long-term presence on the Moon and elsewhere.§[143] Zhao Xiaojin, a Party secretary of the China Aerospace Science and Technology Corporation and member of the National Committee of the Chinese People's Political Consultative Conference, said in 2018 that China plans to begin the construction of a lunar base around 2025 and achieve a manned lunar landing sometime in 2030.[144] Furthermore, Beijing wants to create a lunar R&D base by 2050 that will be primarily equipped with robots.[145] Complementing these efforts, China is also focusing on developing its ability to monitor and potentially control the Moon's surface. Dr. Pollpeter argued in a response to

*China has a nuclear triad and is rapidly expanding its stockpile of nuclear warheads, which totaled around 400 as of November 2022 and could reach 1,500 warheads by 2035 if production continues at its current pace. Moreover, U.S. Strategic Command assessed in January 2023 that China possesses more land-based fixed and mobile intercontinental ballistic missile (ICBM) launchers than the United States has ICBM launchers in general, although the United States still has much larger quantities of ICBM missiles and nuclear warheads overall. As of early 2023, the United States maintained an estimated stockpile of around 3,800 nuclear warheads. Arms Control Association, "Nuclear Weapons: Who Has What at a Glance," June 2023; Michael R. Gordon, "China Has More ICBM Launchers than U.S., American Military Reports," *Wall Street Journal*, February 7, 2023; U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China: 2022 Annual Report to Congress*, 2022, 97–98.

†A satellite constellation (or swarm) is a "network of identical or similar-type artificial units with the same purpose and shared control," according to EOS Data Analytics, a Mountain View, California-based global provider of satellite analytic solutions. EOS Data Analytics says these groups of satellites communicate to ground stations worldwide and typically revolve in low-Earth orbit, transmitting required data with quick signal transmitting times. Compared to single large satellites, these swarms of small units (up to 500 kg) are not only cheaper but also faster to deploy. For more, see EOS Data Analytics, "Satellite Constellations: Existing and Emerging Swarms," October 28, 2022; EOS Data Analytics, "Company."

‡The Defense Intelligence Agency asserts that some counterspace weapons are used to degrade space services temporarily, while others can "damage or destroy satellites permanently." Some of the attacks that can be used for counterspace operations include physical or cyberattacks against ground sites and infrastructure supporting space operations, jamming global navigation and communication satellites, and the deployment of directed energy weapons that target intelligence, surveillance, and reconnaissance satellites, among others. For more, see U.S. Defense Intelligence Agency, *Challenges to Security in Space: Space Reliance in an Era of Competition and Expansion*, April 12, 2022, 4.

§The U.S. Air Force Research Laboratory and Defense Innovation Unit assert that expanding its satellite assets from low-Earth orbit into geosynchronous orbit (GEO) will allow for "a vastly increased number of assets supporting commercial, civil and military applications across a wide range of satellite sizes, constellations sizes and orbits," with a mixed architecture of large GEO satellites and constellations of large numbers of small satellites at lower orbits. Thomas Cooley, Eric Felt, and Steven J. Butow, "State of the Space Industrial Base: Threats, Challenges and Actions," *U.S. Air Force Research Laboratory and Defense Innovation Unit*, May 30, 2019, 7.

China Seeks to Control Access to the Moon for Strategic Aims—*Continued*

a question for the record submitted to the Commission that "the primary security concerns of China's lunar exploration program have centered on its use of orbits around the Moon," such as the Earth-Moon L2 Lagrange point.*[146] He explained that satellites placed in an L2 halo orbit are "relatively stable" and allow "for full surveillance and communication of the lunar surface, with near-constant communication to the Earth."[147] Jeff Gossel, an analyst at the National Air and Space Intelligence Center, assesses that placing a satellite in L2 halo orbit could allow China to fly to the far side of the Moon and attack U.S. satellites in geosynchronous orbits.[148] Dr. Pollpeter also observes that since most U.S. sensors are not focused on deep space, such attacks by China may go undetected.[149] (For more on China's strategic aims in space, see U.S.-China Economic and Security Review Commission, Chapter 4, Section 3, "China's Ambitions in Space: Contesting the Final Frontier," in *2019 Annual Report to Congress*, November 2019.)

China has made rapid gains in these fields over the past 30 years due to internal reforms and in spite of U.S. export controls.†[150] According to Dr. Pollpeter, "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 the fates of nations."[151] Concretely, this approach entailed concerted funding and attention from Chinese policymakers, establishing a modern program management system, and exploiting foreign technology and knowhow wherever it could be found.[152] China's space program has relied heavily on foreign technology and knowhow since its inception in 1956, and today it continues to leverage foreign technology to advance its space program through a combination of cooperative activities, technology theft, and imitation.‡[153] Dr. Pollpeter asserts that China's space and missile programs are "a

*According to the National Aeronautics and Space Administration (NASA), Lagrange points are positions in space "where objects sent there tend to stay put" due to the gravitational pull of two large masses equaling the centripetal force required for a small object to move with them. The L2 point of the Earth-Sun system is ideal for hosting spacecraft that must readily communicate with the Earth, and it can also provide a clear view of deep space for telescopes positioned there. NASA notes, however, that the L2 point is somewhat unstable on a time scale of around 23 days, which necessitates regular course and attitude corrections for satellites in orbit there. NASA, *What Is a Lagrange Point?* March 27, 2018.

†According to the U.S. Department of Commerce, in 1999 Congress passed P.L. 105–261, section 1512, which "requires the President to certify to Congress before any export to China of missile equipment or technology that the specific proposed export is not detrimental to the United States space launch industry and the equipment or technology to be exported, including any indirect technical benefit, will not measurably improve China's missile or space launch capabilities." The president delegated the responsibility of certification to the secretary of commerce in 2009. U.S. Department of Commerce, *Privacy Shield Framework: China-U.S. Export Controls*.

‡China's space industry primarily collaborates with partners in Russia and Ukraine. Following Russia's unprovoked invasion of Ukraine, Beijing and Kyiv still continued to participate in space cooperation, with the Ukrainian Embassy in China publishing a press release highlighting over two decades of collaboration in May 2022. The country's technology theft efforts heavily target the United States because it is currently the leading space power. China's space industry is engaging in what Dr. Pollpeter calls "foreign inspiration," or the idea of "basing designs on the knowledge that something has been done or been done in a certain way." Kevin Pollpeter, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment*

case study in how China has been able to overcome U.S. isolation to become a world-leading technological power," noting that Beijing was able to circumvent U.S. restrictions by cooperating with other countries.[154] China's defense technology gains are especially evident in its conventional missile forces, its hypersonic weapons, and its apparent development of a space-based nuclear weapons capability.

China's Regional Missile Forces

China's inventory of short-, medium-, and intermediate-range conventional ballistic and cruise missiles presents significant challenges to Taiwan as well as the U.S. military.[155] With this inventory, Dr. Pollpeter argues, China possesses a "multilayered area denial capability out to the second island chain," meaning the PLA can use its conventional missiles between its shores and Guam to complicate the efforts of enemy ships or aircraft from operating within that area.[156] China's arsenal features short-range ballistic missiles (SRBM) like the DF-11, DF-15, and DF-16, most likely for use in a Taiwan contingency; medium-range ballistic missiles (MRBM), such as the DF-21, with a range of 1,500–2,000 kilometers (km); and intermediate-range ballistic missiles (IRBM) such as the DF-26, which has a range of 3,000+ km that gives the PLA the ability to strike targets as far as Guam.[157] The PLA's inventory also includes ground attack and antiship cruise missiles (ASCM) such as the DF-10 ground attack cruise missile (1,500 km range), the DF-100 ground attack cruise missile (2,000 km range), the YJ-83 ASCM (185 km range), the YJ-62 ASCM (277 km range), the YJ-18 cruise missile with variants for land-attack and antiship missions (220–540 km range), and several Russian systems.*[158] Dr. Pollpeter noted in his written testimony that the most common U.S. antiship missile, the Harpoon ASCM, with a range of 130 km, "is out-ranged by most PLA antiship missiles, allowing PLA Navy ships to fire their antiship missiles in relative safety from distances well beyond the range of U.S. surface-fired antiship missiles."[159] He noted a similar range problem with the PLA air-launched ASCMs, which allow the PLA Air Force and PLA Navy aviation units to launch their missiles from well beyond the defensive ranges of U.S. air defense systems.[160]

The U.S. military and lawmakers have expressed concerns about the discrepancy between China's and the United States' conventional missile capabilities prepositioned in the Indo-Pacific and the implications of this gap for a potential conflict.[161] During a Senate Committee on Armed Services hearing in April 2023, Admiral John Aquilino, commander of United States Indo-Pacific Command, stated that the United States does not have a single ground-launched missile with ranges between 500 and 5,500 km prepositioned in the theater.[162] This deficit is attributable to the fact that the United States was previously a party to the 1987 Intermediate-Range Nuclear Forces Treaty, which required the United States and Russia to

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Screening Regimes, April 13, 2023, 10–11. Embassy of Ukraine in the People's Republic of China, *Scientific & Technical Cooperation between Ukraine and China*, May 16, 2022.

*While exact figures for each missile system are not publicly available, DOD estimated in 2022 that the PLA Rocket Force had 600 or more SRBMs with around 200 launchers, 500 or more MRBMs with around 250 launchers, and 250 or more IRBMs with around 250 launchers. U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China: 2022 Annual Report to Congress*, 2022, 167.

permanently eliminate all their nuclear and conventional ground-launched ballistic and cruise systems in this range.[163]

Some lawmakers have likened this situation to a modern day "missile gap" and expressed concern that it could compromise U.S. military operations or deterrence in the Indo-Pacific.*[164] A 2020 study by Jaganath Sankaran, an assistant professor in the Lyndon B. Johnson School of Public Affairs at the University of Texas, illustrates the defensive quandary China's offensive missile force could create by simulating the way U.S. forward-deployed and allied ballistic missile defense assets would operate against Chinese missile salvos in a large-scale coordinated attack.[165] The simulation revealed that the United States and allied forces would need to make "risky and painful tradeoffs" to protect critical military installations in the Asia Pacific region if early warning systems failed and if U.S. Aegis ballistic missile defense (BMD)-capable ships were not prepositioned in key locations.[166] Dr. Sankaran's research also found that during a large-scale coordinated attack, the Aegis BMD-capable ships may "quickly run out" of interceptors for incoming missiles because China's large missile inventory can in principle "saturate a number of key targets."[167]

China's Hypersonic Weapons Development

China is a world leader in hypersonic weapons development, a technology with both conventional and nuclear applications.†[168] DOD assesses that China fielded its first operational hypersonic weapons system in 2020.[169] Known as the DF-17, the system is an MRBM equipped with a hypersonic glide vehicle (HGV) that has a range of 1,800 to 2,500 km.‡[170] China conducted a test of the DF-41 ICBM with an HGV attached in 2021, making a successful circumnavigation around the globe.[171] In 2018, China also tested a nuclear-capable hypersonic prototype named the Starry Sky-2, a design that—once fully developed—could be used to carry warheads capable of penetrating any current missile defense system.[172] Beijing's

*The "missile gap" is a Cold War-era concept. According to the Central Intelligence Agency, "The Missile Gap was in essence a growing perception in the West, especially in the USA, that the Soviet Union was quickly developing an intercontinental range ballistic missile (ICBM) capability earlier, in greater numbers, and with far more capability than that of the United States. Even as that perception was disproved, it became evident that the Soviets were placing their major effort toward developing strategic missiles against which, once launched, there was no defense. The perceived missile gap that ensued was based on a comparison between U.S. ICBM strength as then programmed, and reasonable, although erroneous estimates of prospective Soviet ICBM strength that were generally accepted." Central Intelligence Agency, *What Was the Missile Gap?*

†Paul Freisthler, the Defense Intelligence Agency's chief scientist for science and technology, said that "China is leading Russia in both supporting infrastructure and numbers of systems," while General David Thompson, then vice chief of space operations at the U.S. Space Force, said the United States' hypersonic missile programs are not as advanced as China or Russia. Vice Admiral Johnny Wolfe, the director of the U.S. Navy's Strategic Systems program, also asserted that China and Russia have developed hypersonic weapons that the United States has not and explained that "up until just recently, there hasn't been a real driver for us to take that technology and put it into a weapon system" but that "China and Russia are [now] the driver." Jeff Seldin, "U.S. Defense Officials: China Is Leading in Hypersonic Weapons," *Voice of America*, March 10, 2023; Oren Liebermann, "U.S. Is Increasing Pace of Hypersonic Weapons Development to Chase China and Russia, Senior Admiral Says," *CNN*, November 20, 2022; Paul McLeary and Alexander Ward, "U.S. 'Not as Advanced' as China and Russia on Hypersonic Tech, Space Force General Warns," *Politico*, November 20, 2021.

‡Hypersonic glide vehicles are a special type of reentry vehicle carried by a missile. The primary advantage of attaching a hypersonic glide vehicle to a missile over a traditional ballistic missile is its unpredictable trajectory and ability to fly at lower altitudes, making the missile difficult to spot on ground radars. Simone Fontana and Federica Di Lauro, "An Overview of Sensors for Long Range Missile Defense," *Sensors (Basel)* 22:24 (December 2022): 6.

talent recruitment programs have likely contributed significantly to its rapid progress in hypersonic technology.*

China's hypersonic weapons directly threaten U.S. forces operating in the Indo-Pacific.[173] Then Undersecretary of Defense for Research and Engineering Michael Griffin warned in 2018 that China's deployment of a tactical or regional hypersonic system could place at risk the United States' carrier battle groups, surface fleet, and forward deployed forces and land-based forces.[174] Then Undersecretary Griffin argued that the United States faces an "unacceptable situation" in which it presently lacks the ability to defend against or respond in kind to Chinese hypersonic weapons attacks on U.S. forces.[175]

China's Exploration of a Space-Based Nuclear Weapon

China's apparent development of a fractional orbital bombardment system (FOBS) raises the possibility that China could permanently deploy nuclear weapons in space, effectively adding a fourth leg to its nascent nuclear triad. According to the Bulletin of the Atomic Scientists, a FOBS is "a payload that is delivered into low-Earth orbit but re-enters the atmosphere to bombard a target before completing a full orbit."† [176] China's deployment of such a system would deprive the United States of early warning.[177] DOD reported that China's first test of a FOBS capability mounted with an HGV in July 2021 demonstrated "the greatest distance flown (~40,000 km) and longest flight time (~100+ minutes) of any PRC land-attack weapons system to date."[178] Of special note, China's combination of both the FOBS and an HGV may negate many of the technical downsides of older iterations of the FOBS because the HGV enables the FOBS to adjust the flight path of the projectile following reentry into the atmosphere.[179]

The development of the FOBS also illustrates Beijing's commitment to identifying diverse methods of delivering nuclear weapons.[180] The FOBS poses a threat to strategic stability by allowing China to potentially deliver larger nuclear payloads than via ICBMs alone after remaining undetected for long portions of its flight.[181] Dr. Pollpeter asserts that the development of an orbital bombard-

*A 2022 report by Strider, a Salt Lake City-based technology company, found that alumni of the Los Alamos National Laboratory have helped China advance key military and dual-use technologies in areas such as hypersonics, deep-earth penetrating warheads, unmanned autonomous vehicles (UAVs), jet engines, and submarine noise reduction. The report highlights Dr. Chen Shiyi, a world-renowned expert in fluid dynamics and turbulence who spent the 1990s at Los Alamos. After returning to China, Dr. Chen served as president of Southern University of Science and Technology (SUSTech), where he recruited additional scientists who had worked at Los Alamos and made major contributions to China's hypersonics and aerodynamics programs. "Chen served as director of a state laboratory that played a key role in developing the PRC's hypersonic glide vehicle," Strider wrote. "Under Chen's leadership, the laboratory undertook projects with military organizations, defense industry enterprises, and PRC universities that collaborate closely with the People's Liberation Army (PLA). These projects have helped to contribute to the PRC passing the United States in hypersonic R&D." Strider Technologies, "The Los Alamos Club," 2022, 5.

†The FOBS is a Cold War-era technology that was previously developed by the Soviet Union in the 1960s but was subsequently abandoned due to the United States' deployment of early warning satellites that diminished the Soviets' element of surprise. The United States also chose not to pursue FOBS for several other reasons, particularly because it was not as precise or accurate as an ICBM. After both the United States and Russia had developed the capability, the two powers agreed to ban orbital bombardment systems in the SALT II treaty. Ritwik Gupta, "Orbital Hypersonic Delivery Systems Threaten Strategic Stability," *Bulletin of the Atomic Scientists*, June 13, 2023; David E. Sanger and William J. Broad, "China's Weapon Tests Close to a 'Sputnik Moment,' U.S. General Says," *New York Times*, November 3, 2021; Vasudevan Mukunth, "China's New Hypersonic 'FOBS' Takes U.S. By Surprise, Arms Race in Outer Space the New Reality," *Wire (India)*, October 18, 2021.

ment system may signal China's "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," enabling China to possess a global first-strike capability that can evade U.S. missile defenses.[182] Lieutenant General Chance Saltzman, the deputy Space Force chief for operations, said that the FOBS "is a "very forward-edge technology capability" that the Space Force must figure out how to deter swiftly.[183] China's use of the FOBS to launch a nuclear payload into orbit would violate the Outer Space Treaty, to which it acceded in 1983, and which prohibits "nuclear weapons or any other kinds of weapons of mass destruction" in outer space.[184]

China's Evolving Nuclear Posture Raises Possibility of Shifting Strategy

China's evolving nuclear posture may support a new nuclear strategy that envisions the limited first use of a nuclear weapon to achieve its political objectives in the Indo-Pacific region, such as the forcible unification of Taiwan.*[185] Chinese leaders could decide to adopt this new strategy of limited nuclear use against conventional military targets in the Indo-Pacific, such as U.S. aircraft carriers or bases in Guam and Okinawa.[186] The 2020 edition of the authoritative PLA textbook *Science of Military Strategy* discusses launching nuclear weapons as "demonstration strikes," presumably on China's territory or over the open ocean to signal resolve during a crisis, providing some evidence that Chinese military strategists have thought about using nuclear weapons first and in ways that do not cause mass destruction in an adversary's homeland.[187] Several technological developments within China's nuclear force would make this potential shift in strategy possible. The PLA Rocket Force has developed large numbers of the nuclear-capable DF-26 IRBM, a weapon with range and precision that would make it well suited for attacks on U.S. forces.[188] The PLA Air Force has also developed a force of nuclear-capable H-6N bombers which, while limited in range, could nonetheless carry out nuclear missions within the region.[189] Chinese commentators have also discussed the importance of developing nuclear warheads of smaller yields, which they believe could be used in a more limited way against battlefield targets and hypothetically limit nuclear escalation to the region, rather than escalating to an all-out war involving nuclear attacks on the adversary's homeland.[190]

Future Prospects for China's Missile and Space Capabilities

Public remarks by Chinese scientists about the focus of their research and reported cases of Chinese espionage indicate that Beijing

*China has abided by a no-first-use policy since 1964 and claimed as recently as December 2022 that it remains committed to this policy in order to maintain the "minimum level" of nuclear capabilities required for national security, despite being on pace to quadruple its nuclear arsenal by 2035. Julia Shapero, "China Reiterates 'No First Use' Policy in Wake of U.S. Report," *Hill*, December 6, 2022; Ankit Panda, "'No First Use' and Nuclear Weapons," *Council on Foreign Relations*, July 17, 2018.

still perceives technological gaps in its missile and space capabilities requiring concerted scientific attention to solve. One example is radiation-hardened microelectronics, a technology that enables missile and space technologies to withstand the harsh radiation of space and which China has struggled to perfect.[191] A scientist working for the China Aerospace Science and Technology Corporation Limited (CASC) told Chinese state-owned publication *Sixth Tone* in 2019 that his team had made gradual progress developing the technology and claimed that China's radiation-hardened microelectronics were now at "a world-leading level," though his claims are difficult to verify.[192] A May 2022 report published by the Center for Strategic and Emerging Technology (CSET) also found that Chinese state media had identified aerospace-grade stainless steel typically used in missiles, satellites, and spacecraft as an important potential "chokepoint" in Beijing's manufacturing capabilities.[193]

Past federal indictments and export control violations notices suggest that Chinese intelligence officers and companies are still seeking to illegally acquire certain types of sensitive, dual-use, or military equipment with missile and space applications, such as monolithic microwave integrated circuits, accelerometers, gyroscopes, antennas, infrared and thermal imaging systems, and 3-D printed space and missile prototypes.[194] In November 2020, for example, Raytheon electrical engineer Wei Sun received a 38-month sentence from the U.S. Department of Justice for transporting technology related to an advanced missile guidance system to China.[195] More recently, in June 2022, the Bureau of Industry and Security (BIS) at the U.S. Department of Commerce issued a temporary denial order suspending the export privileges of three U.S.-based companies for the unauthorized export of technical drawings and blueprints of satellites, rockets, and defense-related prototypes to China.[196]

China's Undersea Warfare Capabilities

The PLA Navy is keenly aware of the U.S. submarine fleet's ability to intervene in a Taiwan conflict by thwarting an amphibious invasion or disrupting a blockade.[197] Consequently, China is investing in both submarine and anti-submarine warfare (ASW) capabilities to break longstanding U.S. advantages in the undersea warfare* domain and specifically to counter the threats U.S. submarines pose to

*Undersea warfare refers to the employment of submarines and other undersea systems in military operations within and from the underwater domain. There are four main categories that constitute undersea warfare, including submarine warfare, ASW, mine warfare, and mine countermeasures. Diesel-electric and nuclear-powered attack and ballistic missile submarines may be equipped with torpedoes, missiles, or nuclear weapons, as well as advanced sensing equipment, to attack enemy targets. The main purpose of ASW is to "locate, neutralize, and defeat hostile submarine forces," using surveillance and attack aircraft, ships, and submarines, according to the U.S. Fleet Forces Command. Mine warfare involves placing a self-contained explosive device in the water to destroy submarines and surface vessels or to deny the enemy access to certain areas. Mine countermeasures involve using vessels such as the Avenger-class minesweeper ship or aircraft like the MH-53E Sea Dragon to detect and eliminate naval mines. Nuclear Threat Initiative, "United States Submarine Capabilities," March 6, 2023; Jan Tegler, "Navy Mine Warfare Teeters between Present, Future," *National Defense*, January 17, 2023; Naval History and Heritage Command, *Naval Mine Warfare*, July 22, 2021; Bryan Clark, "The Emerging Era in Undersea Warfare," *Center for Strategic and Budgetary Assessments*, January 22, 2015, 1; U.S. Navy, Submarine Force Pacific, *Attack Submarines*. *https://www.csp.navy.mil/SUBPAC-Commands/Submarines/Attack-Submarines/*; U.S. Navy, Submarine Force Pacific, *Ballistic Missile Submarines (SSBNs)*. *https://www.csp.navy.mil/SUBPAC-Commands/Submarines/Ballistic-Missile-Submarines/*; U.S. Fleet Forces Command, *At-Sea Training*. *https://www.usff.navy.mil/Organization/Headquarters/Fleet-Installations-and-Environment/At-Sea/At-Sea-Training/*.

a PLA naval blockade or amphibious forces conducting an invasion of Taiwan.*[198] A major reason for China's rapid progress in these areas is its absorption and subsequent development of proprietary technologies and equipment acquired from Western countries and Russia, often through legal commercial transactions or research collaboration.†[199] China also conducts espionage to acquire undersea warfare technologies.‡[200] If China succeeds in its ambition to break U.S. advantages in undersea warfare, the balance of power in the Indo-Pacific could be fundamentally transformed.[201]

China's Submarine Warfare Capabilities

China's advancements in submarine warfare capabilities reflect growing technological sophistication and operational range. Sarah Kirchberger, the head of Asia-Pacific Strategy and Security at the Institute for Security Policy at Kiel University, testified before the Commission that China has made "significant strides in the design of more hydrodynamic hulls and better propulsion systems" for both conventional and nuclear platforms.[202] Over the last 15 to 20 years, the PLA Navy has extended its areas of operations from almost exclusively within China's near seas into the Northern Indian Ocean area.[203] Due largely to Russian technology imports and consulting services, China has also developed indigenous conventional submarine designs that incrementally incorporate improved stealth features, sensors, and armaments as well as air-independent propulsion (AIP)§ systems that extend maximum undersea endurance from two to three days to over two weeks.[204]

Although China has expanded its submarine fleet, it still faces challenges related to the noise produced by its submarines and the relatively limited missions they can perform.¶[205] Most of China's

*The U.S. submarine fleet is fast, quiet, and capable of carrying out attack missions against surface ships and land targets, mine warfare, surveillance, and other relevant tasks, which could thwart Chinese amphibious forces from conducting an invasion of Taiwan and disrupt a PLA Navy blockade. U.S. Navy, *Attack Submarines—SSN*, March 13, 2023. *https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/article/2169558/attack-submarines-ssn/*; Nuclear Threat Initiative, "United States Submarine Capabilities," March 6, 2023; David Axe, "The U.S. Navy Submarine Force Could Sink the Chinese Fleet and Save Taiwan, but at the Cost of a Quarter of Its Boats," *Forbes*, January 10, 2023; Kris Osborn, "Could the U.S. Navy Save Taiwan?" *Warrior Maven*, January 4, 2023; Mark F. Cancian, Matthew Cancian, and Eric Heginbotham, *The First Battle of the Next War: Wargaming a Chinese Invasion of Taiwan*, January 2023, 3; U.S. Navy, Fleet *Ballistic Missile Submarines—SSBN*, May 25, 2021; U.S. Navy, *Guided Missile Submarines—SSGN*, November 25, 2020.

†China's latest ASW helicopter, the Z-20F, has been in use for the last five years and was developed based on the American Sikorsky H-60 Black Hawk, which China imported prior to 1989. Sarah Kirchberger, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment Screening Regimes*, April 13, 2023, 11.

‡For example, in 2018, Chinese intelligence officials recruited an Estonian scientist who served as a deputy director of the NATO undersea research center, which is responsible for multi-static and networked ASW research. Sarah Kirchberger, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment Screening Regimes*, April 13, 2023, 12.

§AIP systems provide greater underwater endurance for diesel-powered submarines by generating electricity without needing to resurface the vessel for external air. China's state-run *Science and Technology Daily* notes that AIP submarines have "long endurance, good concealment, and excellent quieting ability." Augusto Conte-Rios and Juan-Diego Pelegrin-Garcia, "A Revolution in Submarine Propulsion," *U.S. Naval Institute*, October 2020; Zhang Qiang, "Our Military's AIP Submarine Force Breaks Multiple Records, Experts Interpret Technical Advantages" (我军AIP潜艇部队破多项纪录 专家解读技术优势), *Science and Technology Daily*, December 17, 2018. Translation.

¶According to the Nuclear Threat Initiative, "Submarines must operate quietly in order to evade enemy sensors because water is a highly efficient conductor of sound. The main source of noise from a submarine comes from its propulsion system. Countries such as the United States and China have built networks of hydroacoustic sensors to detect submarines that navigate close

submarines are diesel-electric attack submarines, but there are also small numbers of nuclear-powered attack submarines and nuclear-powered ballistic missile submarines.[206] According to DOD, the PLA Navy currently operates six nuclear-powered ballistic missile submarines, six nuclear-powered attack submarines, and 44 diesel-powered/AIP attack submarines.[207] China also reportedly plans to build 25 or more Yuan-class (Type 039A) AIP diesel-electric attack submarines and to build the new Shang-class (Type 093B) nuclear-powered guided-missile attack submarine by the mid-2020s.[208] The Yuan-class submarine is one of the quietest in the PLA Navy's inventory and offers the force a serviceable option to attack U.S. surface ships operating near China, though it is somewhat limited in range.[209] The noise created by China's front-line Shang-class nuclear-powered attack submarine, however, is reportedly on par with the Soviet Victor III, a class of submarine widely used by the Soviet navy in the 1970s before it transitioned to the super-quiet Akula-class submarine.*[210] The Shang-class nuclear-powered attack submarines are thus still detectable by U.S. underwater detection networks, which are deployed in a "fishhook" that stretches from Japan to India around the East Asian littoral seas.[211] As George Mason University PhD candidate Michael Sweeney observed in a 2020 article, "It is likely no Chinese nuclear attack submarines can leave that area without detection—a major advantage for the U.S. in undersea competition in the Pacific."[212]

The United States remains ahead of China in terms of submarine warfare capabilities for the time being.[213] Compared to China, the United States currently has 53 fast attack submarines, 14 ballistic-missile submarines, and four guided-missile submarines.[214] The United States has conducted regular nuclear deterrent patrols around the world for decades, while China's patrols have been limited to adjacent waters in the South China Sea.[215] Dr. Kirchberger predicts China could struggle to close the gap with the United States in submarine technology if it continues to lack access to Russia's most advanced submarine technology and if the United States and its allies continue to innovate.[216]

China's Anti-Submarine Warfare Capabilities

China's investments in ASW capabilities present a much more urgent challenge to U.S. interests than its progress in submarine warfare.[217] According to Dr. Kirchberger, China "wants to neutralize [the] technological advantages of adversaries by quickly catching up in anti-submarine warfare."[218] Following a long period of underinvestment until the mid-2010s, the PLA Navy is now acquiring a variety of ASW capabilities, including specialized surface combatants, acoustic surveillance ships, and fixed and rotary wing aircraft, to perform missions that could threaten U.S. submarines.[219] Some of the equipment the PLA Navy is now acquiring for ASW includes the KQ-200 maritime patrol aircraft, the Z-9 and Z-18 helicopters, the Type 056 corvette, the Type 927 underwater acoustic survey ship,

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to their coastal borders and strategic military locations." Nuclear Threat Initiative, "Submarine Detection and Monitoring: Open-Source Tools and Technologies," March 2, 2021.

*The Akula-class was the first Soviet submarine class capable of evading detection by the U.S. hydrophone network SOSUS. Mike Sweeney, "Assessing Chinese Maritime Power," *Defense Priorities*, October 26, 2020.

new autonomous underwater vehicles, and two networks of sensors in the South China Sea known as the "Great Underwater Wall" and the "Blue Ocean Information Network."* [220] DOD assessed in 2022 that the PLA Navy is "significantly improving" its ASW capabilities through acquisition of these systems.[221]

Recent PLA ASW exercises illustrate China's continued interest in preventing U.S. submarines from thwarting an invasion.[222] For instance, in August 2022, the PLA Eastern Theater Command coordinated a Y-8 ASW aircraft to operate alongside a Changchun Ka-28 vessel-based anti-submarine helicopter for a submarine detection exercise.[223] The Chinese state-run *Global Times* claimed it was important for the PLA Navy to conduct the exercises in underwater areas around Taiwan because countries like the United States and Japan have more advanced submarines, illustrating that the PLA is keen on inhibiting allied forces in the event of an invasion.[224] The PLA Navy also conducted an additional joint anti-submarine drill alongside police patrol boats in April 2023 as part of a broader set of area denial exercises.[225]

Prospects for China's Future Undersea Warfare Capabilities

Despite the technological hurdles it faces, Beijing is dedicating significant resources to closing the gap with the United States in undersea warfare. China's most challenging technological gaps are in submarine warfare-related areas of hull design, quieting technologies, and propulsion systems.[226] China has also struggled to create AIP technology utilizing lithium-ion batteries due to safety issues associated with thermal runaway.† [227] It is also unclear how capable China is of developing indigenous submarine diesel engines, as underscored by Thailand's rejection of China's "unproven" CHD620 engine in March 2023 as part of a contract signed between the two in 2017 for a Yuan-class submarine.[228] Finally, Beijing may perceive vulnerabilities to its stockpiles of certain critical materials that would be used for its undersea warfare programs.‡ [229] According to Dr. Kirchberger, Chinese technical literature focused on lithium-ion battery technology notes potential supply chain vulnerabilities with nickel and cobalt and recommends instead making iron and phosphate variants of lithium-ion battery technology to prevent import dependencies.[230]

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*The PLA is developing a fleet of autonomous underwater vehicles to carry out missions related to marine surveying and reconnaissance, mine warfare and countermeasures, undersea cable inspection, and ASW. Ryan Fedasiuk, "Leviathan Wakes: China's Growing Fleet of Autonomous Undersea Vehicles," *Center for Security and Emerging Technology*, August 17, 2021.

†According to Dragonfly Energy Corp., a Reno, Nevada-based manufacturer of deep cycle lithium-ion batteries, thermal runaway "occurs when the temperature inside a battery reaches the point that causes a chemical reaction to occur inside the battery" and in extreme cases can "cause batteries to explode and start fires." Dragonfly Energy Corp., "What Is Thermal Runaway in Batteries?" December 14, 2022.

‡China is dependent on other countries for numerous critical materials that may help sustain its submarine program. China relies on Brazil for niobium, for example, which can provide cathodic protection to submarine structures, which helps prevent corrosion on metal surfaces. Beryllium, which China has obtained from the United States, is used in the U.S. military to control reactors on nuclear-powered submarines and surface vessels. Additionally, lithium, which China is dependent on from Australia, is used by Japan in lithium-ion-powered batteries on submarines. Courtney Weinbaum et al., "Assessing Systemic Strengths and Vulnerabilities of China's Defense Industrial Base," *RAND Corporation*, 2022, 56; Eric Wertheim, "Japan's Advanced Lithium-Ion Submarines," *U.S. Naval Institute*, December 2022; U.S. Department of Commerce, *National Security Assessment of the U.S. Beryllium Sector*, July 1993, iv–v; "Palladium Coating on Niobium," *Platinum Metals Review* 17:3 (1973): 89; Cathwell, "Cathodic Protection Explained."

China will likely continue its efforts to acquire technologies and knowhow relevant to undersea warfare through commercial transactions, academic exchanges, espionage, and joint military exercises. Recent evidence suggests China's commercial exchanges with Western firms are helping it acquire dual-use technologies relevant to undersea warfare.[231] For example, a 2021 Chinese research paper stated that the Norwegian-origin multi-beam sonar equipment it had utilized in a deep-sea geography survey improved its awareness of geomorphological features in the seafloor—knowledge that could be used for military purposes.[232] Academic exchanges between foreign and Chinese universities and research institutions are another avenue for transferring technology and knowhow relevant to undersea warfare capabilities. In 2019, for example, an author from Jacobs University in Bremen, Germany, cowrote a study on the software architecture of hybrid underwater robotic vehicles with researchers from several Chinese universities involved in defense research, though it is unclear if the German researcher was aware of the Chinese coauthors' links or the potential defense applications of the research.[233] Chinese state-sponsored espionage has aggressively targeted undersea warfare-related technologies such as hydrophones, side scan sonar systems, autonomous underwater vehicles, sonobuoys, submarine propulsion systems, maritime raiding craft and engines, and specific systems used on the U.S. Virginia-class nuclear-powered fast attack submarine.[234] China is also gaining further operational experience and knowhow through its anti-submarine exercises with Russia (for more, see Chapter 4, Section 1, "China's Relations with Foreign Militaries").[235] In the July Northern Interaction 2023 exercise, for example, China carried out a practice "search and dislodge" exercise using a Ka-27PL anti-submarine helicopter and shipboard sonars to detect and then attempt to expel a mock submarine from a restricted sea area closed to navigation in the Sea of Japan.[236]

Technical assistance from Russia could accelerate the development of China's undersea warfare capabilities.[237] Although Russia has refrained from sharing its most advanced undersea warfare technologies with China, the Kremlin may have no choice but to assist Beijing as it becomes more reliant on the country as a result of the war in Ukraine.[238] Recent signs of collaboration indicate that Russia may be willing to allow greater access to technologies it long held close. For example, Chinese research institutions are reportedly collaborating with Russian counterparts on hydroacoustic communication and fiberoptic hydrophone development in Arctic waters.[239] Furthermore, the two countries have organized "China-Russia Polar Acoustic Symposiums" since at least mid-2019, bringing together over 100 experts from 30 military research facilities and companies in China and Russia.[240] According to Dr. Kirchberger, this level of interaction in such a highly sensitive field "points to an institutionalized rather than ad hoc collaboration."[241] Moreover, Russia could also provide China with access to critical materials for its submarine fleet.[242] For instance, in December 2022 the Russian state-owned Rosatom Corp. supplied 6,477 kilograms of highly enriched uranium for a fast-breeder reactor CFR-600 located in China's Changbiao Island.[243] The weapons-grade plutonium it produced could possibly

be used as fuel for future nuclear-powered submarines, although current Chinese submarines are thought to rely on low-enriched uranium for fuel.[244]

Despite the United States' current dominance in undersea warfare, U.S. officials are concerned that several developments in this area over the next decade could make it more difficult to deter a Chinese invasion of Taiwan.[245] The U.S. advantage in undersea warfare will narrow over time if China successfully acquires new technologies for detecting submarines and if the U.S. acquisition process in undersea warfare does not achieve equally significant new breakthroughs.[246] A particular focus of Chinese research efforts is satellite-mounted light detection and ranging (LiDAR) technology, which could facilitate ASW by locating submarines at depths of up to 500 meters.[247] Moreover, top U.S. military officials and experts have raised concerns that the United States will struggle to maintain undersea superiority as it retires many of its aging submarines faster than they can be replaced, potentially weakening conventional deterrence vis-à-vis China.[248] The number of U.S. nuclear-powered fast attack submarines is expected to hit a "trough" of as few as 41 operational submarines between the mid-2020s and the early 2030s because the United States procured a relatively small number of these submarines during the 1990s.[249] To help fill part of this projected gap, the U.S. Navy plans to refuel and extend the service lives of up to seven Los Angeles-class attack submarines, even though the remaining 27 Los Angeles-class boats will retire by the mid-2030s.[250] The U.S. industrial base will need to build at least two Virginia-class attack submarines a year to meet the U.S. Navy's current requirement of maintaining 50 attack submarines throughout the rest of this decade and its future requirement of 66 to 72 attack submarines.[251] The September 2021 announcement of a deal between Australia, the UK, and the United States, a strategic grouping also known as "AUKUS," on nuclear-propelled submarine technology may also help to sustain the U.S. advantage in undersea warfare by increasing the number of allied submarines that can operate jointly with U.S. forces, but the newly produced Virginia-class submarines to be purchased by Australia will not be available until the 2030s.[252]

Artificial Intelligence: China Leverages AI for Military Use

CCP leadership views AI as a breakthrough technology with the potential to rapidly boost performance in a range of warfighting tasks beyond human capabilities, including navigation, data processing, and targeting. Both military leaders and AI engineers in China perceive AI's application as an inevitability in warfare, and they believe early adoption of AI for military application could provide an opportunity for the PLA to "leapfrog" U.S. military capabilities.[253] Chinese policy documents illustrate this perception, starting with China's national AI development plan in 2017 highlighting the development of AI as a "major strategy to … protect national security."[254] The PLA's most recent defense white paper, published in 2019, assessed that "international military competition is in the midst of a historic change, driven by the new round of technological revolution and industrial transformation" characterized by "the application of cutting-edge technologies such as artificial intelligence

(AI)… in the military field."[255] While the U.S. military leads the PLA in several AI applications, such as in the aerial domain, the PLA has focused on new technologies to become increasingly competitive in certain AI-enabled capabilities, including in AI computer vision and autonomous underwater vehicles.[256] These areas of strength in AI application are potentially paradigm-shifting, with the U.S. military increasingly having to contend with sophisticated Chinese AI tools designed to grant the PLA strategic and operational advantages.[257] The United States, however, is also a global driver of AI innovation and, with its partners, manufactures many of the components needed to enable AI's cutting-edge utilization, including by the PLA. This means that in the broadening competition over AI development, the United States will need to effectively manage access to components to develop AI, convert its commercial AI innovation into hard military power, and decouple U.S. dependencies on Chinese raw materials in manufacturing semiconductors, reducing key potential chokepoints in the AI development supply chain.

The CCP has matched its intense interest in AI with expanded investment. To become an AI leader, China's total government spending on AI development is pegged for 27 percent annual growth, up to $27 billion by 2026.[258] This increased funding in China's broader AI sector is set to be steered by the Chinese government. While commercial Chinese AI companies may nominally not be state-owned, the CCP maintains influential CCP Committees* in many firms. These committees allow for close CCP control of AI development, keeping technology firms subordinate to the state and ensuring that AI develops in ways that align with Party interests.[259] CCP committees and regulators also closely monitor applications of AI, seeking to reduce the risk of commercially available AI, such as AI language models, being used to challenge Party control.[260] Instead, the CCP leverages its control of China's nonstate sector to promote the development of AI technologies that can be deployed for state and military use.[261]

The PLA itself is also spending heavily on AI applications. While many of the most advanced PLA AI contracts are classified, a 2021 analysis of unclassified and publicly available PLA procurement contracts conducted by CSET found that the PLA likely spends at least $1.6 billion each year on AI-related systems, including direct PLA R&D and contracts with Chinese AI firms.[262] A previous CSET report estimated an upward band of PLA expenditures for AI in 2018 at "no more" than $2.7 billion.[263] With recent advancements in the development and application of AI for military use, however, it is reasonable to consider that PLA AI spending has surpassed this $2.7 billion upward band in the last five years. Furthermore,

*Within firms in China's nonstate sector, the CCP's ability to exert influence is becoming more deeply entrenched through CCP committees, among other mechanisms. CCP committees take on three functions: (1) overseeing personnel appointments and management decision-making; (2) coordinating political and ideological education; and (3) monitoring the behavior of employees, for instance to report on corrupt practices. While these are all existing functions of the CCP administrative apparatus, these CCP committees enhance the ability of the Party to exercise these functions within firms by strengthening coordination between the committees and the larger Chinese government bureaucracy as well as increasing CCP members' accountability to the Party and their employing firms. Tamar Groswald Ozery, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on U.S. Investment in China's Capital Markets and Military-Industrial Complex*, March 19, 2021, 89; Tamar Groswald Ozery, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on U.S. Investment in China's Capital Markets and Military-Industrial Complex*, March 19, 2021, 13.

the PLA has benefited from commercial and civil advancements in Chinese AI technologies, despite these advancements not being a direct product of PLA-led R&D, a dynamic discussed in this section.

Nonstate Firms Drive Chinese Military AI Development

China has leveraged its nonstate sector* tech environment, combined with top-down data collection policies, to manage AI development and advance the adoption of AI for military use. These nonstate partnerships provide clear demonstrations of MCF, with the PLA harnessing civil AI development. As Ms. Kania testified before the Commission, the PLA in 2017 created the Agile Innovation Defense Unit (AIDU) to operate in a fashion akin to DOD's Defense Innovation Unit (DIU).[264] Placed under the CMC's Science and Technology Commission, the AIDU was initially set up in the startup and tech hub of Shenzhen, and it hosts technology competitions and facilitates partnerships between the PLA and China's most innovative firms, contracting for product delivery on a short timeline.[265] Ms. Kania identified similar organizations designed to draw together the commercial AI sector with the military, including a "new AI Military-Civil Fusion Innovation Center" in Tianjin spearheaded by the Academy of Military Sciences and the Tianjin government.[266]

Recent PLA procurement contracts indicate that the majority of the PLA's AI equipment suppliers are nonstate sector Chinese tech firms founded after 2010.[267] This includes Anwise Global Technologies, founded in 2016, which has grown to be China's largest intelligent equipment manufacturer, primarily through servicing the military aerospace and electronics industries.[268] AI firm Realis, founded in 2015, also develops virtual reality training rooms equipped with AI that allows for multi-person training for PLA personnel.[269] The PLA's Strategic Support Force (PLASSF) is particularly well-positioned to seek out AI partnerships, as it strives to fulfill a mission portfolio with high AI applicability, including building algorithms, managing satellite constellations, and conducting potential offensive electronic warfare.[270] While total expenditures of the PLASSF are hard to gauge, it too is actively partnering with Chinese space and cybersecurity companies, such as one 2021 contract with Beijing Uxsino Software to build a "geospatial information perception and intelligent analysis subsystem."[271] The company builds AI-enabled data processing systems akin to products developed by U.S. firm Oracle and could be utilized by the PLASSF for geospatial information gathering, management, and analysis.[272]

The growth of these nonstate AI firms counted on to engineer Chinese defense technologies has been aided by a regulatory regime that limits data privacy and mobilizes mass data collection, along

*Although the Chinese government is not the majority shareholder for nonstate Chinese firms, China's corporate governance environment and structure affords the state bureaucracy numerous channels through which to exercise de facto control over enterprises in which it is a minority shareholder, while the central and local government have extensive equity investments in nonstate firms, particularly in the technology sector. Furthermore, the CCP operates numerous extra-legal channels to steer nonstate firms' decision-making, including via CCP committees within companies. For more on the Party-state's influence in corporate decision-making, see Chapter 2, Section 3, "The Chinese Government's Evolving Control of the Nonstate Sector" in U.S.-China Economic and Security Review Commission, *2021 Annual Report to Congress*, November 2021, 214–239.

with willing financing provided by state-led investors. China's extensive surveillance system provides vast datasets where nascent AI firms, partnered with the government, can experiment with and develop technologies, allowing China to grow into a global leader in related AI applications.[273]

This allows China's government to gain experience in managing AI development and has spurred on breakthroughs in certain AI fields, such as computer vision, where AI enables information gathering and analysis of image and video data.[274] Computer vision is valued by the Chinese government for both its surveillance and military applications. China robustly supports computer vision research; according to a 2022 CSET report, researchers with Chinese institutional affiliations produced more than one-third of publications in both computer vision and visual surveillance research, making China by far the most prolific country in producing research on computer vision and its uses by government actors.[275]

In one case of government support for R&D in computer vision capabilities, AI firm SenseTime, which provides facial recognition software, has been provided with state capital to pursue advances in computer vision, with state-backed entities comprising two-thirds of SenseTime's initial public offering (IPO) investors.[276] SenseTime partners with the Chinese government to develop AI recognition tools to monitor and track Uyghurs across Xinjiang (leading to SenseTime being placed on BIS's Entity List).[277] SenseTime can then draw on this government-run surveillance program to build training data for its models, refining its AI recognition capabilities based off of hundreds of thousands of facial scans cultivated by the Chinese government.[278] Through this partnership, SenseTime has become a global leader in computer vision on its way to a multibillion-dollar valuation, developing rapid image recognition and remote sensing capabilities that rival U.S. technologies, tools essential for the Chinese government.[279] StarSee, another AI-enabled computer vision firm, has leveraged the support of state-owned investment funds and the backing of the Chinese Academy of Sciences to break into the military market.[280] Drawing on Chinese advances in computer vision, StarSee builds algorithms for AI mapping tools for the PLA capable of identifying foreign weapons systems, including tracking U.S. naval assets as far away as the coast of California.[281] StarSee's research team draws from China's wide range of commercial Chinese companies conducting AI research, including Baidu, Alibaba, Tencent, and Microsoft Research Asia.[282]

Even commercial-facing AI firms have engaged with the PLA, at times jeopardizing their global markets to do so. Drone-making company DJI has applied machine learning tools for object detection and navigation on its way toward achieving a 76 percent global market share of commercial drones.[283] However, in 2022, DOD labeled DJI a "Chinese military company," due to its links with the PLA and overseas military operations.[284] As Ms. Kania testified before the Commission, PLA drones include DJI's "RoboMaster S1," a small unmanned ground vehicle that has been reportedly employed for Eastern Theater Command urban warfare training.*[285]

*China's Eastern Theater Command trains for and would be involved in operations against Taiwan. Wu Che-yu and Jonathan Chin, "Xi Might be Doubting PLA Loyalty," *Taipei Times*, July 9, 2023.

AI Military Firms Use U.S. Technologies, Navigate U.S. Sanctions

Despite the partnership of nonstate AI firms with China's military on AI development, many continue to operate as civilian nonstate technology firms, avoiding the scrutiny and sanctions that come with aiding an adversarial military. Of the 273 PLA AI equipment suppliers identified in a study by the Center for the Study of Emerging Technology, only 8 percent, or 22 companies, were named in U.S. export control and sanctions regimes as of 2021.[286] Many of these firms drew on U.S. technology advancement—and in some cases U.S.-based funding—during their development.

AI technologies require semiconductors to function, and many aspects, including critical components, of the semiconductor ecosystem are controlled by the United States and its partners.[287] As recently as 2020, of the 97 AI chips identified by CSET in public PLA purchase records, nearly all were designed by NVIDIA, Xilinx (now a part of AMD), Intel, or Microsemi, all U.S-based chip firms.[288] Almost all AI models are trained on graphics processing units (GPUs)—chips highly capable of training sophisticated AI models. As of September 2022, NVIDIA and AMD, two U.S. GPU providers, were responsible for 95 percent of China's domestic GPU market, including providing essential chips for the development of Chinese AI, likely including for military use.[289]

However, the October 2022 restrictions of Chinese access to the United States most advanced chips threatens to slow Chinese AI development. As a result of the introduction of these restrictions, many firms expanded sanction evasion activities, including scaling up thousands of intermediaries to smuggle some of the world's highest-end chips, including from U.S.-based NVIDIA, into China.* Such practices are not likely viable in the long term as the United States and its partners refine their export control regime. This poses challenges for Chinese AI, as experts view China's domestic-produced chips as being a full three generations behind the cutting-edge foreign chips many advanced defense technologies rely on, risking the development of AI-enabled equipment falling behind.[290]

The October 2022 restrictions play into a point of concern the central government has highlighted since 2018, when Chinese state media outlined 35 "chokepoints" where China is outpaced by the international community in technological development.[291] Seven of these chokepoints reflect China's relatively immature chip standards and highlight how the country's reliance on foreign technologies poses "national security concerns" for China.[292] Facing U.S.-led curbs on chip access, the Chinese government at the end of 2022 introduced a $149 billion (1 trillion RMB) incentive program for its semiconductor industry to boost domestic research activity and production over the next five years.[293] Despite these planned investments, it remains to be seen whether domestic Chinese investment

*For example, in Shenzhen's Huaqiangbei subdistrict, the world's largest electronics wholesale market, vendors marketed NVIDIA's A100 GPUs, a chip banned for export to China, charging $17,700 per chip (128,000 RMB), a $7,000 dollar markup from NVIDIA's suggested retail price. Che Pan and Iris Deng, "Tech War: Strong Demand in China for Advanced Chips Used in AI Projects Creates a Growing Market for Smuggled Nvidia GPUs," *South China Morning Post*, June 27, 2023.

can rapidly replace decades of international advancements in semiconductor innovation and design.

Capital from the United States has also boosted the development of these Chinese AI defense tech firms. This includes funds connected to prominent U.S. venture capital funds, such as Sequoia Capital China, which has formerly been affiliated with Sequoia Capital, the Silicon Valley venture capital firm.[294] While Sequoia Capital is in the process of separating and rebranding its China firm from its United States and Europe operations by March 2024, Sequoia Capital China continues to draw investments from U.S. university endowments and charitable trusts.[295] Sequoia Capital China was an early investor in Eversec, which currently provides AI-based open-source data mining and information technology support to the PLA.[296] In November 2021, the PLA Strategic Support Force awarded a contract to Eversec for an AI-based "cyber threat intelligent sensing and early warning platform."[297] In 2020, Goldman Sachs invested in 4Paradigm, one of the largest AI firms in China, just months after it received contracts to design AI software to boost PLA operational abilities.[298] 4Paradigm currently serves PLA contracts including working to provide a "battalion and company command decision-making model and human-machine teaming software."[299] Goldman Sachs has also acted as a joint sponsor on multiple applications by 4Paradigm for an IPO on the Hong Kong Stock Exchange (HKEX).[300] Sponsorships have been as recent as September 2022, with Goldman Sachs Asia serving as a joint sponsor for 4Paradigm's IPO application.[301] Goldman withdrew its sponsorship of 4Paradigm's IPO in April 2023, following the company's March 2023 addition to the Entity List.*[302] Sequoia Capital China was also an early investor in 4Paradigm and its largest outside shareholder in 2021.[303]

U.S.-led advancements in AI Large Language Models (LLMs), which generate text and fulfill tasks in ways that mimic human production, also stand to be a point of interest for the Chinese military, given these LLM's potential capabilities to analyze data points rapidly, author advanced algorithms, and formulate disinformation campaigns.[304] Chinese firms have aggressively recruited international AI scientists to boost Chinese AI LLM capabilities. Additionally, according to research from CSET, as of 2020 10 percent of the total AI research labs for Facebook, Google, IBM, and Microsoft are located in China.[305] Microsoft notably maintains Microsoft Research Asia, its largest non-U.S. research base† in China's tech hub cit-

*In a disclosure with HKEX in April 2023, 4Paradigm indicated the partial state-owned China International Capital Corporation had become its sole IPO sponsor. In July, 4Paradigm became one of the first Chinese firms to complete the China Securities Regulatory Commission's new offshore listing procedures, which have slowed overseas IPOs to a near halt since the securities regulator introduced the requirement at the end of March 2023. For more on changes to China's overseas listing requirements, see Chapter 1, Section 1, "U.S.-China Bilateral and China's External Economic and Trade Relations." Kane Wu, "Chinese AI Startup Fourth Paradigm Receives China's Nod for Hong Kong IPO," *Reuters*, July 5, 2023; Hong Kong Stock Exchange, "Beijing Fourth Paradigm Technology Co., Ltd." April 24, 2023; China Securities Regulatory Commission, *Trial Measures for the Administration of Overseas Issuance and Listing of Securities by Domestic Companies* (境内企业境外发行证券和上市管理试行办法), February 17, 2023. Translation.

†Microsoft's China-based operations were impacted by a round of broader company layoffs announced in January 2023. However, the layoffs were most fully felt in Microsoft's U.S. operations, with comparably fewer China-based employees impacted. Microsoft Research Asia also canceled a lease on a new building in Beijing meant to add to its research headquarters. Li Jingya and She Xiaochen, "Microsoft Announces That It Will Lay Off 10,000 People, Human Resources De-

ies including Beijing, Shanghai and Shenzhen.[306] Microsoft also acts as a leading investor in OpenAI, having exclusive access to the underlying codes and algorithms that assist some of their cutting-edge LLMs, such as GPT-3.[307] These close ties between leading U.S. AI research firms and China lead to emerging risks, including continued technology transfers in the most strategic areas of AI research.[308] Already, Chinese state entities have leveraged their formidable hacking abilities to target advances in AI models made by private U.S. firms—U.S.-led advances that could be applied for the benefit of the Chinese government and its military.*[309]

Data and Talent Inhibit Military AI Development

China's development of AI-enabled defense technologies faces further drag due to both limited access to training data for specific warfighting scenarios and a shortage of AI engineers. While China's development in computer vision expanded in part thanks to China's nation-wide surveillance program, providing AI firms millions of use cases through which to develop and test the operational uses of their AI computer vision technology, it provided little training data for other critical areas.[310] With China rarely engaging in foreign conflict to directly test its AI, it has limited data through which to develop, train, and refine its AI-enabled warfighting capabilities.[311] As Gregory Allen of the Center for Strategic and International Studies testified before the Commission, "China may have data advantages related to facial recognition for domestic surveillance applications… but these data sets have limited relevance for military applications. For some military AI applications, such as precision missile targeting or autonomous drone navigation, China may have no data advantage whatsoever compared with the United States."[312]

Furthermore, many of China's most talented engineers are trained abroad and seek employment and possible emigration overseas following their education.[313] Retention of AI talent is a decade-long problem for China, as the United States routinely draws in top Chinese talent. A 2019 study from China-focused think tank MacroPolo surveyed a pool of 2,800 elite Chinese AI engineers and found that about three quarters now reside outside of China, and 85 percent of those have come to the United States to work at firms such as Google and IBM or to take up prominent positions in U.S. academia.[314] The United States is a hub for AI research, with U.S. engineers leading several AI breakthroughs in military applications, including AI researchers in California developing breakthroughs in autonomous fighter jet navigation and researchers affiliated with Virginia-based General Dynamics developing advanced unmanned ground vehicles.[315]

China has moved to close this gap by offering incentive programs for Chinese AI researchers returning to China and for foreign AI researchers coming to China. Recruitment efforts have targeted talent hubs for semiconductors, including Taiwan. Between 2014 and 2019,

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partment May Be the Most Impacted, China Will Be Affected" (微软官宣裁员1万人, 人力资源部或成重灾区, 中国区将受波及), *Jiemian News*, January 18, 2023. Translation.

*Despite Microsoft's research and relationship with China, the company has already been targeted by Chinese hacking attacks on its digital infrastructure this year. Jenna McLaughlin, "China Accused of Massive Hack into U.S. Government and Microsoft," *NPR*, July 12, 2023.

over 3,000, or 7 percent, of Taiwanese semiconductor technicians moved to the Mainland.*[316] China has also expanded the presence of defense technology research at Chinese universities, hosting conferences—such as the formative, "first forum on military-civil fusion in the AI industry," convened by Harbin Engineering University in 2018—featuring discussions of partnerships between Chinese academia and the PLA in the fields of intelligent underwater robots and high-speed unmanned boats.[317] Since then, links between the PLA and Chinese academia have only accelerated, with the PLA seeking to ensure that Chinese science, technology, engineering, and mathematics (STEM) research aligns with defense technology ambitions. As a result, the PLA now relies on university partnerships for critical AI development, particularly in the field of autonomous underwater vehicles (AUV).[318]

The PLA Prioritizes AI Use in Autonomous Underwater Vehicles

China's application of AI to underwater sensing and navigation has advanced in recent years, seeking to challenge U.S. power in the undersea domain, although substantial challenges remain in integrating these advances into practical and reliable warfighting capabilities. The PLA has leveraged AI capabilities in an attempt to offset geographic challenges in its surrounding maritime environment, where from the Taiwan Strait to the South China Sea, shallow reefs and complex littorals pose challenges to the PLA's operating abilities. To meet this challenge, the PLA has focused heavily on the development of AI-powered AUV, viewing them as critical to achieving area dominance on China's periphery.[319] In seeking AI dominance in the undersea domain, the PLA has turned to its university base to spur advanced research in AUV. A 2021 report by China technology expert Ryan Fedasiuk for the Center for International Maritime Security outlined how by 2019, China had established 159 AUV projects at over 40 universities.[320] Another report by a professor at Hebei University of Science and Technology listed 48 universities engaged in research on unmanned and autonomous underwater vehicles, working on submersibles that have relevant military applications.[321]

Through these partnerships, the PLA Navy has secured advances in underwater mapping and reconnaissance, using AI-enabled AUV to monitor China's surrounding waters for foreign vessels and other activity. AI-enabled AUV may be deployed to augment the PLA's "Smart Ocean," initiative which seeks to incorporate satellite sensing, intelligent buoys, AUV, and other AI-enabled technologies to increase undersea awareness.[322] Research papers published by the PLA Navy indicate an intention to also add AUV to China's "Great Underwater Wall" monitoring system, utilizing

*Taiwan's government has launched multiple initiatives to combat Chinese attempts to steal top talent. In May 2022, Taiwan's Legislative Yuan amended the National Security Act in May 2022 to prohibit Taiwan workers in key industries from traveling to the Mainland without prior permission. Taiwan's Bureau of Investigation has also launched a number of raids on Chinese companies operating in Taipei and Hsinchu, Taiwan's hubs for semiconductors. For more on Taiwan's efforts to combat China's economic espionage, see U.S.-China Economic and Security Review Commission, Chapter 4, "Taiwan" in *2022 Annual Report to Congress*, November 2022, 628.

The PLA Prioritizes AI Use in Autonomous Underwater Vehicles—*Continued*

small and medium-sized AI-enabled AUV to detect and identify potential enemy undersea vehicles.[323]

Advances in ultralight Chinese underwater "glider" AUV have further bolstered PLA maritime reconnaissance capabilities. These AI-enabled vehicles demonstrate both the technological capabilities to conduct surveying and reconnaissance of deep waters, and the endurance to travel far beyond China's littorals. Their appearance across the Indo-Pacific region reflects a PLA ambition to deploy glider AUV with broad capability to detect and identify undersea objects, including potential U.S. submarines.[324] Advances in AUV and similar AI-enabled undersea vehicles provide further capabilities in mine laying and in accessing underwater cables, with China recognizing the advantage that both capabilities provide in combat scenarios, such as in a conflict over Taiwan.[325]

However, barriers persist in China's AUV technology, largely stemming from technological roadblocks. China's largest AUV are energy intensive and constrained by a 24-hour battery life, limiting their range of travel.[326] Its undersea gliders must surface in order to transmit information to PLA operators, becoming vulnerable to detection from adversaries.[327] Despite recent advancements, PLA AI technology supporting Chinese AUV in mapping underwater geography still has inconsistencies and is not yet mature enough to reliably identify undersea targets.[328] This casts doubts on the prospect that AI-enabled AUV will be able to effectively engage foreign undersea vehicles in the near future without human assistance.[329] This means the PLA has yet to achieve true AI-enabled dominance in the undersea domain, especially in a contested environment or during a conflict. As indicated by CSET, despite strides in the state of current Chinese AUV AI technology, "the complexity of antisubmarine warfare, and the sheer scale and physics-based challenges of undersea sensing and communications all suggest these [AI] systems have a long way to go."[330]

Still, Chinese investment in AI-enabled undersea capabilities provides serious challenges to the U.S. military and that of its partners in the region. The United States has long been assessed by experts to have an advantage in the Taiwan Strait in undersea capabilities, due to its ability to operate submerged military assets efficiently and quietly in the surrounding waters.[331] Chinese advancements in AI-equipped AUV may soon begin to erode this advantage. While China may not be able to produce cutting-edge submarines at the level of the United States, AI-enabled AUV provide new capabilities in tracking and reconnaissance and may challenge the U.S. military's previously assumed ability to operate quietly in China's undersea periphery. With the range of PLA AUV broadening, and their capabilities increasing, the PLA may soon be able to track military activity on an increasingly wide scale, including along the Japanese archipelago, near U.S. military installations in Guam, and beyond.[332]

The PLA Prioritizes AI Use in Autonomous Underwater Vehicles—*Continued*

Furthermore, in a combat scenario, these AUV threaten to strike at infrastructure essential to U.S. capabilities. PLA AUV have been designed to identify and access undersea cables, posing an emerging threat to digital infrastructure.[333] As Mr. Fedusiak outlines, this includes a looming danger to a concentration of fiber-optic cables near northern Taiwan that are essential for information dissemination on Taiwan, as well as trans-Pacific data exchanges, including for internet access in parts of the United States.[334] However, China also relies on these and nearby fiber-optic cables for its own internet access and data needs.[335] This means that while the PLA has designed AUV capable of striking cables relied on by Taiwan and the United States, doing so would also likely cause disruptions to China's own digital infrastructure.

Export Control and Investment Screening

Current U.S. export controls and investment restrictions, even when coupled with multilateral export control and the investment screening regimes of U.S. allies and partners, are insufficient to stem the flow of U.S. and foreign technology, expertise, and capital to China's defense sector. MCF presents a unique challenge to export controls, requiring a renewed focus on dual-use technologies where foundational frameworks, particularly in the multilateral regimes, focus on counterproliferation. This is compounded by the pace at which technology evolves, as well as the increasing globalization of R&D of new technologies and the supply chains used in those technologies. Slow development and implementation of export controls has allowed Chinese firms to develop workarounds. For instance, in March 2023, the *Australian Financial Review* reported that Chinese voice recognition firm iFlytek, added to the Entity List in 2019, was skirting controls on buying advanced U.S. chips by renting time on cloud computing servers powered with advanced NVIDIA chips to train its AI models.[336] These challenges are exacerbated by the difficulty reaching consensus with allies and partners on which technologies need to be controlled and at what level of maturity they should be controlled.

Beyond controlling transfer and development of discreet technologies with clear specific potential for military end uses, the United States faces broader strategic questions of whether and how to control China's acquisition of technology and knowhow that advance its economic competitiveness at the expense of U.S. workers and producers and undermine the resilience of the U.S. defense industrial base. China's dual circulation strategy and related efforts to increase self-reliance, localize production, and secure global access to critical inputs like minerals could exacerbate U.S. dependence on Chinese components and strengthen China's ability to employ economic coercion. Additionally, many challenges that work against controlling exports for military end use also apply to controlling exports of U.S. hardware and software to surveillance technology firms

involved in human rights abuses, such as the Chinese government's mass repression in the Xinjiang Uyghur Autonomous Region.

Progress and Limits in Addressing China's Challenge to Export Controls

Since the Export Control Reform Act (ECRA) became law in 2018, application of U.S. export controls to end users based in China or affiliated with Chinese entities has expanded substantially, though they face significant and growing limitations, including in developing tighter controls, sharing information, and monitoring end use. In contrast to controls that regulate export of a specific technology or to a jurisdiction regardless of the recipient, end user-based controls are more targeted and narrower (for an overview of U.S. export control authorities and implementing regulations, see Appendix). Additionally, the October 7, 2022, restrictions on exporting advanced semiconductors and semiconductor manufacturing equipment to China constitute a step-change in U.S. export control policy toward the country.[337]

Despite increasing the number of specifically named Chinese entities barred from receiving technology, the U.S. Department of Commerce's BIS has made limited progress in expanding the scope of technologies controlled. In 2018, ECRA tasked the agency with identifying "emerging and foundational" technologies and imposing controls where necessary, but BIS has not identified any foundational technologies, and in a May 2022 statement it announced it would no longer attempt to do so.[338] In testimony before the Commission in 2021, then Acting Undersecretary for Industry and Security Jeremy Pelter indicated that BIS did not want to outpace U.S. allies and partners in regulating developing technologies and inhibit multilateral coordination.[339]

United States Expands Export Controls on Chinese Firms and Chips

Heightened controls on the export of U.S. technology and software to Chinese companies have foremost been implemented via Commerce's Entity List, and since 2018 Commerce has modified the Export Administration Regulations (EAR) to more precisely target specific Chinese companies and activities via the list. Transfer of all items controlled by the EAR* to designees on the Entity List is prohibited without first receiving a license from BIS, and such licenses are subject to a presumption of denial.† There are currently 611 China-based entries on the Entity List, 525 of which have been add-

*This includes not just dual-use items and munitions on the Commerce Control List that have an Export Control Classification Number but also items regulated under EAR99, a designation for low-tech consumer goods that are not subject to licensing requirements except for embargoed countries or end users of concern. U.S. Department of Commerce Bureau of Industry and Security, "Frequently Asked Questions to Export Licensing Requirements," November 2018, 4.

†Exporters may nonetheless apply for and receive a license to continue transferring specified products to a designated entity if their application demonstrates exclusive civil end use, consistent with U.S. national security interests. For instance, between November 2020 and April 2021, BIS approved 113 export licenses involving Huawei, valued at up to $61 billion. Additionally, some entries on the Entity List specify exemptions to the presumption of denial, ranging from particular export control classification numbers to the entirety of the EAR99 (see prior footnote), though often with a case-by-case review. Kate O'Keefe, "U.S. Issued $100 Billion in Export Licenses to Suppliers of Huawei, SMIC," *Wall Street Journal*, October 21, 2021; U.S. Department of Commerce International Trade Administration, *Consolidated Screening List*.

ed since January 2018.*[340] Inclusion of Chinese firms, government agencies, research institutes, and individuals on the Entity List has principally sought to prevent their acquisition of dual-use technologies and application of these technologies to military end uses. However, the Trump and Biden Administrations have also used the list for broader purposes, primarily targeting entities involved in:

- *China's military modernization:* Numerous Chinese defense conglomerates, research institutes, and nonstate firms have been added to the Entity List for their role in advancing specific PLA capabilities, including hypersonics, technology used in missiles, and other advanced weapons systems.[341] Other entities have been added for acquiring dual-use technology for military purposes. For instance, Chinese supercomputer manufacturer Sugon and two of its subsidiaries were added to the Entity List in June 2019 for assisting in China's development of supercomputers that could be used for military applications, including cryptography and complex simulations like nuclear weapons testing simulations.[342]
- *China's MCF program:* Beyond entities advancing specific defense capabilities, BIS has added Chinese firms and research institutes participating in MCF and other ostensibly civilian companies transacting with China's military industrial complex to the Entity List. Chief among these is Semiconductor Manufacturing International Company (SMIC), which was added in December 2020.† Additions within the past year have focused especially on AI, including a final rule from December 2022 that added 21 firms involved in AI chip R&D, manufacturing, and sales.[343]
- *Diversion to military end users:* BIS's monitoring activities also encompass potential diversion to military end uses and supporting other blacklisted entities. Many recent additions include Chinese firms attempting to acquire goods in support of the PLA. Notably, three subsidiaries of Chinese biotech giant BGI Group were also added to the Entity List in March 2023, partly due to concerns that they were collecting and analyzing genetic data for the PLA.[344]
- *Aiding other militaries:* The Entity List also includes Chinese firms assisting other potential adversaries in violation of U.S. export controls, including by supplying the Russian military following the imposition of U.S. restrictions on Russia for its

*The Entity List is arranged by destination country according to U.S. customs territories, so affiliates of the same corporation may be treated as separate entities. As of July 26, 2023, the list includes 2,523 total entries in all jurisdictions. The 611 China-based entries consequently do not include overseas affiliates of other Chinese firms but do include Hong Kong-based entities. For instance, over 100 subsidiaries of Huawei based outside of China have been added to the Entity List. Five China-based entities do not have dates of addition listed. U.S. Department of Commerce, *Department of Commerce Adds Dozens of New Huawei Affiliates to the Entity List and Maintains Narrow Exemptions through the Temporary General License*, August 19, 2019; U.S. Department of Commerce International Trade Administration, *Consolidated Screening List*.

†The entry only applied a presumption of denial for "items uniquely required for production of semiconductors at advanced technology nodes," however, and BIS approved 118 licenses valued at up to $42 billion involving SMIC between its addition to the Entity List and April 2021. Kate O'Keefe, "U.S. Issued $100 Billion in Export Licenses to Suppliers of Huawei, SMIC," *Wall Street Journal*, October 21, 2021.

unprovoked invasion of Ukraine as well as by providing U.S. electronics to Iran's military.[345]

- *Human rights abuses:* Dozens of Chinese technology firms and government agencies have been added to the Entity List for their role in advancing mass surveillance and arbitrary detention against Uyghurs and other Muslim minority groups in Xinjiang. These include state-owned camera maker Hikvision and AI startups SenseTime and Cloudwalk, among other venture-based tech firms.[346]
- *Other activities contrary to U.S. interest:* BIS has also sought to advance other U.S. foreign policy objectives through the Entity List. For instance, in August 2020, it added 24 Chinese companies involved in artificial island building in the South China Sea,* including subsidiaries of state-owned infrastructure conglomerate China Communications Construction Corporation.[347] Additional entities were added for the same reason in December 2020.[348] It has also added China-based firms and individuals to the Entity List for involvement in industrial espionage.[349]

Extending U.S. Export Controls through the Foreign Direct Product Rule

To inhibit companies from circumventing Entity List restrictions by offshoring production, the U.S. government has strengthened extraterritorial regulations on exports made using U.S. technology. Foreign direct product rules prohibit foreign countries from exporting or reexporting controlled items made with a certain portion of U.S.-origin technology or software, as defined by the EAR, to restricted end users unless the exporter receives a license or license exception.† Following Huawei's addition to the Entity List in 2019, Commerce introduced two rules to prevent Huawei's purchase of advanced semiconductors made using U.S. technology. The rules blocked chip design subsidiary HiSilicon from contracting Taiwan Semiconductor Manufacturing Company (TSMC) to fabricate chips for its devices by restricting TSMC from using U.S.-made electronic design automation software in chips made for Huawei, damaging the company's handset busi-

*China claims 90 percent of the South China Sea as its historic sovereign territory in a demarcation called the nine-dash line, and it initiated aggressive land reclamation program on features it occupies in the Spratly and Paracel Islands in 2013. Construction of runways and other facilities has enabled China to deploy advanced military equipment on the islands since 2015. In July 2016, a tribunal at the Permanent Court of Arbitration in The Hague issued a ruling on the merits of a case brought by the Philippines that overwhelmingly ruled against multiple claims China had made in the South China Sea. The tribunal concluded that the nine-dash line had no legal basis, that none of the land features China claimed were actually islands, and that China had violated the Philippines' sovereign rights by interfering in its exclusive economic zone (within 200 nautical miles of its coast). China's land reclamation projects attempt to establish both that the features are actual islands and that China has a sovereign claim to them. For more on China's excessive maritime claims in the South China Sea, see Chapter 2, Section 1, "Rule by Law: China's Increasingly Global Legal Reach." Shannon Tiezzi, "Why Is China Building Islands in the South China Sea?" *Diplomat*, September 10, 2014.

†De minimis rules establish that items produced outside the United States incorporating certain controlled U.S. goods that do not exceed a certain de minimis threshold (10 percent or 25 percent depending on the technology) are not subject to the EAR. Some controlled technologies, including certain software, are ineligible for de minimis rules and some restricted countries are excluded. 15 C.F.R. §734.4 - De Minimis U.S. Content, 1996.

Extending U.S. Export Controls through the Foreign Direct Product Rule—*Continued*

ness.*[350] Because of the rules, the UK government also reversed its decision to permit Huawei in its telecommunication networks, noting "the new restrictions make it impossible to continue to guarantee the security of Huawei equipment in the future."[351] The October 7 restrictions also make use of foreign direct product rules, prohibiting export of advanced graphics processing units used in AI applications to China if they were made using U.S. technology or software.[352] Additionally, export controls on Russia and Belarus following Russia's invasion of Ukraine apply foreign direct product rules.[353]

The U.S. government has also developed and expanded other end user-based tools to complement the Entity List, including the Military End User List and the Unverified List. The former, introduced at the end of 2020, encompasses entities BIS has identified as military end users in denying license applications or in case-by-case license exemption reviews.[354] In publishing the list, BIS is effectively providing a screening tool to industry to assist in identifying transactions with prohibited parties, though not removing exporters' requirement to ensure they are not aiding potential adversaries' militaries. The list's creation followed an April 2020 rule from BIS expanding the definition of "military end use" to lower the threshold for restricting exports to military end users from China.†[355] The list included 71 China-based entities as of July 2023.[356] Parties on the Unverified List (UVL) are ineligible to receive items subject to the EAR with a license exemption because BIS cannot complete an "end use check" either verifying the identity of the party or confirming it is acquiring U.S. goods for its stated purposes.[357] As of July 2023, there are 126 China-based entities on the Unverified List.[358]

October 7 Controls Attempt to Restrain China's Access to Advanced Semiconductors, for Now

BIS's October 7, 2022, export controls on advanced computing and semiconductor manufacturing equipment substantially impact China's AI, computing, and semiconductor industries and represent a major advancement in the United States' approach to curtailing China's technology development. The controls limit access to advanced chips for AI and supercomputer development as well as semiconductor manufacturing equipment that can further China's domestic

*Huawei's addition to the Entity List also prevented it from licensing Google's Android operating system and Google's apps like Gmail, further damaging its handset business. Arjun Kharpal, "Google Cuts Ties with Huawei. That May Be a 'Kill Switch' for the Chinese Firm's Global Smartphone Ambition," *CNBC*, May 20, 2019.

†The rule also applies to exports to Russia and Venezuela and prohibits transferring certain items on the Commerce Control List if the exporter believes they may be used for military end use. Where the EAR defines "military end use" as encompassing a full product lifecycle, including "operation, installation (including on-site installation), maintenance (checking), repair, overhaul and refurbishing" of military items, under the broadened definition any one of these functions constitutes military end use. U.S. Department of Commerce Bureau of Industry and Security, "Expansion of Export, Reexport, and Transfer (in-Country) Controls for Military End Use or Military End Users in the People's Republic of China, Russia, or Venezuela," *Federal Register* 85:82 (April 28, 2020).

capacity to produce advanced semiconductors.* Where prior controls had informally sought to keep China's semiconductor fabrication capabilities two generations behind those of the United States, the new restrictions seek to hold China's domestic capabilities at current levels.[359] The rationale for applying broad-based controls to a sector, rather than to specific end users or end uses, focuses on AI and semiconductors' nature as general purpose technologies that assist in multiple defense applications, including using machine learning to improve the speed and accuracy of China's autonomous military systems and complex simulations used in designing and testing weapons systems.[360]

Semiconductor analysts, however, question the efficacy of the current U.S.-led export controls, particularly in light of advances at SMIC and Huawei. First, preventing China from importing advanced "commodity chips" or mass-manufactured chips that are not designed for a highly specialized application is extremely difficult due to their prevalence.[361] Second, given the way in which the rules are written, as well as the difficulty of enforcing controls via end-use checks, Chinese semiconductor fabrication plants are likely still obtaining equipment needed to manufacture chips one or two generations behind the leading edge, beyond the threshold imposed by the controls.[362] When news first broke in 2022 that SMIC had produced a 7 nm processor, many were skeptical of their ability to scale production with good yield (i.e., percentage of nondefective chips on a wafer).[363] Analysts have increasingly converged on the view that SMIC's yield is better than skeptics initially held and represents a genuine feat, as evidenced by mass production capacity for SMIC's Kirin 9000, the 7 nm processor used in the new Huawei Mate Pro.[364] Underestimation of SMIC's progress prior to the October controls may account for some of the recent surprise, but several analysts also believe recent achievements reflect fundamental flaws in the new restrictions. Dylan Patel, a leading semiconductor analyst, argues that the current restrictions on U.S. semiconductor manufacturing equipment are ineffective because "equipment companies… are selling basically every tool they offer to China… most deposition, etch, metrology, cleaning, coaters, developers, ion implant, epitaxy, etc. tools for 7nm and even 5nm can also plausibly be used in 28nm."[365] With BIS using a 14nm restriction limit, importers are often able to purchase the equipment if they claim it is being used on an older production line, and with limited capacity for end-use inspections it is difficult to verify the equipment is not being used to produce more advanced chips.[366] Douglas Fuller, pro-

*The rules introduce five new license requirements: (1) to sell top-end chips necessary for training machine learning models and building supercomputers; (2) to sell certain advanced semiconductor manufacturing equipment; (3) expanding the scope foreign direct product rules to cover advanced computing chips, supercomputers, and advanced semiconductors for high performance applications in China or to 28 firms that aided China's military in developing high performance computing capabilities; (4) for all items subject to the Export Administration Regulations when there is "knowledge" that the item is destined for end use in the "development" or "production" of chips in China at facilities fabricating advanced chips; and (5) for U.S. persons, including U.S. citizens, passport holders, green card holders, juridical citizens, U.S. residents, and others, to "support" the "development" or "production" of advanced chips in China without a license from BIS. Roughly, BIS has set the threshold for advanced chip fabrication as follows: for logic chips, 16 nm or 14 nm, or below; for DRAM memory chips, this is 18 nm; for NAND flash memory chips, this is 128 layers or more. U.S. Department of Commerce Bureau of Industry and Security, *Commerce Implements New Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC)*, October 7, 2022.

fessor at Copenhagen Business and School and multidecade analyst of China's semiconductor ecosystem, initially believed SMIC's yield for its 7 nm chips was extremely low, but in September of 2023 altered his assessment after receiving industry insider information that Chinese fabrication plants were still able to obtain semiconductor manufacturing equipment due to porousness of the controls.[367]

To the extent such controls are effective, it is only possible because of plurilateral coordination with other major players in the global semiconductor supply chain.[368] Following its unilateral imposition of the controls, the U.S. government secured cooperation from Taiwan, which uses U.S. technology in its foundries.* Subsequently, the Netherlands and Japan, both of which also control chokepoints in the semiconductor supply chain, agreed to impose related controls.†[369] Dutch firm ASML is the world leader in advanced photolithography equipment, machines that use lasers to etch circuitry onto silicon wafers, producing semiconductors.[370] Japan similarly has substantial market share in some of the specialized tools used in semiconductor fabrication and is also a leading supplier of chemicals used in the process.[371]

Limitations in U.S. and Multilateral Export Controls

Despite the increased application of end user-based controls, U.S. export controls face a series of challenges in inhibiting transfer of defense and dual-use technology to China. First, export controls are, in the words of former Acting Undersecretary of Commerce for Industry and Security Cordell Hull, a "time-limited solution" that can at best delay China's acquisition and development of key technologies but will not completely prevent it.[372] Second, the end user-focused approach requires extensive resources to track a proliferation of new firms acting on behalf of the PLA, and data on ownership and transactions to identify these firms may be inaccurate or impossible to obtain. Third, for many technologies, the United States does not have sufficient control over the supply chain to introduce effective controls unilaterally. Fourth, multilateral coordination is difficult, as the existing regimes focus on nonproliferation rather than constraining transfer of dual-use technology and require consensus of all members. Each of these challenges is discussed in further detail below.

- *Export controls are a time-limited and often reactive solution:* As Giovanna Cinelli, fellow at the National Security Institute at George Mason University Antonin Scalia Law School, explained in testimony before the Commission in 2021, the U.S. government has shifted from a "deny and delay" approach that sought to prevent potential adversaries from obtaining U.S. technology to a "run faster" approach.[373] The latter assumes the United

*BIS granted South Korean chipmakers SK Hynix and Samsung, both of which have foundries in China, a one-year reprieve from the October 7 restrictions through a temporary general license. Erika Na, "South Korea Caught in the Middle of U.S.-China Chip War, but American Export Control Requests Unlikely," *South China Morning Post*, November 14, 2022.

†Although Japan and the Netherlands have broadly agreed to cooperate with the United States on imposing controls on exporting chips, equipment, and software to China, the countries have not agreed to apply a key provision of the U.S. restrictions to their own citizens: U.S. restrictions prohibit U.S. persons from aiding or providing knowhow to facilitate China's development of advanced semiconductors without a license. Toby Sterling, "Dutch Curb Chip Equipment Exports, Drawing Chinese Ire," *Reuters*, June 30, 2023.

States can allow a certain degree of transfer because U.S. industry will maintain several generations' lead in development. However, the increasingly global nature of R&D and production networks has shortened or altogether dissolved U.S. industry's lead in many technology areas. Additionally, U.S. export controls often react after a concerning transfer has occurred.[374] Even when the U.S. government takes a proactive approach to identifying technologies with security implications, Chinese industry may maneuver to stockpile vital components or otherwise evade controls. As noted above, sanctioned Chinese voice recognition firm iFlytek has worked around the controls to rent cloud computing time on servers powered by chips from NVIDIA.[375]

- *Corporate shell games, poor data visibility, and capacity constraints make end user-based controls less effective:* Restricted end users can evade controls by acquiring items through intermediaries, whether independent resellers or shell companies connected to the restricted entities.[376] For tracking exports to China in particular, this has created a substantial administrative burden and vast expansion of the Entity List to include problematic affiliates, especially as BIS often relies on time-intensive manual inputs to update the list.[377] The Entity List includes numerous firms and institutes associated with the major state-owned defense groups, such as Aviation Industry Corporation of China (AVIC) and China Electronics Technology Company (CETC).[378] Tracing connections between military end users and seemingly civilian affiliates can be especially challenging in China and other jurisdictions, where obtaining information is difficult.[379] The Chinese government's recent restrictions on foreign access to domestic corporate registry databases and crackdown on due diligence firms compounds this challenge (for more on China's efforts to limit data access, see Chapter 1, Section 1, "U.S.-China Bilateral and China's External Economic and Trade Relations"). Last, but not least, BIS faces capacity constraints in enforcement. Of the 41,446 licenses it issued in fiscal year 2021, only 1,030 received end use checks.[380]
- *Unilateral controls are ineffective in many technologies:* The example of the October 7 restrictions on semiconductors demonstrates the difficulty of inhibiting China's ability to acquire and develop a discreet technology in a relatively straightforward case: the U.S. government was able to impose controls viewed as effective, at least in the short term, with cooperation from the governments of the Netherlands and Japan and compliance with U.S. foreign direct product rules from Taiwan and South Korean fabrication plants.[381] Coordinating controls with allies and partners may not always be as straightforward, and for many mature technologies and their supply chains, effectively slowing China's acquisition could require policy alignment between a broader group of countries.[382] For emerging technologies, coordination challenges become even more complex, as it is not yet clear how related industries will evolve as commercial and potential defense applications develop, which countries possess the greatest capabilities or chokepoints in the technologies, and at what stage of technological maturity controls should be

imposed.[383] In a nascent technology, such as quantum computing, for instance, imposing restrictions may undermine promising research that could lead to breakthroughs in developing the technology.*[384] Even for technologies in which the United States retains a decisive lead and control over the related supply chain, controls can put stress on U.S. firms and their suppliers.

- *Multilateral coordination is difficult:* As Martijn Rasser, managing director at Dutch due diligence firm Datenna, Inc., described in testimony before the Commission, "The fundamental hurdle to crafting more aligned and effective export control policies among the leading techno-democracies remains diverging views on the nature of the China challenge."[385] The four current multilateral regimes are consensus based, constraining their ability to implement new controls if one member dissents, and Russia is in three out of four (see Table 1 below).[386] Additionally, the current regimes have limited mandates, so they are constrained in responding to emerging challenges, including supply chain resiliency and China and Russia's MCF policies.[387] Additional multilateral groupings like the G7 and Organization for Economic Cooperation and Development tend to have too broad of mandates and membership to align on controls.[388] Emerging plurilateral groupings like the U.S.-EU Trade and Technology Council have made progress in key areas, such as coordinating on evasion and diversion efforts in exports to Russia and Iran, but their remit is far from sufficient to encompass the breadth of novel and emerging technologies China seeks to acquire from participating countries.[389] Moreover, a proliferation of contending plurilateral groups could create additional administrative and coordination challenges for U.S. government and business.[390]

Table 1: Overview of Multilateral Export Control Regimes

Regime	Purpose, Membership, and Controlled Items
Nuclear Suppliers Group (NSG)	Founded in 1974 in response to India's first nuclear test, the NSG consists of 48 participating governments, including nuclear supplier states and nonnuclear weapons states. The NSG has two lists: Part 1 covers nuclear materials, facilities, and equipment for nuclear reactors; and Part 2 includes technology, equipment, and components with dual-use applications in nuclear and nonnuclear industries.
Australia Group	Formed in 1985 in response to concerns about the spread of chemical and biological weapons, the Australia Group includes 43 chemical and biological exporters. It controls exports of dual-use items, including chemicals, toxins, and biological agents that could be used to develop chemical or biological weapons.

*Quantum computing is a subfield of quantum information science. Currently, within quantum information science, some export controls are only imposed on quantum sensing, which is more mature and has clear defense applications, such as detecting stealth technologies. Martijn Rasser, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on China's Pursuit of Defense Technologies: Implications for U.S. and Multilateral Export Control and Investment Screening Regimes*, April 13, 2023, 5.

Table 1: Overview of Multilateral Export Control Regimes—*Continued*

Regime	Purpose, Membership, and Controlled Items
Missile Technology Control Regime (MTCR)	The MTCR aims to limit the proliferation of missiles, rocket systems, and related technologies. Founded in 1987, it counts 35 members who control export of items that could contribute to missile systems capable of delivering nuclear, chemical, and biological payloads.
The Wassenaar Arrangement	Founded in 1996 to succeed the Coordinating Committee for Multilateral Export Controls (COCOM),* the Wassenaar Arrangement is more general purpose than the other regimes detailed above. It seeks to promote transparency and responsibility in the transfer of conventional arms and dual-use technologies. The arrangement comprises 42 participating arms exporters and technology suppliers and controls a broad range of conventional arms and dual-use items, including electronics, software, telecommunications equipment, and sensors.

Source: Paul Kerr and Christopher Casey, "The U.S. Export Control System and the Export Control Reform Act of 2018," *Congressional Research Service* R46814, June 7, 2021, 17.

Progress and Limits in Investment Screening

With the passage of the Foreign Investment Risk Review Modernization Act (FIRRMA) in 2018, the United States has a well-established legal framework to screen inbound foreign investments for national security risks, including targeted Chinese investment and acquisitions designed to appropriate U.S. innovation.[391] FIRRMA brought significant reforms to the Committee on Foreign Investment in United States (CFIUS), including expanding its jurisdiction to encompass noncontrolling investments and greenfield real estate transactions.[392] FIRRMA also introduced mandatory notifications for certain transactions involving critical technology and facilitated international cooperation.[393]

In testimony before the Commission, Emily Kilcrease, senior fellow and director of the Center for a New American Security's Energy, Economics, and Security Program, noted that CFIUS is facing capacity constraints in fully utilizing its expanded jurisdiction. Additionally, inbound investment review has sometimes struggled to articulate risks associated with emerging technologies, as their applications are not yet fully understood.[394] CFIUS has traditionally defined critical technologies through reference to export control authorities rather than developing a separate list of sensitive technologies.[395] In other words, it looked to technologies already subject to export controls, such as those on the Commerce Control List or U.S. Munitions List. These lists focus more narrowly on potential adversaries' acquisition of specific capabilities, but they exclude other questions relevant to national security that may merit consideration for an investment rather than simply the purchase of an export, such as the implications of China gaining significant market share in an emerging technology or supply chain control over a legacy technology.[396] Additional-

*COCOM was established in the years following World War II to restrict arms exports to the Council for Mutual Economic Assistance led by the Soviet Union. It was implemented in the United States via the Arms Export Control Act, which tasked the State Department with regulatory supervision of the International Traffic in Arms Regulations (ITAR).

ly, while CFIUS has the authority to review any covered transaction, its authority to review noncontrolling investments is limited to those engaged in critical technologies already encompassed by U.S. export controls, certain infrastructure, or processing data of U.S. citizens.[397] Additionally, new FIRRMA authorities mandate notification of transactions in critical technologies, so CFIUS may not have visibility into transactions with potential national security implications that are not captured under existing export control categories.[398]

Scoping and Objectives for Outbound Investment Screening

An outbound investment screening mechanism could inhibit the flow of U.S. capital, technology, and knowhow to potential adversaries and build on and potentially mirror inbound investment restrictions that prevent foreign companies from obtaining specific capabilities through U.S. acquisitions. Such a mechanism could also complement export controls, which prevent the transfer of technology to potential adversaries but not its development overseas. Various proposals for restricting outbound investment frequently focus on three main areas:

1. *Technology development*, particularly in emerging fields through venture capital and private equity investments as well as corporate foreign direct investment and joint ventures that typically include transfer of IP and knowhow;
2. *Offshoring and supply chain development concerns*, including risks that the United States does not maintain sufficient domestic capacity in critical sectors to the economy beyond those required for ensuring technological competitiveness (e.g., the COVID-19 pandemic revealed U.S. dependence on foreign sources of personal protective equipment); and
3. *Financial flows*, also including venture capital, private equity, and potentially portfolio investments that fund activities and entities acting contrary to U.S. interests and values.*

Proponents of an outbound investment screening mechanism argue that there are clearly outbound capital flows that advance potential adversaries' technological capabilities, and the U.S. government should be able to track and block such investments. Foremost, capital and technology flows are often accompanied by technical expertise, managerial acumen, and business networks to support the investment target's development—and U.S. investors are incentivized to leverage all tools at their disposal to guarantee the success of their overseas investments. These intangible benefits of investment help foreign firms build operational capabilities, such as how to run advanced manufacturing processes, that current controls

*Such restrictions are imposed by the investment prohibitions on publicly traded securities of roughly 60 Chinese defense contractors, surveillance technology companies, and their affiliates under the June 2021 Executive Order 14062. The EO replaced EO 13059 introduced by the Trump Administration on a similar set of companies in November 2020. EO 13059 faced legal challenges from firms on the list successfully obtaining preliminary injunctions against the EO's enforcement under the Administration Procedure Act, described in the second footnote on the next page. Executive Office of the President, "Addressing the Threat from Securities Investments that Finance Certain Companies of the People's Republic of China," *Federal Register* 86:107 (June 7, 2021).

may be insufficient to target* and into which the U.S. government currently has limited visibility.[399] Advocates for outbound screening argue that the potential difficulty in establishing a regime is not a compelling reason not to try, and moreover the difficulty may be overstated. Many have urged a narrow scope, either indefinitely or as a first step, suggesting that outbound investment screening will be most effective if it examines technology chokepoints in supply chain networks where U.S. firms currently have the advantage.[400]

Skeptics of outbound investment screening argue that any regime is likely to cause more harm than good and that modifications to existing structures like CFIUS can address many concerns. A primary challenge of developing an outbound screening mechanism is the legal complexity of defining its authorities and the potential enforcement difficulties on transactions outside U.S. jurisdiction. In contrast with existing restrictions on investing in Chinese companies with military ties, which rest on the International Emergency Economic Powers Act (IEEPA) authorities,† the potential scope of a completely new outbound investment screening mechanism may be vague and abstract. The mechanism's notifications could require extensive legal review by private sector firms, and its determinations may be subject to legal challenges requiring additional government resources to address.‡

From an enforcement perspective, limiting outbound flows is also much more difficult than controlling market access. U.S. multinationals could decide to route prohibited investment through a third country, for instance. Additionally, China may block attempts by the U.S. government to obtain information on a China-based investment target of a U.S. outbound transaction. By contrast, the U.S. government can more easily compel a U.S.-based acquisition target to provide CFIUS with sensitive nonpublic information to consider national security risk.[401] Given the challenges, detrac-

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*There are some avenues to target intangibles. Aside from licensing requirements, the EAR prohibits U.S. persons from knowingly providing "support," broadly defined, for the development or production of missiles, nuclear weapons, chemical, and biological weapons, as well as foreign maritime nuclear projects. Additionally, BIS also has the authority to inform U.S. persons that their activities could support these end uses and impose a licensing requirement on the activities. The October 7 restrictions use this authority to prevent U.S. persons from supporting advanced semiconductor development in China. Thomas J. McCarthy et al., "International Trade Alert: BIS Imposes New Controls to Limit the Development and Production of Advanced Computing and Semiconductor Capabilities in China," *Akin Gump*, October 27, 2022, 4.

†IEEPA grants the president sweeping authority to "nullify, void, prevent, or prohibit" transactions in response to "any unusual and extraordinary threat . . . to the national security, foreign policy, or economy of the United States." Importantly, the Supreme Court has held that the president is not a U.S. government agency under the Administrative Procedure Act (see next footnote), creating a very high threshold for challenging EOs that invoke IEEPA authorities. Jared Cole and Daniel T. Shed, "Administrative Law Primer: Statutory Definitions of 'Agency' and Characteristics of Agency Independence," *Congressional Research Service* R43562, May 22, 2014, 11.

‡For instance, Chinese smartphone maker Xiaomi and big data processor Luokung both successfully challenged prohibitions on U.S. investment in their publicly traded securities. The prohibitions relied on IEEPA authority invoked under EO 13059, which restricted investment in Chinese companies designated as contributing to China's military by DOD. The U.S. District Court for the District of Columbia granted Xiaomi and Luokung preliminary injunctions in March and May 2021, respectively, arguing that the designation by DOD failed the "arbitrary and capricious test" established by the Administration Procedure Act (APA). Section 706(2)(A) of the APA indicates courts reviewing regulation may overturn agency actions if they find factual assertions or underlying rationale "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." United States District Court for the District of Columbia, Xiaomi Corporation v. Department of Defense, et al., *Memorandum Opinion: Granting Plaintiffs' Motion for Preliminary Injunction; Granting Plaintiffs' Motion for Leave to File Supplemental Declaration*, March 12, 2021, 7–9.

tors fear that a poorly coordinated outbound screening process could hamper U.S. competitiveness by encouraging foreign start-ups to seek capital from other countries and encouraging investors to move to less restrictive countries. Former CFIUS Lead Counsel Ben Joseloff has also observed that several proposals cut from FIRRMA would have given CFIUS more expansive authority to review select outbound transactions and that revisiting these proposals would be less disruptive than establishing a completely new process.[402]

Biden Administration Executive Order Takes First Step in Narrowly Scoped Screening Mechanism

On August 9, 2023, the Biden Administration released an executive order (EO) requiring notification of, and in some cases prohibiting, U.S. persons making certain investments in China related to semiconductors and microelectronics, quantum information technologies, and AI systems (see Table 2). The EO on "Addressing United States Investments in Certain National Security Technologies and Products in Countries of Concern" directs the secretary of the treasury to develop regulations identifying categories of: (1) notifiable transactions that may contribute to a national security threat; and (2) prohibited transactions that "pose a particularly acute national security threat because of their potential to significantly advance the military, intelligence, surveillance, or cyber-enabled capabilities of countries of concern."[403] The EO also requires the U.S. Department of the Treasury to evaluate whether to amend the investment screening program and to submit a report on its effectiveness after one year. It invokes the president's authority to declare a national emergency under the International Emergency Economic Powers Act (IEEPA) and the National Emergencies Act and allows for Treasury to submit reports to Congress on the status of the emergency declared in the order.*[404]

Concurrent with the EO's release, Treasury issued an advanced notice of proposed rulemaking (ANPRM) seeking public comment on implementation of the EO, particularly on definitions for "U.S. persons," "covered foreign persons," and "covered transactions."[405] The questions in the ANPRM indicate that implementation of the EO is in its nascent stages but that Treasury and relevant agencies are focused on closing potential loopholes and could interpret the scope of key definitions quite broadly.[406] For instance, the ANPRM indicates the rules will also apply to indirect investments to prevent U.S. persons from purposely designing transactions to circumvent investment prohibitions or notification requirements.[407] For the present, the ANPRM proposes using definitions taken from related extant regulation, such as the definition of "U.S. person" from IEEPA and the definition of "covered transaction" and "foreign person" from CFIUS.[408] Treasury has signaled that its focus for "covered foreign persons" is to capture parent

*The EO indicates that China's advances in "sensitive technologies and products critical for the military, intelligence, surveillance, or cyber-enabled capabilities" constitute a grave threat to U.S. national security and that China's MCF strategy facilitates U.S. outbound investments in China enabling these advances. White House, Executive Order 14105 of August 9, 2023, "Addressing United States Investments in Certain National Security Technologies and Products in Countries of Concern," *Federal Register* 88:154 (August 11, 2023).

companies and their subsidiaries, where a broad interpretation might include a joint venture with a non-Chinese company employing Chinese nationals.[409]

Table 2: Technology Areas Potentially Prohibited for Investment or Requiring Notification

Technology Category	Potentially Prohibited	Requires Notification Only
Semiconductors and microelectronics	Investments in developing or producing electronic design automation software; developing or producing front-end semiconductor manufacturing equipment for volume chip fabrication; designing chips that exceed certain thresholds subject to export controls; fabricating certain advanced chips;* packaging chips that support three-dimensional integration; and installing chips for or selling them to customers likely using them for supercomputers.	All other investments that involve chip design, fabrication, and packaging.
Quantum information technologies	Investments in producing quantum computers and components; developing quantum sensing platforms designed exclusively for military end use, intelligence, or mass surveillance; and developing quantum networks or communication systems designed exclusively for secure communications.	Not applicable
AI systems	Investments in developing software that uses AI and is designed exclusively for (though the definition may expand to "primarily for") military end use, government intelligence, and mass surveillance.	Investments in developing software that uses AI designed exclusively for (though the definition may expand to "primarily for") cybersecurity, digital forensics, penetration testing, controlling robotic systems, covert listening devices, location tracking, and facial recognition.

Note: The thresholds for advanced chips are the same as those defined in October 7 restrictions.
Source: Adapted from Reva Goujon, Charlie Vest, and Thilo Hanemann, "Big Strides in a Small Yard: The U.S. Outbound Investment Screening Regime," *Rhodium Group*, August 11, 2023, 4–5.

Treasury officials have described the EO as taking a "small yard, high fence" approach, and notably the initial scope excludes many technology areas China has prioritized for development in industrial policy documents that may have national security implications.[410] For instance, China's 14th Five-Year Plan emphasizes innovation in space and aviation, airplane engines and gas turbines, ships and maritime equipment, advanced energy equipment, high-end new materials, high-end medical equipment and innovative drugs, the

Beidou navigation satellite system,* major technical equipment, and smart manufacturing and robotics.[411] These technology areas are largely consistent with the areas prioritized in Made in China 2025, a 2015 blueprint to gain dominance in high-tech industries.[412] In an analysis of the implications of the EO, researchers at Rhodium Group note that U.S. investors in China have already started to avoid semiconductors and quantum information sciences, as these are under scrutiny for national security concerns.[413] However, biotechnology startups have been a key focus of investors for the past five years.[414]

Implications for the United States

The PLA has long feared technological surprise and is now trying to create that danger for the United States.[415] As Ms. Kania points out, the United States' historical advantage in many decisive military technologies "is neither assured, nor unassailable."[416] China's pursuit of advanced defense technologies therefore has several implications for the United States.

First, technological breakthroughs by the PLA in certain warfighting domains could change the balance of power in the Asia Pacific region and challenge strategic stability. China's dedicated efforts to improve its ASW capabilities could ultimately enable the PLA to detect U.S. submarines and prevent them from operating near China during a war over Taiwan, undermining the deterrent effect of U.S. dominance in this domain. More broadly, China's pursuit of a space-based nuclear weapons capability threatens to undermine strategic stability by creating uncertainty and depriving the United States of early warning against an incoming nuclear attack. Future Chinese gains in AI could erase the United States' historic advantages in information technology and make U.S. warfighting systems and processes in all applications more vulnerable to attack. For example, the PLA's significant investments in autonomous undersea and surface vehicles, as well as AI-enabled ISR systems, may someday enable it to limit U.S. Navy and allied access to the undersea space between the first and second island chains. More broadly, the application of AI to information and electronic warfare, such as through cyberattacks, data manipulation, and electromagnetic spectrum interference, could compromise U.S. situational awareness and command and control systems. Some of these capabilities, even if developed with the intention of enabling or protecting a PLA force invading Taiwan, clearly have global applications.

Second, China's MCF strategy accelerates Chinese defense innovation, contributes to the development of emerging capabilities, and may confer operational advantages in wartime.[417] MCF has the potential to lower costs and minimize redundant development efforts in the PLA weapons development process, conserving resources while allowing the more expeditious deployment of new weapons systems that could target U.S. forces.[418] By providing a civilian substitute for military functions, such as logistics, MCF could also obscure early indicators of a potential attack on Taiwan related to military mo-

*Beidou is China's global navigation satellite system and has achieved global coverage as of 2020 with 35 satellites worldwide. Beidou is operated by the China National Space Administration. GPS, "Other Global Navigation Satellite Systems."

bilization and contribute to the sustainment of PLA equipment or personnel amid a protracted conflict.[419]

Third, China's efforts to become more innovative in defense technology pose a distinct challenge to the United States, even if China does not close the gap in overall innovativeness. Because of the Party-state's role in steering R&D activity toward policy goals, much more of R&D conducted in China may be geared toward establishing specific capabilities for defense applications than would be the case in another country.[420] Beijing is prioritizing reducing foreign dependence in areas it has identified as "chokepoint" technologies, reducing the number of avenues through which the United States can constrain the growth of its military-industrial complex. Despite China's efforts to achieve original innovation, it also continues to aggressively acquire technology from foreign countries through licit and illicit means in an effort to narrow the capability gap with the United States.

Lastly, despite increased export controls against China and strengthened investment screening, transfer of technology, capital, and expertise to China continues to undermine U.S. national security, economic competitiveness, and values. The evolving nature of technology heightens this challenge, as export controls increasingly target digital goods, such as software, and the cycle between R&D versus commercial deployment becomes shorter and blurrier between general purpose applications of technologies like AI and their military use. Moreover, the United States is unable to effectively restrict China's access to many technologies through unilateral controls. China's commercial environment poses additional challenges for the end user-based controls the United States has used extensively toward Chinese entities for the past five years. End-user and end-use verification is particularly difficult in a data-poor environment like China in which the government restricts access to information that may be used to implement economic restrictions and penalizes due diligence efforts.

Appendix: Overview of U.S. Export Controls

The United States controls the export, reexport, and transfer of U.S.-produced hardware, software, commodities, and services for a number of reasons, including to fulfill national security, economic competitiveness, and foreign policy objectives. Foremost, U.S. export controls seek to prevent potential adversaries, including other countries, rogue states, and terrorists, from obtaining capabilities that could threaten U.S. interests. China's technological development and mercantilist trade practices have also driven increased consideration of more expansive export controls to shore up U.S. economic competitiveness or inhibit China's economic and technological development. Additionally, the United States has placed a number of restrictions on exports that could aid in human rights abuses, including exports to numerous Chinese surveillance technology firms facilitating repression in the Xinjiang Uyghur Autonomous Region.

U.S. export controls are primarily managed and enforced by two key U.S. government agencies, BIS within the Department of Commerce and the Directorate of Defense Trade Controls (DDTC) within the U.S. Department of State (see Table 3). Commerce is authorized to regulate and license exports of dual-use goods and technologies, or products and technologies that have both civilian and military applications, as well as some defense articles, under the EAR (see Figure 1). The State Department is authorized to regulate and license exports of munitions under the International Traffic in Arms Regulation (ITAR). Additionally, the U.S. Department of Energy and independent Nuclear Regulatory Commission are authorized to regulate and license various exports relating to nuclear technology. Each of these agencies is responsible for administrative enforcement, while Treasury administers restrictions on exports based on U.S. sanctions,* and criminal penalties for export control violations are issued by units within the U.S. Department of Homeland Security and the U.S. Department of Justice.

Table 3: Overview of U.S. Export Control Authorities and Administration

Characteristic	Dual-Use	Munitions	Nuclear
Legislative Authority	Export Control Reform Act of 2018 (ECRA); International Emergency Economic Powers Act of 1977 (IEEPA)	Arms Export Control Act of 1968, 1976 (AECA)	Atomic Energy Act of 1954

*The United States restricts exports to countries on which it imposes economic sanctions, such as Cuba and Iran.

Table 3: Overview of U.S. Export Control Authorities and Administration—*Continued*

Characteristic	Dual-Use	Munitions	Nuclear
Agency of Jurisdiction	Bureau of Industry and Security (BIS) (Commerce)	Directorate of Defense Trade Controls (DDTC) (State)	• Nuclear Regulatory Commission (NRC) (facilities and material) • Department of Energy (DOE) (technology) • BIS ("outside the core" civilian power plant equipment) • DDTC (nuclear items in defense articles)
Implementing Regulations	Export Administration Regulations (EAR) (15 C.F.R. 730 et seq)	International Traffic in Arms Regulations (ITAR) (22 C.F.R. 120 et seq)	• 10 C.F.R. 110—Export and Import of Nuclear Material and Equipment (NRC) • 10 C.F.R. 810— Assistance to Foreign Atomic Energy Activities (DOE)
Control List	Commerce Control List (CCL)	Munitions List (USML)	• List of Nuclear Facilities and Equipment; List of Nuclear Materials (NRC) • Nuclear Referral List (CCL) • USML • Activities Requiring Specific Authorization (DOE)
Relation to Multilateral Controls (see Table 2)	• Wassenaar Arrangement (dual use) • Missile Technology Control Regime (MTCR) • Australia Group (AG) • Nuclear Suppliers Group	• Wassenaar Arrangement (munitions) • MTCR • AG	Nuclear Suppliers Group
Licensing Policy	Based on item, country, or both. Antiterrorism controls proscribe exports to four countries for nearly all CCL listings	Most Munitions List items require licenses; 20 proscribed countries	• General/Specific Licenses (NRC) • General/Specific Authorizations (DOE)

Source: Paul Kerr and Christopher Casey, "The U.S. Export Control System and the Export Control Reform Act of 2018," *Congressional Research Service* R46814, June 7, 2021, 39.

Figure 1: Commerce Control List (CCL) Categories and Function Groups

CCL Categories

1	Nuclear materials, facilities, and equipment
2	Materials, organisms, microorganisms, and toxins
3	Materials processing
4	Electronics
5 Part 1	Computers
5 Part 2	Telecommunications and information security
6	Lasers and sensors
7	Navigation and avionics
8	Marine
9	Propulsion systems, space vehicles, and related equipment

CCL Functional Groups

A	Equipment, assemblies, and components
B	Test, inspection, and production equipment
C	Materials
D	Software
E	Technology

Source: Paul Kerr and Christopher Casey, "The U.S. Export Control System and the Export Control Reform Act of 2018," *Congressional Research Service* R46814, June 7, 2021, 7.

Deemed Exports Regulate Transfer of Technology within the United States

Deemed exports refer to the release of controlled technology or technical data to a foreign national within the United States. They are considered "deemed" because the transfers are treated as if they were actual exports to the foreign national's home country and are subject to the same regulations and licensing requirements as traditional exports. Exporters, whether employer, research institutions, or other organizations, are responsible for ensuring deemed exports are appropriately controlled and licensed. For example, if a U.S. company employs foreign nationals and these foreign employees gain access to controlled technology or technical data, it is considered a "deemed export" of that technology to the foreign employees' home countries. Similarly, if a U.S. university allows foreign students or researchers access to controlled technology or technical data during their studies or research, it is also deemed as an export of that technology to the foreign students' home countries. In both these situations, release of controlled technology to foreign persons, even within the United States, may require a license from BIS, DDTC, or one of the nuclear regulatory agencies, depending on the specific technology involved and the nationality of the foreign person.

Implementing Export Controls

The U.S. government's process for enforcing export controls and ensuring compliance can be divided into three stages: monitoring and enforcement, auditing and assessing compliance, and penalizing noncompliance.

1. *Monitoring and Enforcement:* BIS and DDTC continuously monitor export activities to prevent unauthorized exports of controlled items or technology. They conduct investigations

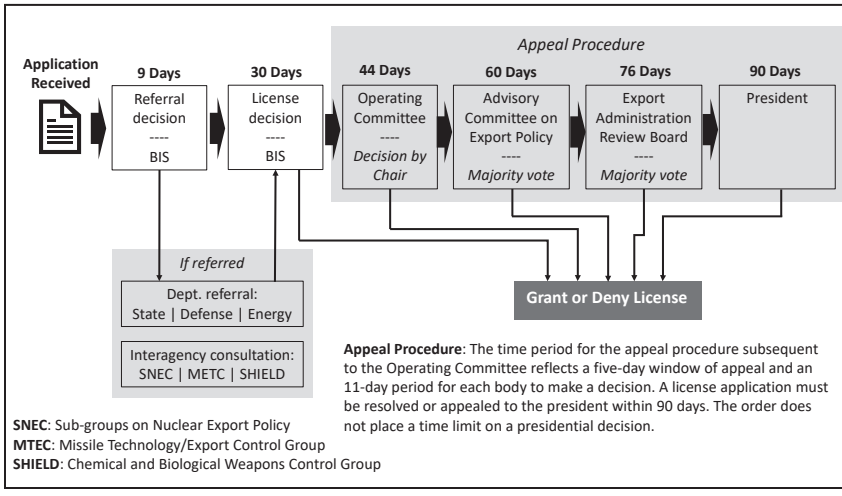
and cooperate with other government agencies to identify potential violations. For instance, BIS might investigate an aerospace company suspected of exporting restricted technology to a blacklisted entity. The investigation could include reviewing export documentation, interviewing employees, and examining the company's compliance practices.

2. *Auditing and Assessing Compliance:* The government may audit exporters to assess their compliance with export control regulations. They may also perform compliance checks at ports of export to verify that shipments comply with the applicable licenses and regulations. For example, DDTC might conduct an audit of a defense contractor to assess the company's compliance with ITAR requirements. The audit could focus on how the company handles technical data and ensuring proper controls are in place for foreign national employees.
3. *Penalizing Noncompliance:* If an exporter is found to have violated export control regulations, the government can impose penalties, including fines, denial of export privileges, and criminal prosecution.

From the exporter's perspective, complying with export controls often involves five steps:

1. *Determining Export Control Classification:* Exporters must first determine the Export Control Classification Number (ECCN) or the appropriate regulatory control for their product or technology. This involves identifying whether the item is listed on the Commerce Control List (CCL) managed by BIS or the United States Munitions List (USML) overseen by the DDTC in the State Department. For example, encryption software designed for commercial use falls under the Commerce Control List, while military-grade night vision goggles are controlled under the U.S. Munitions List. Exporters may seek guidance from BIS or DDTC if they are unsure about the classification or licensing requirements for an item (see Figure 2).
2. *Determining License Requirements:* If the item or technology is listed on the CCL or USML, it may require an export license from the respective agency (BIS or DDTC) before being sent to a foreign destination or shared with foreign nationals. Exporters can consult the ECCN or USML entry to check if a license is needed or use the "Commerce Country Chart" to determine license requirements based on the destination country. For example, if a U.S. company wants to export advanced semiconductor manufacturing equipment (ECCN 3B001) equipment, which is on the CCL, to China, the exporter must obtain a license from BIS before shipping it.
3. *Applying for a License:* The application with BIS or DDTC typically requires detailed information about the item, its intended use, end user, and the destination country. For example, a commercial space company exporting satellite communication systems to a country subject to export restrictions would need to submit a detailed application to BIS, including information about the end user and the system's intended use (see Figure 2).

Figure 2: The Export License Application Process for BIS



Source: Paul Kerr and Christopher Casey, "The U.S. Export Control System and the Export Control Reform Act of 2018," *Congressional Research Service* R46814, June 7, 2021, 10.

4. *Restricted Party Screening:* Exporters must conduct "restricted party screening" to ensure they are not transacting with individuals, companies, or organizations that are prohibited from receiving U.S. exports due to national security concerns or other restrictions. For example, before exporting sensitive electronics components, an exporter must check whether the foreign customer or recipient is listed on the Denied Persons List maintained by BIS.
5. *Compliance Management:* Exporters must maintain records, monitor changes in controls, and implement internal compliance programs to ensure ongoing adherence to regulations. A robust compliance program often requires regular training for employees, recordkeeping of all export transactions, and internal audits to ensure adherence to export control regulations.

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